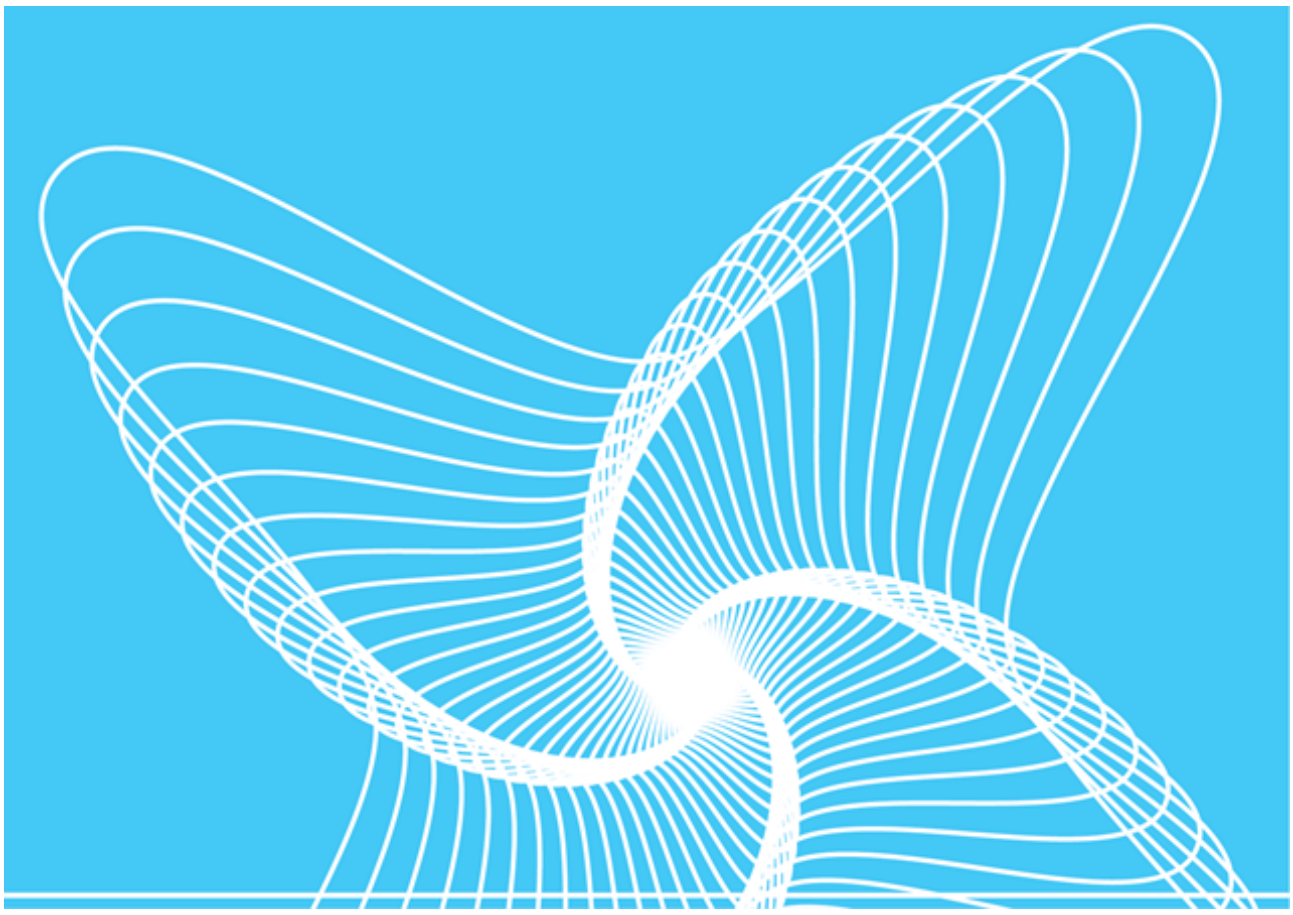
DNV·GL

SESAM USER MANUAL

WAJAC

Wave and Current Loads on Fixed Rigid Frame Structures

Valid from program version 7.7-01



SAFER, SMARTER, GREENER

Sesam User Manual

Wajac

Date: April/2021

Valid from program version 7.7-01

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List of changes, Wajac 7.7-01

The table below lists changes introduced between this and the previous version of Wajac User Manual. All changes in this document are highlighted in blue color. If a change relates to specific command or one of the options of the command, only relevant item is highlighted.

Topic	*Reference*	*Description*
New selection for wave spectrum	SEASIM, SPECTR	For Irregular wave and Constrained wave analysis Wajac will now offer three new, double-peaked spectrums. These are: Ochi-Hubble spectrum, Torsethaugen Full spectrum and Torsethaugen Simplified spectrum.
Description for new wave spectra	2.3.7	Theoretical description for Ochi-Hubble spectrum [22] and two versions of Torsethaugen spectra [23, 24].
Modified printout of COMP.LIS file	FCOMP	File generated by FCOMP command, COMP.lis is the default name, now contains new column storing values of spectral density function. Also, a header describing columns will be printed.
New option	OPT17	New option has been added to OPTI command to select decimal accuracy for some of the quantities printed in Wajac.lis file.
New option	OPT15, Description of Loads Interface File	New option for OPT15, OPT15=2, to allow user write marine growth weight to a separate Loads Interface File. Please refer to the OPTI command for more information.
New section	4.1.4	New section describing input arguments to the process of Wajac.exe.
Corrected description	Notes for SEA command, THEO parameter of SEA command	Previous description suggested that no buoyancy at all is included, however for the relevant example of *THEO=16.10* buoyancy and weight of marine growth, if defined, will also be included among other loads. Updated description for *THEO* parameter.

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1 INTRODUCTION

1.1 Wajac – Wave and Current Loads on Fixed Rigid Frame Structures

Wajac calculates wave and current loads on fixed and rigid frame structures that have structural members of relatively small cross-sectional dimensions compared to the wave lengths. Typical examples of such structures are offshore jacket platforms and jack-up rigs.

The loads are calculated according to Morison's equation (plus optionally MacCamy-Fuchs) and may automatically be transferred for subsequent structural analysis and statistical postprocessing.

Three different approaches for load calculations are available in Wajac. These are

- deterministic load calculation in the time domain (generally used for design purposes),
- calculation of force transfer functions in the frequency domain,
- time domain simulation of wave loads for a given short-term seastate.

1.2 Wajac in the Sesam system

The structure for which loads are calculated by Wajac are modelled using the Sesam preprocessor GeniE. The model is transferred to Wajac through the Input Interface File. Global transfer functions calculated by Wajac may be written to the Hydrodynamic Results Interface File for statistical postprocessing in Postresp. Detailed loads are stored on the Loads Interface File for transfer to subsequent structural analysis in Sestra. The Input Interface File, Hydrodynamic Results Interface File and Loads Interface File all belong to the Sesam Interface File, a general file system for data transfer between Sesam programs, see Figure 1.1.

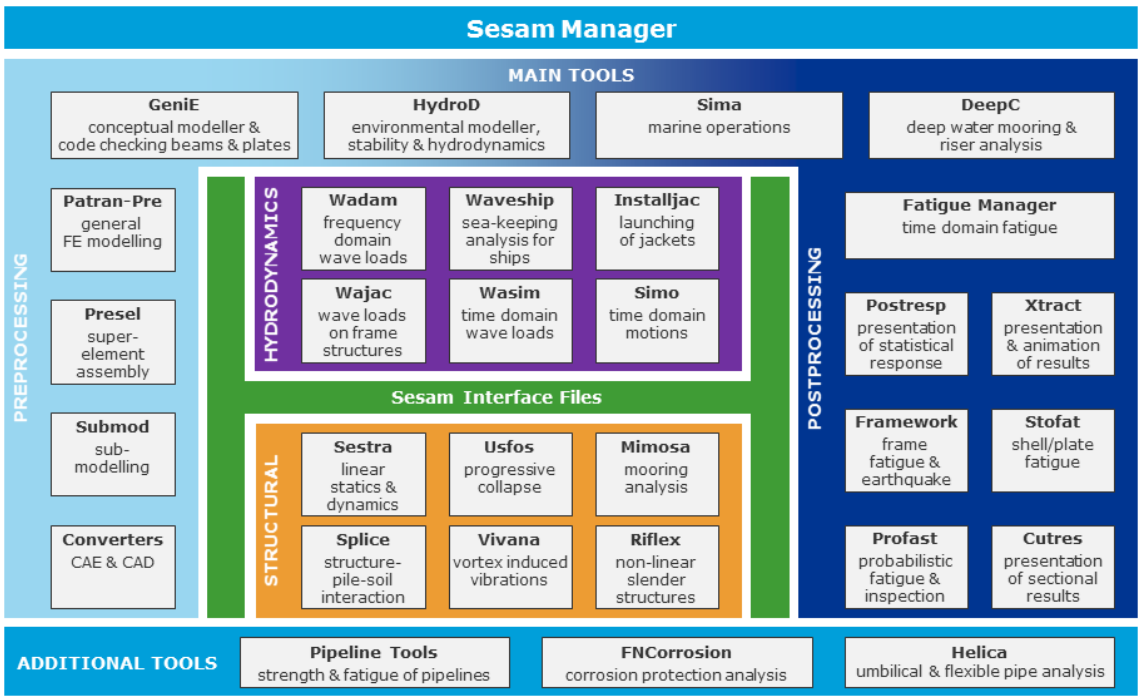


Figure 1.1: Wajac in the Sesam system

1.3 How to Read this Manual

Section 2 FEATURES OF WAJAC presents the principles and characteristics of the various features of Wajac.

Section 3 USER'S GUIDE TO WAJAC contains examples of Analysis Control Data (program input) for typical applications of Wajac. Each example is accompanied by an explanation of its characteristics and limitations.

Section 4 EXECUTION OF WAJAC contains information on file assignment and on program environment. Program requirements in terms of storage space and execution time is also discussed. Finally the Section lists the size dependent limitations of Wajac.

Section 5 WAJAC ANALYSIS CONTROL DATA contains detailed description of the Wajac Analysis Control Data.

2 FEATURES OF WAJAC

2.1 Analysis Capabilities

Deterministic wave load calculation, calculation of force transfer functions, simulation of wave loads in a given seastate and constrained wave analysis are the four different approaches available in Wajac. These approaches are described in the following sections.

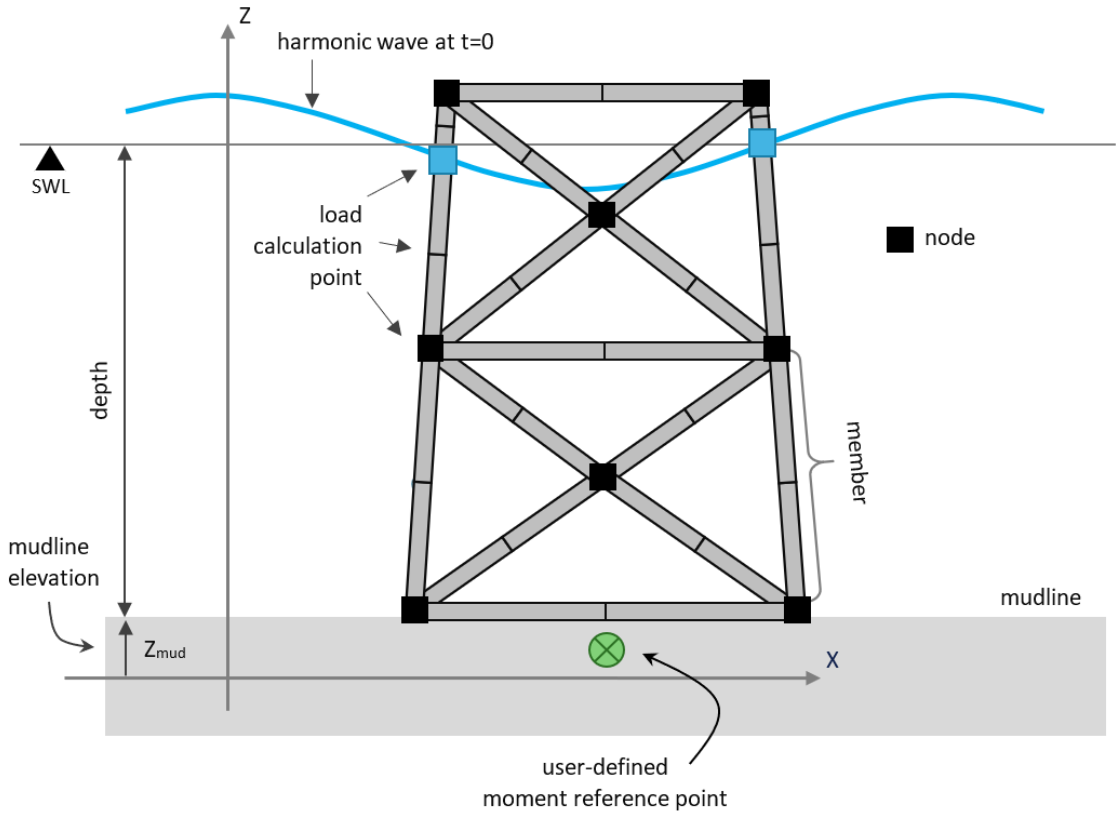


Figure 2.1: Definition of terms

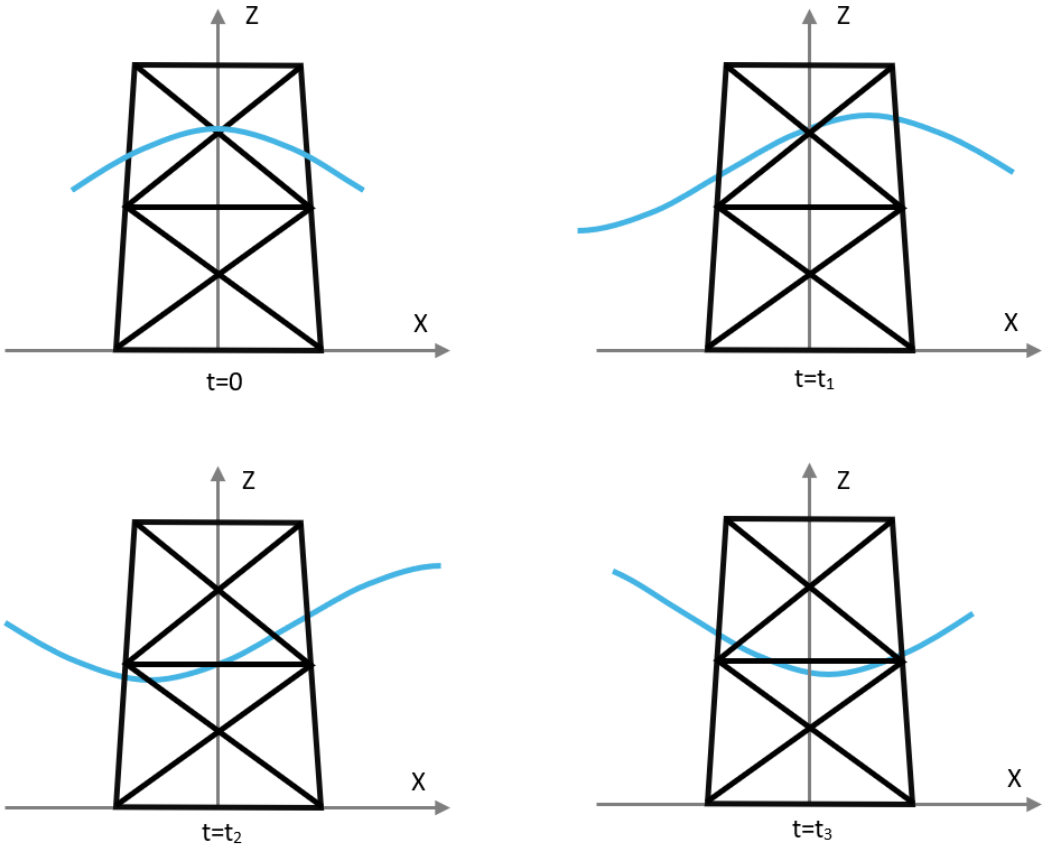


Figure 2.2: Time instants

2.1.1 Deterministic Wave Load Calculation

Using the deterministic approach for wave load calculation the structure is exposed to a unidirectional, periodic wave. The loads are calculated in the time domain, that is calculated at given time instants or phase angles of the wave cycle, see Figure 2.2. The minimum requirement to trigger deterministic analysis is to specify SEA command. Additional control data may be introduced using SEAOPT command.

Four different wave models are available with the deterministic approach. These are

- linear harmonic waves (Airy wave theory),
- Stokes' fifth order wave theory,
- Dean's stream function wave theory and
- cnoidal wave theory.

In addition to surface waves the structure may also be exposed to current, see Section 2.3.9.

The hydrodynamic forces are calculated according to Morison's equation with non-linear drag formulation as described in Section 2.4.1. By default buoyancy is calculated and added to the hydrodynamic forces for all members, see Section 2.4.8. The buoyancy may be neglected.

At each time instant loads are calculated up to the instantaneous water surface, see Figure 2.3.

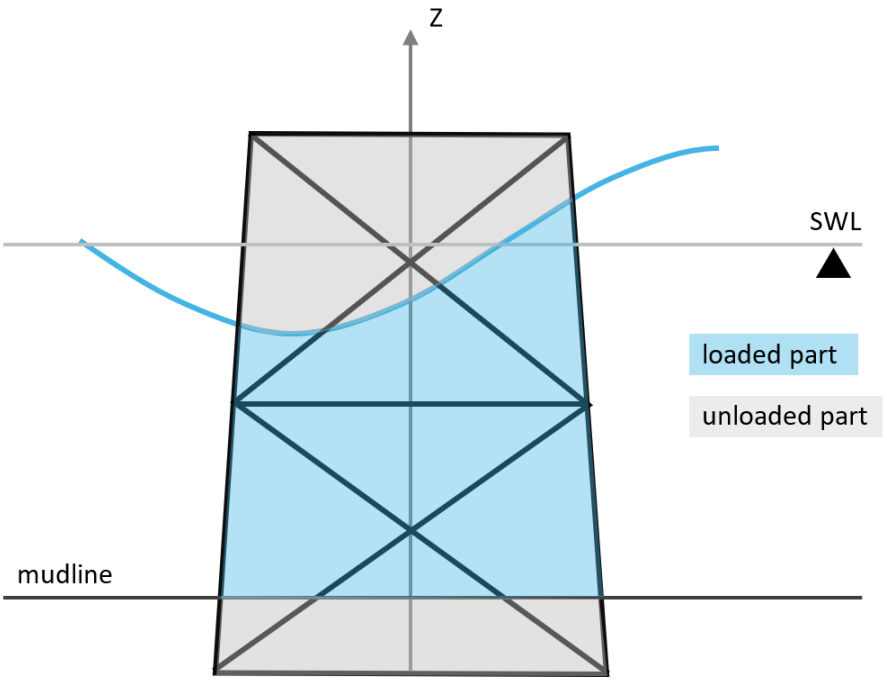


Figure 2.3: Loads are calculated up to instantaneous water surface

2.1.2 Calculation of Force Transfer Functions

Frequency domain load calculations are carried out in order to determine hydrodynamic transfer functions for member force intensities and total structural loads. A transfer function is defined as the harmonic response due to harmonic waves of unit wave amplitude. Only linear waves (Airy wave theory) can be used for the calculation of force transfer functions. The transfer function is a function of the wave angular frequency ω and the wave direction β. Given the complex transfer function $f(\omega, \beta)$ the time dependent, real response variable $F(t, \omega, \beta)$ is given by

$$F(t,\omega,\beta) = A\,\mathrm{Re}\{|f(\omega,\beta)|e^{i(\omega t+\delta)}\} = A|f(\omega,\beta)|\cos(\omega t+\delta) \tag{2.1}$$

where

$$|f(\omega,\beta)| = |f_r(\omega,\beta) + if_i(\omega,\beta)| = \sqrt{f_r^2 + f_i^2}$$

and

$$\delta = \mathrm{atan}\left(\frac{f_i}{f_r}\right)$$

t	is the time,
ω	is the wave angular frequency,
β	is the wave direction,
A	is the amplitude of the incident wave,
f_r	is the real part for the transfer function f,
if_i	is the imaginary part for the transfer function f,
e^x	is the exponential function,
i	is the complex unit defined by $i = \sqrt{-1}$.

This defines the response variable relative to the incident wave. δ is the phase lead relative to the incident wave with the wave crest at the origin of the global coordinate system as illustrated in Figure 2.4.

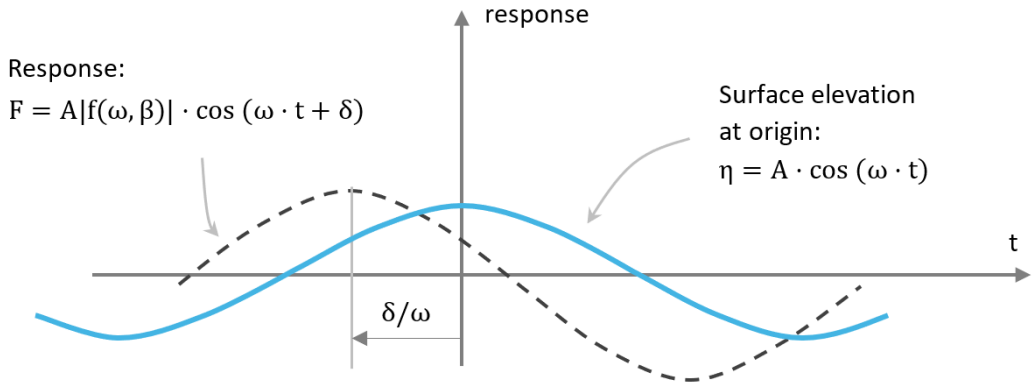


Figure 2.4: Definition of the phase lead

In Wajac frequency domain analysis is requested by using SEAFRQ command. Wave periods for which values of the transfer functions are calculated must be specified by the FRQ command. Depending on linearisation option selected on SEAFRQ command, user will have to specify either SPECTR or AMP command.

The hydrodynamic forces are calculated according to Morison's equation with linearised drag. The linearisation may be performed with respect to the wave heights as described in Section 2.4.2 or by equivalent linearisation with respect to a wave spectrum as described in Section 2.4.3. Only the total static force is calculated when performing a frequency domain analysis. This constant force is printed in the output listing but not written to the Loads Interface File.

If current is defined in addition to the wave the current will affect the results through the linearisation process and be reported as a constant force. This constant force is printed in the output listing but not written to the Loads Interface File.

Members with varying degrees of submergence during a wave cycle will also lead to non-harmonic response. The force intensities are therefore applied up to the maximum submergence of each member when linearisation with respect to the wave height is performed. If the equivalent linearisation process is used the force intensities are applied up to the still water level.

2.1.3 Time Simulation of Wave Loads in a Short-Term Seastate

Using the seastate simulation options the structure is exposed to irregular waves which simulates the specified seastate. The calculated loads are given as time series with a given time increment and for a given time interval. See Figure 2.5.

In addition to surface waves the structure may also be exposed to a stationary current, see Section 2.3.9.

The hydrodynamic forces are calculated according to Morison's equation with non-linear drag formulation as described in Section 2.4.1. By default, buoyancy is calculated and added to the hydrodynamic forces for all members, see Section 2.4.8. The buoyancy may optionally be switched off (or altered) for individual members using BUOA.

At each time instant loads are applied up to the instantaneous water surface, see Figure 2.3.

The most common method to specify seastate simulation is to use SEASIM command. In this method seastate is specified using by a wave energy spectrum and associated directional spreading. Two types of standard wave spectra are available, the Pierson-Moskowitz spectrum and the JONSWAP spectrum. A short description of these are given in Section 2.3.7.

The irregular sea simulating the specified seastate is generated by superposition of regular waves and thus linear wave theory is used.

The irregular sea is generated by Fast Fourier Transform (FFT) of the wave energy spectrum. This gives a finite set of discrete wave components. Each component is expressed as a harmonic wave with given wave angular frequency and amplitude. By superposition of all extracted harmonic wave components in all specified directions with random phase angles uniformly distributed between 0 and 2π the surface elevation of the irregular sea will be approximated by

$$\eta(\mathbf{X},t) = \sum_{j=1}^{n}\sum_{k=1}^{m} A_{jk} cos(\omega_k t - \mathbf{k}_k \cdot \mathbf{X} + \delta_{jk}) \tag{2.2}$$

where

A_{jk}	is the amplitude for wave direction j and harmonic component k,
ω_k	is the angular frequency of harmonic k,
$\mathbf{k}_k$	is the two-dimensional wave number for harmonic component k,
$\mathbf{X}$	is the horizontal coordinate vector in the global (X,Y,Z) frame of reference, and
δ_{jk}	is the phase angle for wave direction j and harmonic component k.

It is also possible to conduct simulation based on data specified on SEAIN command. User may define wave by specifying time series of surface elevation or by introducing series of individual wave components (defined by their amplitude, frequency and phase). More information can be found in the description of SEAIN command. Note that it is not yet possible to conduct constrained wave analysis when SEAIN command is used to define background random sea instead of SEASIM command. Example of usage of SEAIN command is presented in section 3 of this user manual, please refer to example 3.7.

Additionally user may request to save data related to wave components used during simulation using FCOMP command. Wajac will save such quantities like amplitude, angular frequency, phase and wave number for each of the components used. It must be pointed out that in case of constrained wave analysis (see 2.1.4) only components of the background random sea are saved.

The fluid velocities and accelerations are given by similar expressions through linear wave theory (Airy theory). For more detailed description of the seastate simulation option see Ref. [10]. Additionally user may filter out wave components corresponding to periods lower than the threshold value specified on TSKI command. This may be especially useful when fine resolution in time is required, in such case amplitudes of kinematics may rise to significant values and some unwanted oscillations may appear near still water level.

For all seastate specification methods LOASIM command must be specified. This command, beside other options enables to include Wheeler stretching through. The idea of Wheeler stretching is to determine kinematics for updated z-coordinate z', instead of using the actual z-coordinate. Eq. (2.3) presents the relation used during that transformation.

$$z' = \frac{z-\eta}{1+\frac{\eta}{depth}} = -\frac{\eta - z}{depth+\eta} \cdot depth \tag{2.3}$$

where

$depth$	is the mean water depth,
η	is the elevation of water surface; as stated in Eq. (2.2) this is a function of horizontal coordinate vector $\mathbf{X}$ and time t,
z	is the vertical coordinate expressed relative to still water level

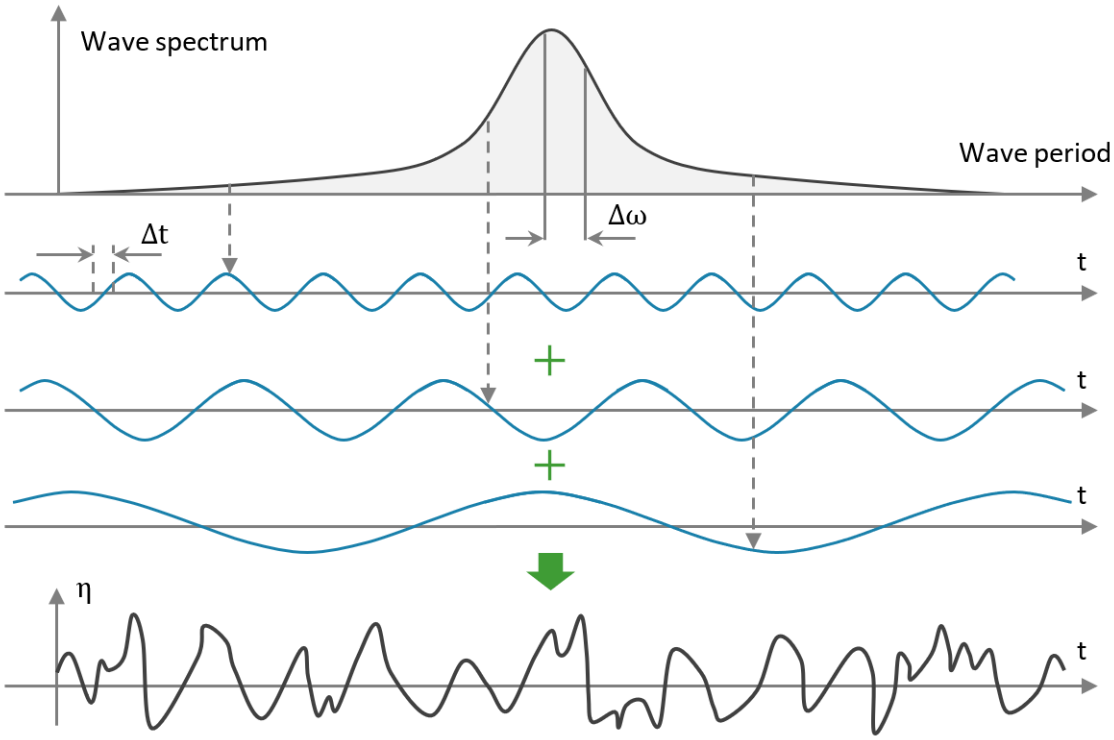


Figure 2.5: Time series of surface elevation

Given the expression in Equation (2.2) and the corresponding expressions for the fluid kinematics, time series for all wave characteristics are calculated in all points of a three dimensional grid, automatically generated by Wajac according to the given input data. These wave characteristics may optionally be stored on file (see Figure 4.1). When calculating loads the wave kinematics are determined by space and time interpolations on the information generated for the grid points.

Alternatively to generating wave kinematics in a 3D grid there is an option for calculating wave kinematics directly during the load calculation. Wave kinematics will be calculated at each end node and midpoint of the current member for each time step. If a beam happens to have two segments (i.e. NSEG$= 2$), the wave kinematics will be directly calculated at all load calculation points (two end nodes and midpoint of each segment). However, if this beam has more than two segments, the wave kinematics at those load calculation points (LCP) along the beam will be interpolated from the loads at the ends of the current member.

This option can be activated by setting a positive value for variable TIMESTEP which is included in the command card SEASIM. If TIMESTEP is zero or left as blank, the 3D grid option is applied.

For irregular time sea states the computed loads by the direct option are slightly higher, which is caused by a more precise algorithm. Meanwhile, the direct option can handle many more time steps ($262144 = 2^{18}$) than the 3-D grid option where only 8192 time steps can be handled ($8192 = 2^{13}$ time steps). The time steps can thus be much smaller to represent a typical sea state. Computation time, dependent on the size (number of elements) of the structure, sea-state simulation length and load calculation length, will be longer.

The limitation of number of time domain time steps, printed in WAJAC.LIS file, is still 8192.The correct limitation statement should be

TIME DOMAIN SIMULATION (3-D GRID) :	8192
TIME DOMAIN SIMULATION (DIRECT) :	262144

2.1.4 Constrained Wave

When using Direct Time Simulation, i.e. Time Simulation without grid option, one can specify a *Constrained Wave* embedded in an irregular sea using WAVC command. The general idea is to allow the user to constrain such parameters as wave height (trough to crest) H_c or wave period T_c, at specific instant of time t_c and space, by specifying two coordinates in the global horizontal plane (x_c, y_c). Fig. 2.6 presents the constrained parameters with relevance to the specific coordinate system. The implementation of Constrained Wave in Wajac is based on Ref. [20]. The same implementation is part of Bladed (see Ref. [21]).

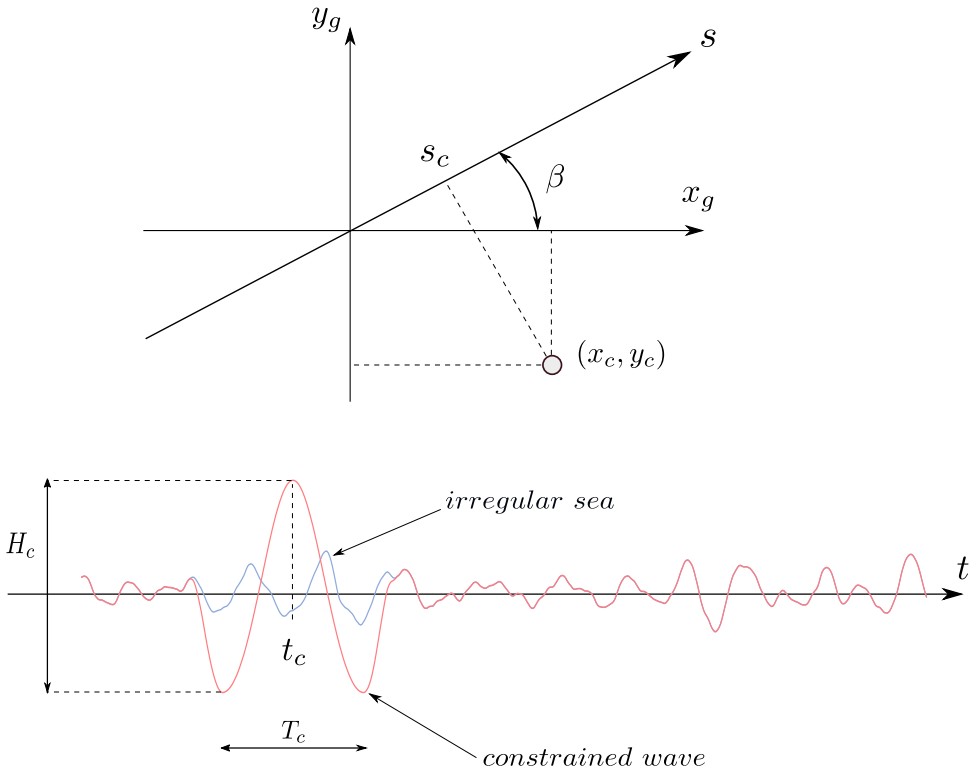


Figure 2.6: Constrained parameters

Upper plot presents global horizontal plane, where β relates to main direction of wave propagation. Lower plot presents time series of surface elevation generated for point (x_c, y_c). The distance along main wave direction is denoted here by s, while s_c corresponds to constrained point.

The constrained wave itself can be generated with or without constraining the period around constrained time t_c. For both options different wave theories can be applied in order to meet the constraints. The user can choose here from NewWave (see Ref. [17]) theory and Stream Function theory. In general there are 3 options to choose from using WAVC command, these are summarized below. A detailed description of the implementation can be found later on.

NewWave only (T_c not constrained)

(This section refers to Option 1 on WAVC card)

Constrained period T_c is not specified. NewWave theory is used to meet the constraints. The solution (e.g. surface elevation) for the final/constrained wave is determined from the following relation:

$$V_c(t) = f_{blend}(t) \cdot V_{NW}(t) + V_{irr}(t) \tag{2.4}$$

where: V_c represents the constrained-wave solution; f_{blend} represents the blending function (see Fig. 2.10 and Eq. 2.6); V_{NW} represents the NewWave solution; V_{irr} represents the irregular sea solution.

The only thing we require here is that there is a local maximum at t_c imposed on $V_c(t)$. In case of surface elevation being the quanity considered, first a NewWave function of unit slope is added to the solution with

proper coefficient (time derivative of irregular sea at t_c taken with opposite sign) which ensures a local maximum is obtained at t_c. Second step involves NewWave function of unit amplitude which is multiplied accordingly and then added to the updated solution so the height of the wave near t_c is equal to the constrained height H_c.

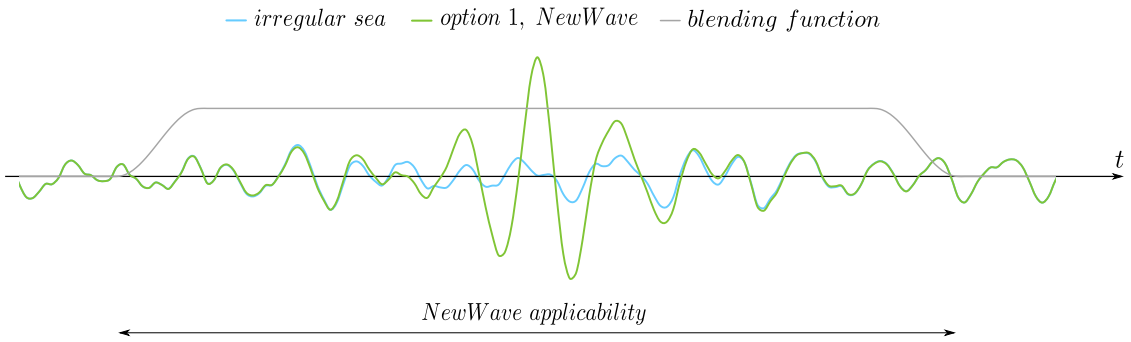


Figure 2.7: Constrained Wave related to Option 1

Stream Function only (T_c constrained)

(This section refers to Option 3 on WAVC card)

Constrained period T_c is specified. Stream Function theory is used to meet the constraints. The solution for the final/constrained wave is determined from the following relation:

$$V_c(t) = f_{b,SF}(t) \cdot V_{SF}(t) + (1 - f_{b,SF}(t)) \cdot V_{irr}(t) \tag{2.5}$$

where: V_c represents the constrained-wave solution; $f_{b,SF}$ represents the blending function (see Eq. (2.7)); V_{NW} represents the Stream-Function solution; V_{irr} represents the irregular sea solution.

NOTE: The blending function used for merging Stream Function solution with the background sea differs a bit from the blending function used when NewWave theory is blended with background sea. In the latter case irregular sea is present at every instant of time, while for the former case there is a one-constrained-period interval where only the Stream Function solution is present.

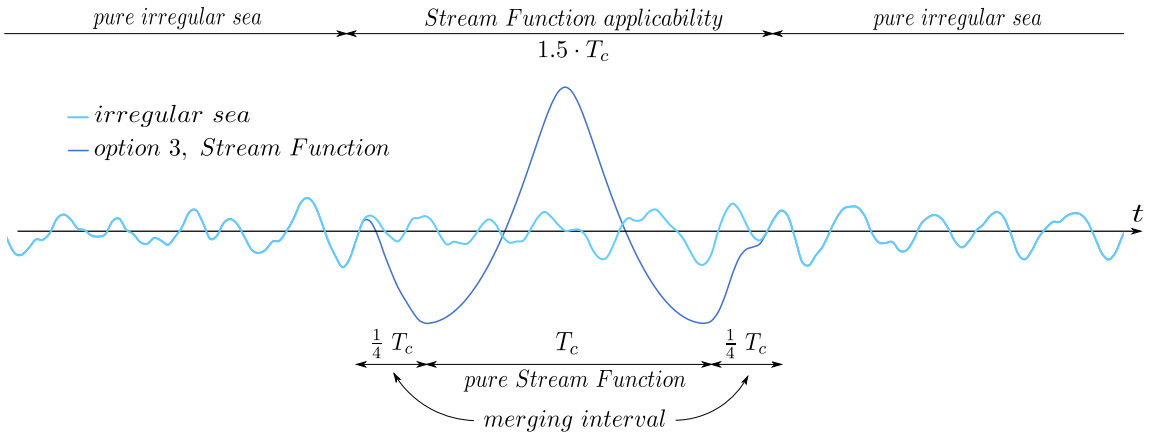


Figure 2.8: Constrained Wave related to Option 3

NewWave and Stream Function (T_c constrained)

(This section refers to Option 2 on WAVC card)

Constrained period T_c is specified. Both NewWave and Stream Function theories are used to meet the constraints. Firstly NewWave is applied and then Stream Function is applied the same way as described in Option 2. Regarding the NewWave part there is one difference in the implementation as compared to Option 1. This time the NewWave function is composed in such a way that local extrema are met at three points, being one crest at $t = t_c$, and two troughs at $t = \pm\frac{1}{2}T_c$. To ensure this, we now need two specific NewWave functions for each extremum (as described for Option 1), thus in total six NewWave functions. This is why for Option 2 the solution outside the Stream function interval differs from the solution obtained for Option 1 (where the option numbers refer to those on the WAVC card).

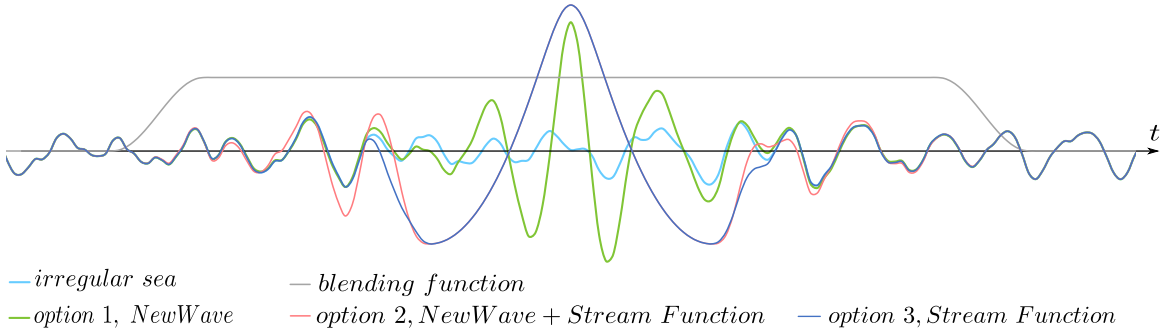


Figure 2.9: Comparison of all three options available for constrained wave

Blending function (NewWave)

$$f_{blend} = \begin{cases} 1, & \text{for } |t - t_c| \leq \Delta t_{blend=1} \\ 0, & \text{for } |t - t_c| > \Delta t_{blend=1} + \Delta t_{merge} \\ 0.5 \cdot \left(1 + \cos\left(\left(\frac{\pi}{\Delta t_{merge}} \cdot ||t - t_c| - \Delta t_{blend=1}|\right)\right)\right), & \text{otherwise} \end{cases} \quad (2.6)$$

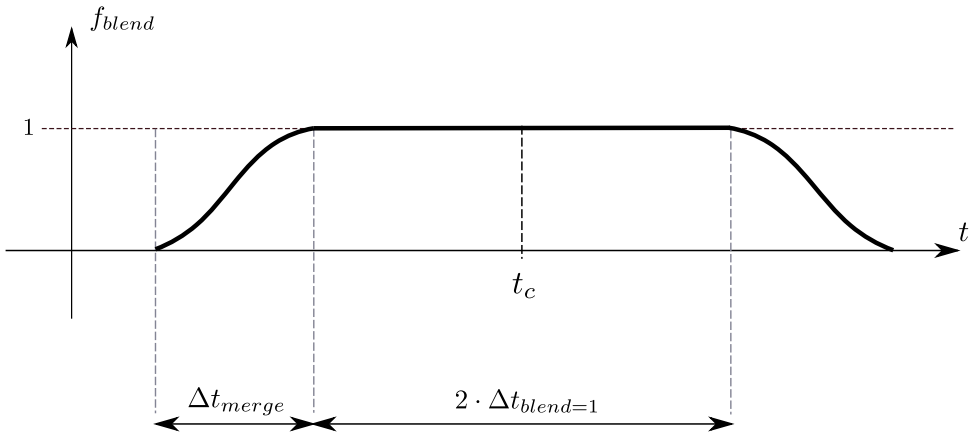


Figure 2.10: Definition of blending function used when NewWave theory is selected

where

$\Delta t_{\text{blend}=1}$	$= R_{blend=1} \cdot T_p$.
Δt_{merge}	$= R_{merge} \cdot T_p$.
T_p	Peak period, i.e. period referring to maximum spectral density.
$R_{blend=1}$	Value expressed in number of peak periods defining length of time period for which blending function is equal 1. Specified through WAVC card.
R_{merge}	Value expressed in number of peak periods defining length of time period for which the blending function gradually increases from 0 to 1 or decreases from 1 to 0. Specified through WAVC card.

Blending function (Stream Function)

$$f_{b,SF} = \begin{cases} 1, & \text{for } |t - t_{c,SF}| \leq \frac{1}{2} T_c \\ 0, & \text{for } |t - t_{c,SF}| > 1\frac{1}{2} T_c \\ 0.5 \cdot \left(1 + \cos\left(\left(\frac{\pi}{0.25 \cdot T_c} \cdot ||t - t_{c,SF}| - 0.5 T_c|\right)\right)\right), & \text{otherwise} \end{cases} \tag{2.7}$$

where

$t_{c,SF}$	time at which crest of Stream Function appears at specific location.

Profile of NewWave

Should the NewWave function be used, one may choose from two profiles of the NewWave function, referred to here as *evolving* and *frozen*. The crucial difference between the two is that while for the *frozen* option the shape of the wave remains unchanged over space, for the *evolving* profile this is no longer true. To better understand it recall that the NewWave solution constitutes of many linear waves. For each n-th component the surface elevation can be expressed with the following relation.

$$\eta_n(\mathbf{X}, t) = A_n \cdot \cos(k_n \cdot \mathbf{X} - \omega_n \cdot t) \tag{2.8}$$

For the *frozen* profile ω_n can be expressed in terms of k_n as $\omega_n = C \cdot k_n$, where $C = const$. The consequence of such definition is that the frozen profile does not vary over space, while the evolving profile does.

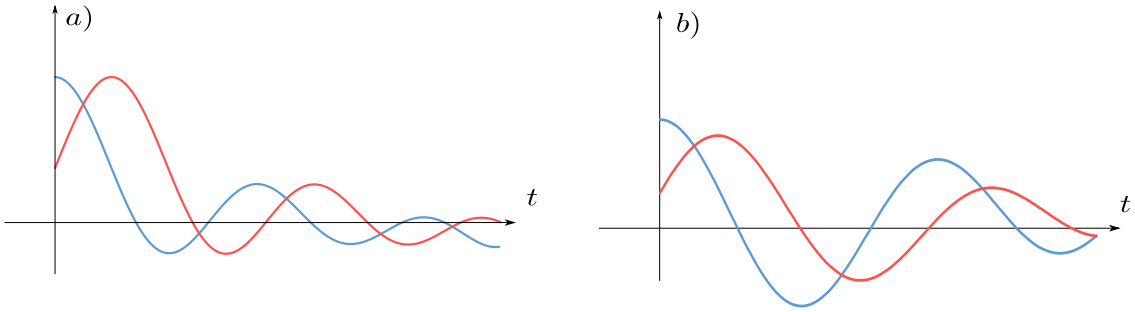


Figure 2.11: a) *frozen* profile; b) *evolving* profile

Both profiles presented above were determined for two different spatial coordinates.

Spatial and time extent of Constrained Wave

The characteristic behavior of the *frozen* profile can also be observed for Stream Function, which already is a regular wave. Additionaly, Stream Function is not bound in time as the NewWave solution, Stream Function wave travels unmodified through space, but its extent is bounded to $3/4\ T_c$ (upstream and downstream) from the instantaneous crest location denoted on Fig. 2.12 by $t_{c,SF}$.

On the other hand region of applicability of New Wave is bounded in time exactly the same way for all spatial coordinates.

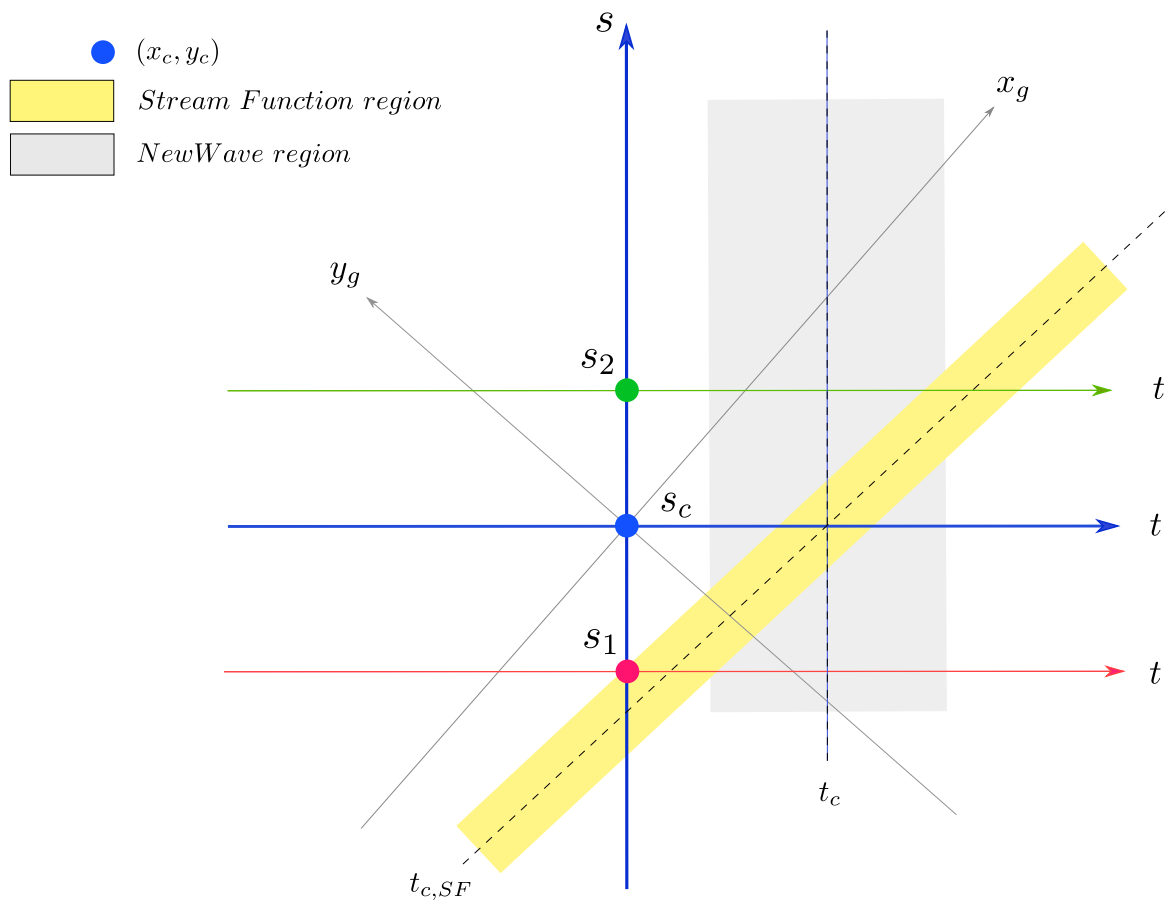


Figure 2.12: Presentation of spatial and time applicability of NewWave and Stream Function wave theories

In the figure presented above s represents the distance along main wave direction; x_g, y_g represent the horizontal coordinates of global coordinate system; t_c represents the constrained time; $t_{c,SF}$ represents the time of Stream Function crest occurrence. The blue bold timeline relates to constrained point (x_c, y_c) (or s_c), while other timelines relate to spatial coordainte s_1 (the red one) and s_2 (the green one).

2.2 Modelling Features

2.2.1 Geometry Model

The geometry of the structure is read from the Input Interface File generated by e.g. the Sesam preprocessor GeniE. The model may consist of nodes and elements of any type (called basic elements). Loads are only calculated for 2 node beam elements, called members in Wajac. If there are no such elements in the structure Wajac will terminate. The members are referred to by their element numbers as defined in GeniE.

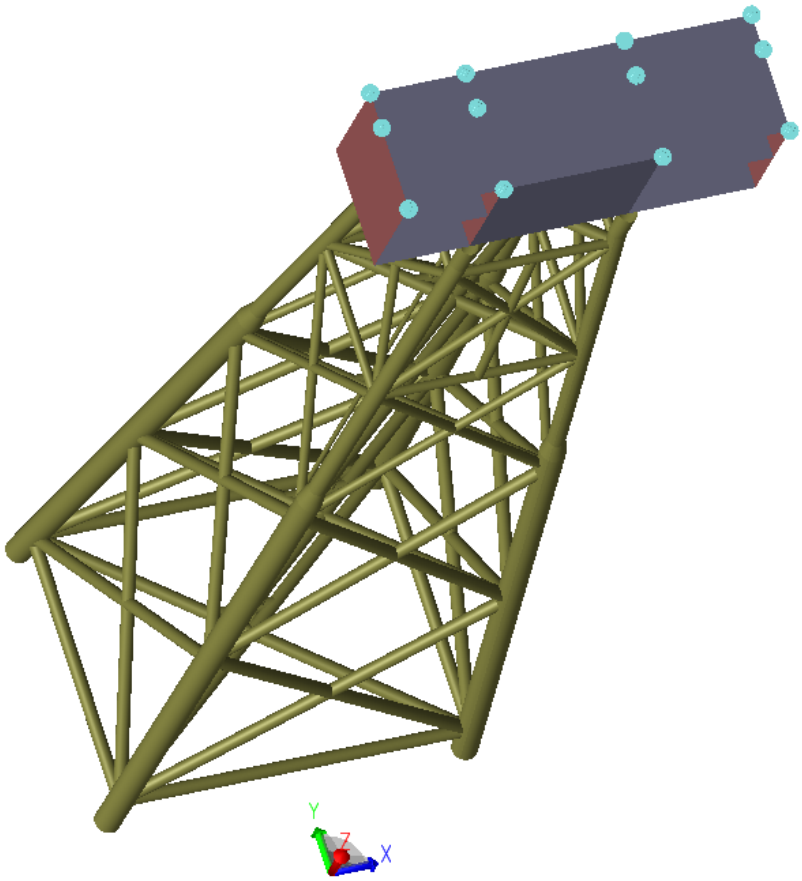


Figure 2.13: Geometry generated by GeniE

Information on the hydrodynamic properties and the type of analysis to perform is given to Wajac through the Analysis Control Data described in Section 5. Any eccentric attachment of member ends to nodes (defined in GeniE) will by default be included. The eccentricities may optionally be neglected.

By default the diameter used in the Morison's equation is the member diameter. This is defined as the outer diameter of circular or pipe cross sections as defined in GeniE. For members with non-circular cross section the member diameter is defined as the member's largest cross sectional dimension called the equivalent diameter. See Figure 2.14.

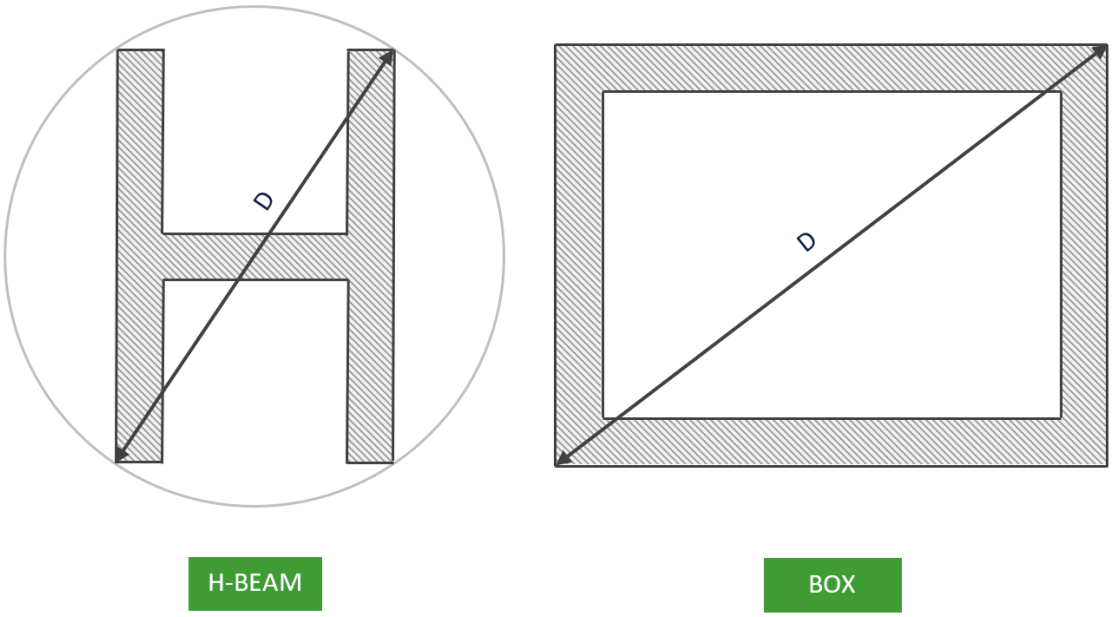


Figure 2.14: Diameters of members with non-circular cross sections

If this is not appropriate for hydrodynamic purposes the diameter may be redefined through the Analysis Control Data using SPEC or SPEX command. For beams with general cross section a member diameter must be defined through the Analysis Control Data, otherwise they will be disregarded in the load calculations.

The model — or top level superelement if the superelement technique is employed — must be modelled with the Z-axis pointing upwards. See Figure 2.1.

The origin of the global coordinate system can be placed anywhere. In order to position the structure with respect to the sea bottom (mud line) the mud line elevation is given as input to Wajac. Members or parts of members below the mud line will only, optionally, receive buoyancy forces. Load calculation may be switched off for selected members.

2.2.2 Superelement Model

The model may consist of a single superelement or several superelements assembled using the Sesam module Presel, see the Presel user manual. The same superelement type may occur in several different positions. See Figure 2.15.

Any member of the assembled structure is referred to through the first level superelement to which it belongs. A superelement is identified by its type number and its index as given in the superelement hierarchy printed by Presel. Figure 2.15 is an example of a superelement hierarchy.

Individual superelement types may be excluded from the wave load calculation using SELI command.

Load cases will be generated for each first level superelement. Load combinations must be defined for higher level superelements in Presel.

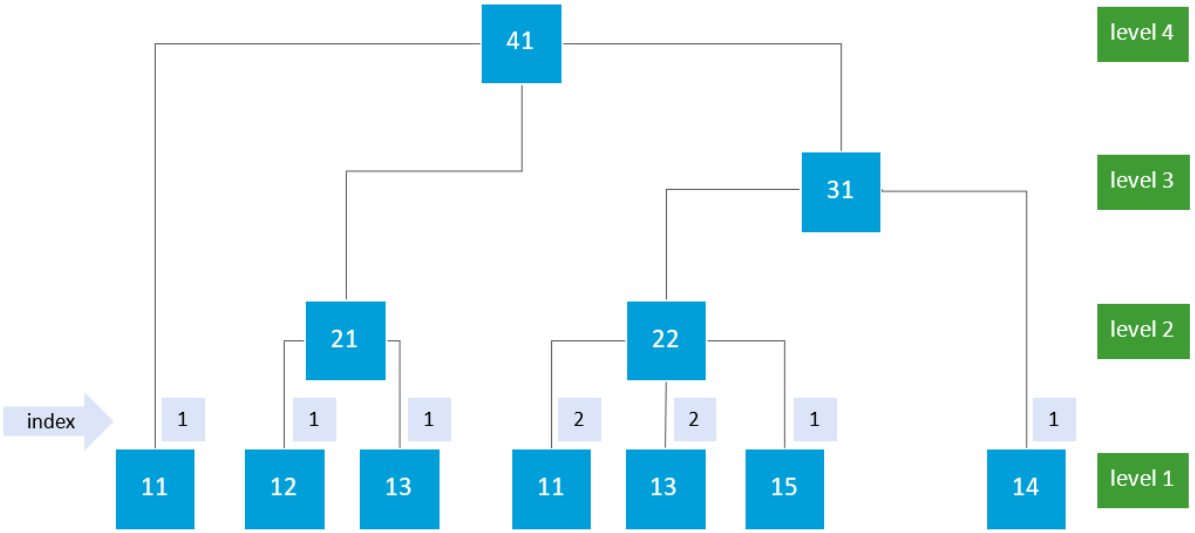


Figure 2.15: Superelement assembly

2.2.3 Member Segmentation

Each wet or dry part of member is divided into at least two segments. For deterministic analysis Wajac will detect all member-wave intersection points, while for other analysis types only the first detected point will be accepted. The force intensities are calculated at the ends of each segment. These points are called load calculation points. The number of segments used depends on the wave frequency and the member segmentation coefficient. This coefficient is given in the Wajac Analysis Control Data either as a global constant, specified for each member on MSEG command or it may also be made dependent on the vertical position of the members using SEGM and MEMSEG. Figure 2.16 shows typical member segmentations.

For deterministic analysis additional load calculation points will be included at marine growth definition points (both wet and dry part of member) and at current profile definition points (only for part of member under water).

Auto-segmentation

Additionally for deterministic analysis only it is possible to turn on auto-segmentation feature via MSEG card. Auto-segmentation will allow Wajac to determine optimal segmentation to ensure predefined accuracy and minimize number of segments at the same time.

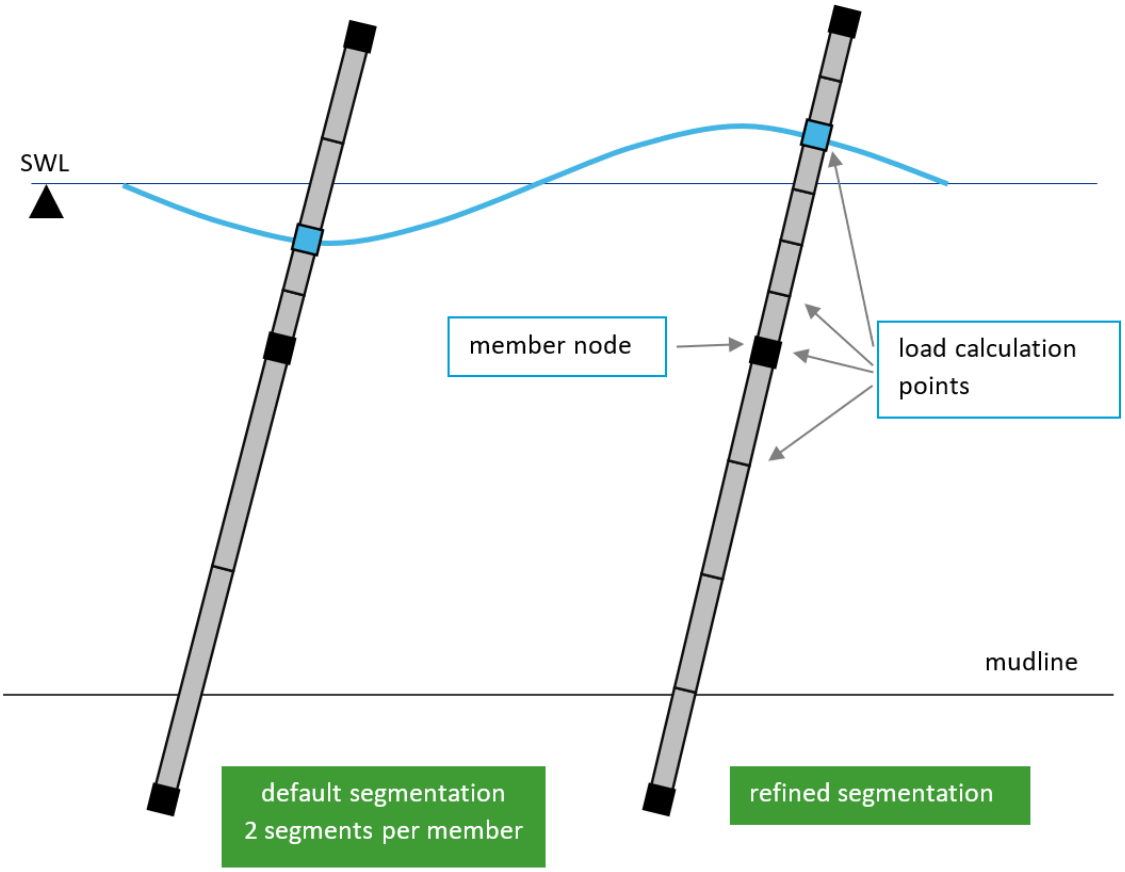


Figure 2.16: Member segmentation

2.2.4 Flooded Members

When calculating buoyancy loads, all members are assumed to be filled with air, i.e. non-flooded, see Figure 2.17. This means that an open section such as a T-section will be assumed to have some air inside, according to the equivalent diameter for the section as can be seen in Figure 2.14. For the non-flooded members, both the steel and the air contributes to the buoyancy. The members may be defined as flooded using FLOO command in which case only the steel area will contribute to the buoyancy load.

The buoyancy areas for calculating non-flooded or flooded buoyancy can be overridden through card BUOA.

The calculation of buoyancy is further described in Section 2.2.5 and Section 2.4.8.

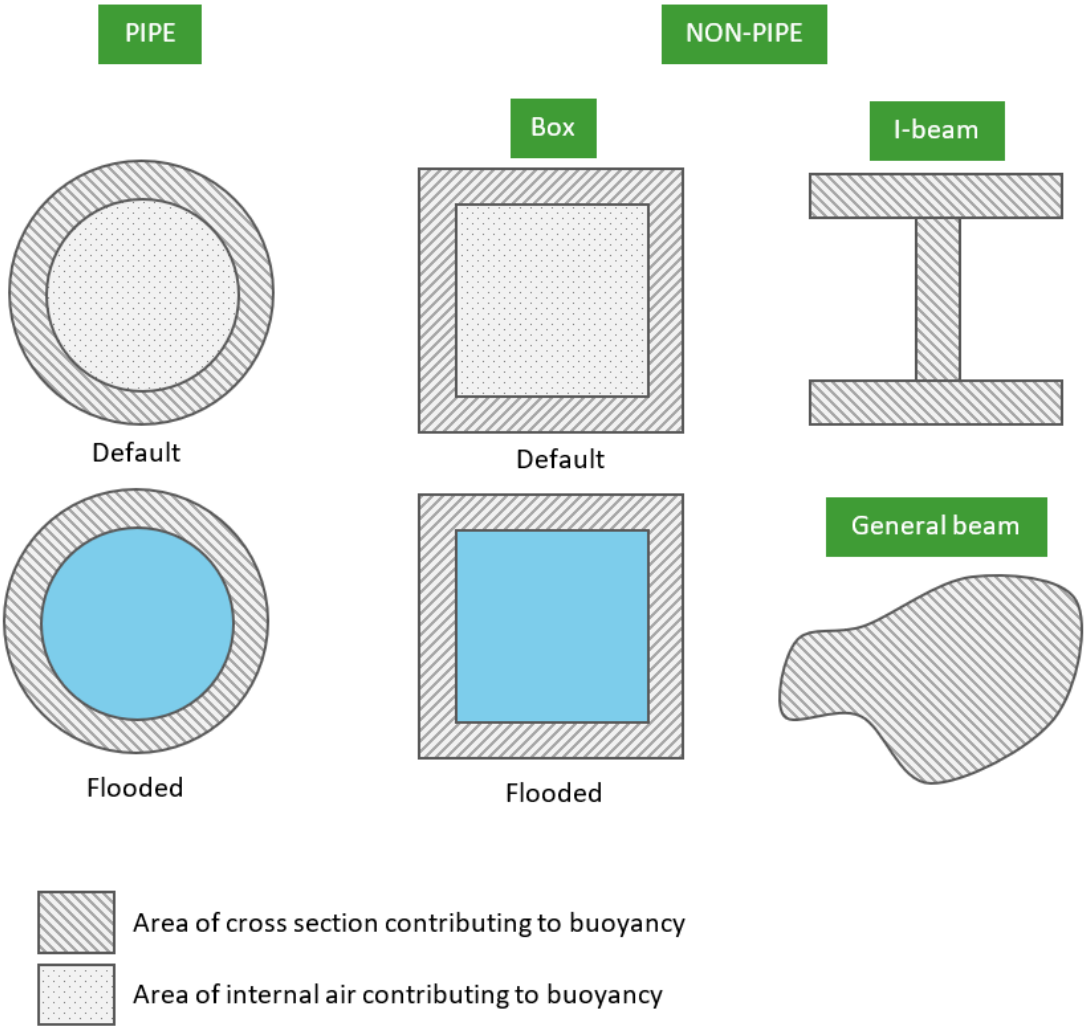


Figure 2.17: Pipe and non-pipe cross sections

2.2.5 Mudline and Soil Permeability for Legs

The mudline is specified relative to the origin of the global coordinate system, see Figure 2.1. Loads are calculated down to the mudline.

To account for reduced soil permeability the buoyancy of a leg sinking into the soil may be reduced by a factor using LEG command. The leg is identified as the most vertical members between two specified nodes. These nodes should be the bottom node (below the mudline) and a node above the water surface including the wave crest, for instance the top node of the leg, see Figure 2.18.

In addition to reducing buoyancy for a leg sinking into the soil the command may be used to reduce or eliminate buoyancy for any fully or partly submerged member. Note that the two specified nodes should be the free end nodes of the member.

Additionally for deterministic analysis user may also reduce buoyancy and weight of marine growth. Three different options are available:

a) buoyancy and weight of marine growth is reduced by common factor, other than the permeability factor used for member,

b) only marine growth weight is included,

c) only marine growth buoyancy is included.

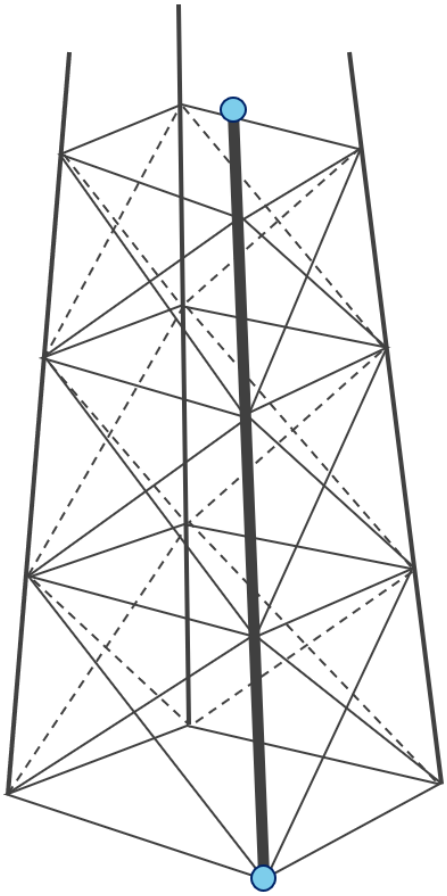


Figure 2.18: Identification of leg for specification of soil permeability

2.2.6 Marine Growth

Increased diameter and roughness height may be specified using MGRW command to account for additional forces due to marine growth locally. The given marine growth will be added to the member diameter at the load calculation points before calculating the viscous drag forces. See Figure 2.19. The roughness height may be used to specify varying hydrodynamic coefficients. See Section 2.2.7. More than one MGRW commands may be specified.

The user may specify the density of the marine growth. By default this is assumed to be equal the density of water. The density is used to calculate the weight of the marine growth in water (static load), and additional mass for use in subsequent dynamic structural analysis (transversal component only by default and longitudinal component can be included if preferred).

The marine growth data is given as function of the vertical position, or by referring directly to members or sets of members. The additional thickness may optionally also be added to the member diameter before calculating the inertia forces.

User may apply specific marine growth definition to selected members using MEMGRW command.

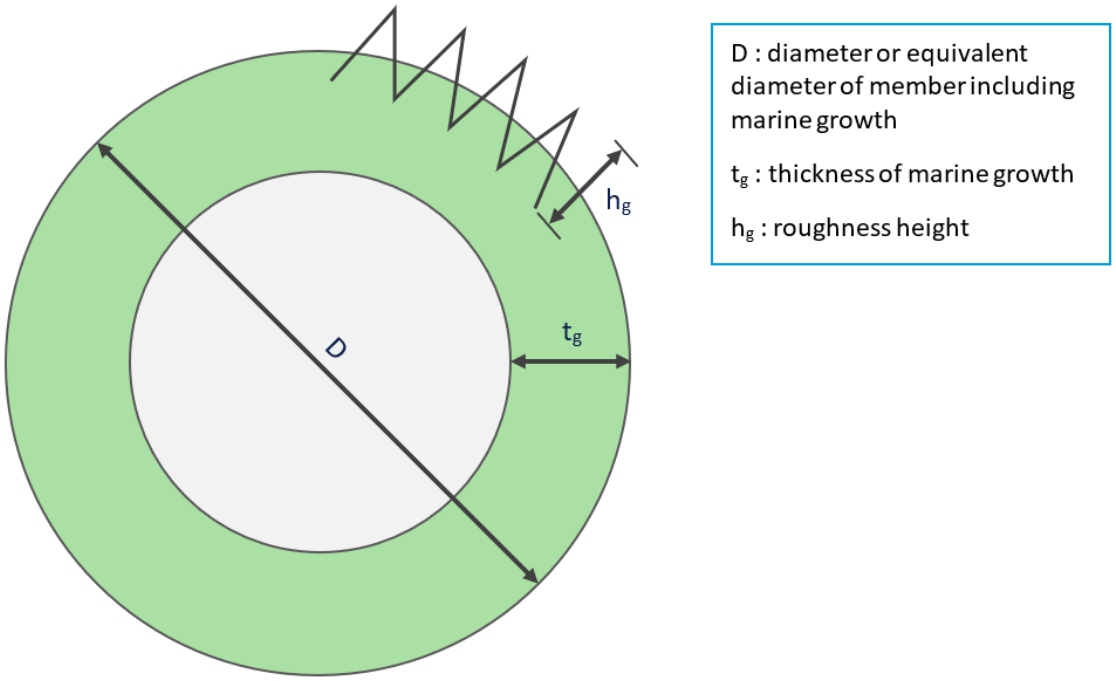


Figure 2.19: Marine growth and roughness height

2.2.7 Specification of Hydrodynamic Coefficients

The Morison's equation as described in Section 2.4 requires specification of inertia and drag coefficients at each load calculation point. Since the coefficients are empirical in nature their determination is based on engineering judgement. In Wajac there exist several options for specifying these coefficients. These are:

1 specified on the Input Interface File, see Section 2.2.8,

2 specified according to API, see Section 2.5, command: API,

3 given as a function of the vertical position above the mudline, command: COEF,

4 given as a function of the diameter including marine growth, command: CDIA,

5 given as a function of the diameter for fouled and non-fouled (clean) members, command: CDFN,

6 given as a function of the Reynolds number and the roughness number at the individual load calculation point, commands: CDRG, CMAS,

7 given as a function of the Keulegan-Carpenter number and the roughness number at the individual load calculation point, commands: CDRG, CMAS,

8 specified for individual members assuming unidirectional coefficients. For deterministic analyses, global wave direction and/or seastate dependent coefficients can be specified (see command CGWD), commands: SPEC, SPEX,

9 specified as directional coefficients for individual members, commands: CDIR, CDIX.

The options are given priority, and by default, the priority is as defined in Table 2.1. The priority hierarchy may be modified by the user with CPRI command. Specification with higher priority (1 is highest) will supersede any other coefficients specified. Specification by diameter, by diameter for fouled/non-fouled members, by Keulegan-Carpenter- and Reynolds number (option 4, 5, 6 and 7) have the equal priority and only one of these can be used at the same time. For restrictions on the use of the different options see Table 2.1.

For most methods the inertia and drag coefficients are specified for force components normal to the members. In addition, longitudinal coefficients may be given when specified as function of vertical position or for individual members (options 1, 3, 5, 8, and 9). When specifying directional coefficients (option 9), both the inertia and drag coefficients are specified relative to the axis of the local coordinate system of each individual member, see description below for more information about definition of local coordinate system in Wajac. Notice that the longitudinal component of member forces will only contribute to the total loads calculated by Wajac and not to the distributed member forces written to the Loads Interface File (see Section 2.6.3). See Table 2.1 for use of the different options.

Table 2.1: Use of options for specifying force coefficients (X means OK)

option	option no.	priority	A	B	C	D	E	F
Input Interface File	1	6	•	•	•	•	•	•
API	2	5	•				•	
vertical position	3	4	•	•	•	•	•	•
diameter	4	3	•	•	•	•	•	
diameter for fouled/non-fouled	5	3	•	•	•	•	•	•
KC. number	6	3	•		•			
Rn. number	7	3	•		•		•	
individual	8	2	•	•	•	•	•	•
directional	9	1	•	•	•	•	•	•

A — deterministic load calculation
B — seastate simulation
C — wave height linearisation
D — equivalent linearisation
E — only current
F — longitudinal component

The member local coordinate system used in Wajac is not necessarily corresponding to the one defined in the preprocessor having created the model, see the GeniE user manual. Wajac reads the local coordinate system from the Input Interface File and define local y-axis along the length axis of the member, see Figure 2.20. The relation between the local coordinate system in Wajac and the local coordinate system in the Sesam preprocessors is

Wajac	Preprocessor
x	$-y$
y	x
z	z

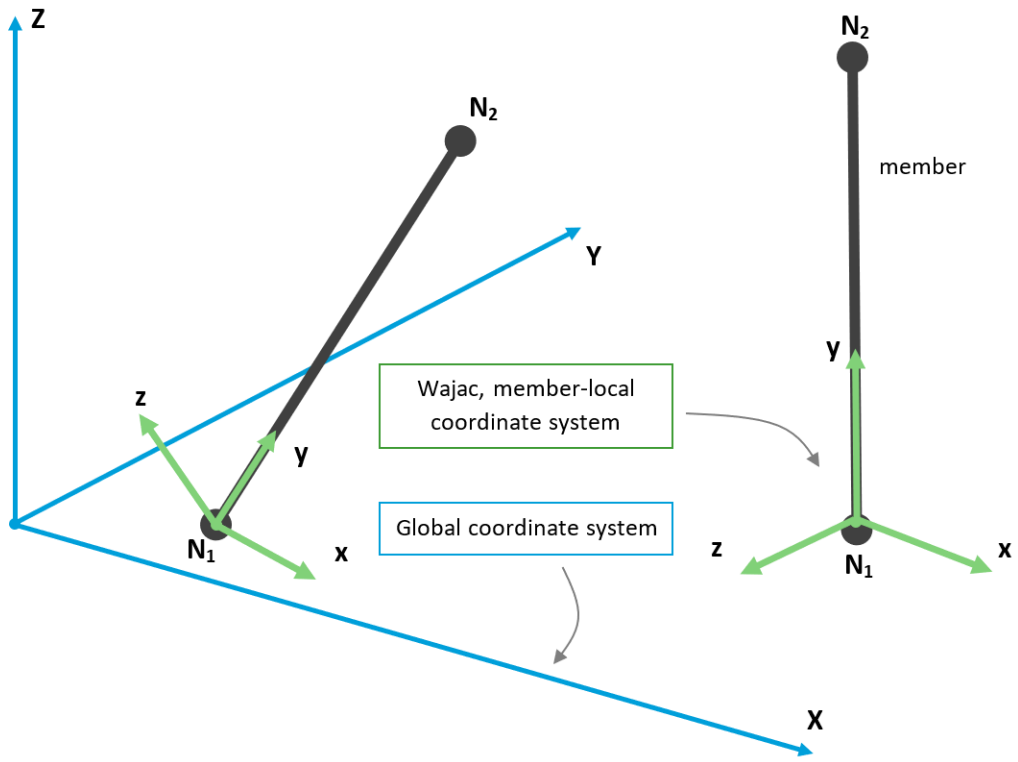


Figure 2.20: Local coordinate system in Wajac

If for a member no local coordinate system is specified on the Input Interface File, a default definition in Wajac will be used. In this definition the local x-axis will always lie in the global X–Y plane and this will then determine the local z-axis. If the member is vertical the local x-axis will be parallel with the global X-axis. See Figure 2.20.

The Keulegan-Carpenter number is defined by

$$\mathrm{KC} = \frac{2\pi U_m}{\omega D} \tag{2.9}$$

and the Reynolds number is defined by

$$\mathrm{Rn} = \frac{U_m D}{\nu} \tag{2.10}$$

where

U_m is the maximum fluid velocity in a wave cycle normal to the member (including current velocity component in the direction of the wave propagation), at the load calculation point in question,

Note: The maximum fluid velocity is calculated based on airy wave, irrespective of which wave theory specified by users.

ω is the wave angular frequency,

D is the member diameter including marine growth and

ν is the fluid kinematic viscosity.

The roughness numbers are specified by the roughness height (see Section 2.2.6) divided by the member diameter.

The specification of hydrodynamic coefficients as functions of the Keulegan-Carpenter number is invalid for a calm seastate (only current specified). This also applies for the time simulation of seastates. This is due to the fact that the fluid velocity cannot be associated with any wave frequency in these cases. When using the Reynolds number dependency in a seastate simulation analysis the fluid velocity used to calculate the Reynolds number is the instantaneous velocity.

Neither Keulegan-Carpenter nor Reynolds number dependency can be used for frequency domain calculations when equivalent linearisation is specified. The amplitudes of the wave particle velocity are not known at this step in the load calculation procedure.

2.2.8 Hydrodynamic Parameters on the Input Interface File

Drag coefficients, inertia coefficients and flooding parameters may also be specified as structural concept data on the Input Interface File, see Section 4.1.3. The values will be superseded if the parameters are given by Analysis Control Data as part of Wajac analysis. For further information on how to specify the structural concept data, see the GeniE documentation.

2.3 Environment Description

The environment is specified by the water depth, type of surface waves, wind, current and seastates. A description of each of these factors is given in the following sections.

2.3.1 Surface Waves

The plane, periodic surface waves used in Wajac, are specified by their wave period T, the wave angle β defined as the angle measured counter-clockwise from the global positive X-axis to the propagation direction of the waves, the wave height H (Figure 2.21), and the wave theory in which the mathematical model of the waves is given.

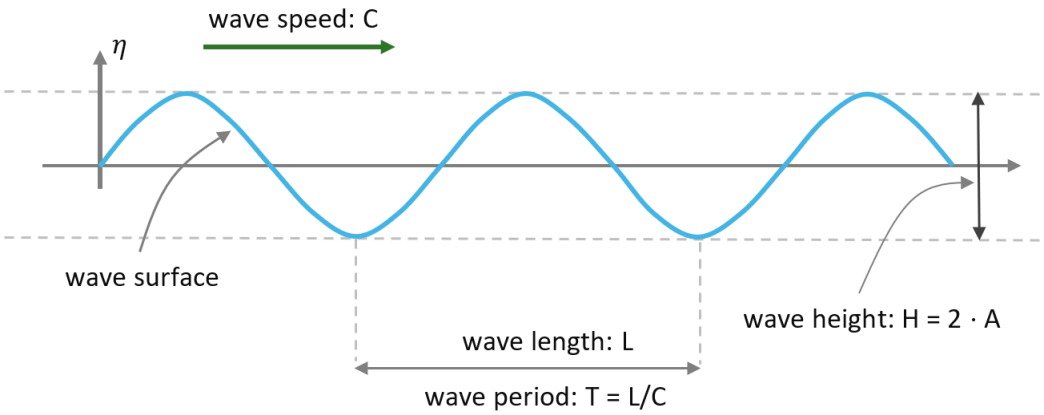


Figure 2.21: Plane, periodic surface waves

When performing a deterministic wave load calculation five finite depth wave theories are available in Wajac. These are

- the linear wave theory, often referred to as the Airy wave theory,
- the Stokes' fifth order wave theory,
- the Dean's stream function wave theory,
- cnoidal wave theory for shallow water, and
- the Newwave theory.

The wave kinematics in specified points may be written to the Print File when performing load calculations in time domain.

When simulating wave loads in a short-term seastate the surface waves are defined through a wave spectrum and a wave spreading function.

When loads are calculated in frequency domain or by time simulation of a seastate, only linear wave theory is available. The user is referred to Ref. [14] and Ref. [17] for an in-depth discussion of the different wave theories.

2.3.2 Linear Harmonic Waves

The surface waves as defined in Wajac may according to linear wave theory be written as

$$\eta(\mathbf{X},t) = A\cos(\mathbf{k}\cdot\mathbf{X} - \omega t) \tag{2.11}$$

The undisturbed fluid velocity $\mathbf{v} = v_x\mathbf{i}_1 + v_y\mathbf{i}_2 + v_z\mathbf{i}_3$ and acceleration $\mathbf{a} = d\mathbf{v}/dt = a_x\mathbf{i}_1 + a_y\mathbf{i}_2 + a_z\mathbf{i}_3$ are given as horizontal and vertical components as follows:

$$\begin{aligned}\mathbf{v}_h &= v_x\mathbf{i}_1 + v_y\mathbf{i}_2 = A\omega\frac{\mathbf{k}}{k}\frac{\cos(k(Z+d))}{\sinh(kd)}\cos(\mathbf{k}\cdot\mathbf{X} - \omega t)\\ v_z &= A\omega\frac{\sinh(k(Z+d))}{\sinh(kd)}\sin(\mathbf{k}\cdot\mathbf{X} - \omega t)\end{aligned} \tag{2.12}$$

$$\begin{aligned}\mathbf{a}_h &= a_x\mathbf{i}_1 + a_y\mathbf{i}_2 = A\omega^2\frac{\mathbf{k}}{k}\frac{\cos(k(Z+d))}{\sinh(kd)}\sin(\mathbf{k}\cdot\mathbf{X} - \omega t)\\ a_z &= -A\omega^2\frac{\sinh(k(Z+d))}{\sinh(kd)}\cos(\mathbf{k}\cdot\mathbf{X} - \omega t)\end{aligned} \tag{2.13}$$

where

d	depth
k	absolute value of wave number
ω	wave angular frequency,
A	wave amplitude
$\mathbf{X}$	$= X\mathbf{i}_1 + Y\mathbf{i}_2$ — location in the X-Y plane
$\mathbf{k}$	$= k(\mathbf{i}_1 \cos\beta + \mathbf{i}_2 \sin\beta)$ — two dimensional wave number
Z	vertical coordinate with Z-axis upward, $Z = 0.0$ at still water level
β	direction of wave propagation

The finite depth dispersion relation used in the above expressions is

$$\omega^2 = gk\tanh(kd) \tag{2.14}$$

The wave period is given by

$$T = \frac{2\pi}{\omega} \tag{2.15}$$

and the wave length is

$$L = \frac{2\pi}{k} \tag{2.16}$$

For a more detailed description of linear wave theory reference is made to Ref. [14].

The fluid kinematics above the still water level are not defined by linear wave theory. When loads are applied above the still water level using linear waves (in a time domain load calculation or linearisation with respect to wave height) assumptions on the fluid velocity and acceleration must be made. The kinematics in the wave crest are in this case set equal to their values at the still water level. In a deterministic load calculation analysis the kinematics above the still water level may alternatively be obtained by continuation of the exponential curve below the still water level or by Wheeler stretching. See Figure 2.22.

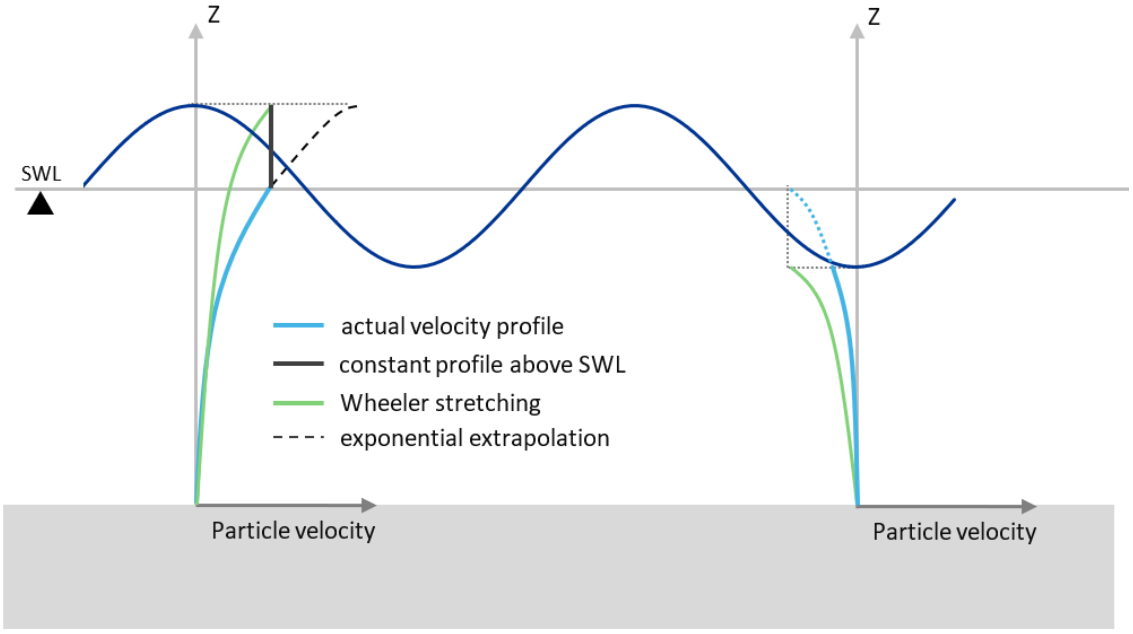


Figure 2.22: Fluid kinematics in the wave crest and trough of a linear wave

The exponential extrapolation may give wrong results since the particle velocities are overestimated in the wave crest.

The Wheeler stretching implies that the fluid kinematics are adjusted by calculating the kinematics at a corrected level, Z', using linear wave theory and applying the calculated fluid kinematics at the actual level Z. The corrected level is given by

$$Z' = \frac{Z - \eta}{1 + \frac{\eta}{d}} \tag{2.17}$$

where

Z' is the corrected Z coordinate where the kinematics are calculated
Z is the actual Z coordinate where the kinematics are applied,
η is the instantaneous surface elevation and,
d is the water depth

When the Wheeler stretching is applied the same procedure will also apply to any specified current.

2.3.3 Stokes' Fifth Order Wave Theory

Stokes' fifth order wave theory is required for steep waves at intermediate to deep water.
For a detailed description of Stokes' fifth order wave theory see Ref. [16].

2.3.4 Dean's Stream Function Wave Theory

The Dean's stream function wave theory is a purely numerical procedure for approximating a given wave profile and has a broader range of validity than the Stokes' fifth order wave theory.

When using the stream function wave theory the order of the wave theory must be chosen. The closer to the breaking wave height the more terms are required in order to give an accurate representation of the wave. For more information see Ref. [5], Ref. [6] and Ref. [14].

2.3.5 Cnoidal Wave Theory

Cnoidal wave theory is typically used for shallow waters.

For a detailed description of cnoidal wave theory see Ref. [11].

2.3.6 The Newwave Theory

The Newwave theory provided by Shell uses a statistically-based superposition of linear wavelets do define a wave profile and associated kinematics representing the most probable maximum condition in a real sea. The model can be applied with the economy and convenience of traditional deterministic waves.

For a description of the Newwave theory see Ref. [17].

2.3.7 Wave Spectra

Two types of standard wave spectra for time simulation of seastates and for equivalent linearisation in frequency domain calculations are available in Wajac. These are the modified Pierson-Moskowitz spectrum (also known as Bretschneider spectrum) and the JONSWAP spectrum, see Ref. [7].

In addition to the two standard wave spectra, three double-peaked spectra (also referenced to as bimodal or dual-peaked) are available for irregular sea and constrained wave analysis. These are:

- Six-parameter Ochi-Hubble, [22].
- Torsethaugen (full version), [23].
- Torsethaugen (simplified version), [24].

Please note that the values of the spectral density function can be printed to a separate file using FCOMP command.

The **Pierson-Moskowitz** spectrum applies to deep water conditions and fully developed seas. The spectrum may be described by the significant wave height H_s and the zero up-crossing period, T_z. The spectrum is then given by

$$S(\omega) = \frac{H_s^2 T_z}{8\pi^2}\left(\frac{\omega T_z}{2\pi}\right)^{-5} \exp\left[\frac{-1}{\pi}\left(\frac{\omega T_z}{2\pi}\right)^{-4}\right] \tag{2.18}$$

The **JONSWAP** spectrum applies to limited fetch areas and homogeneous wind fields and may be expressed as

$$S(\omega) = \alpha g^2 \omega^{-5} \exp\left[\frac{-5}{4}\left(\frac{\omega}{\omega_p}\right)^{-4}\right] \gamma^a \tag{2.19}$$

where

$$a = exp\left(-\frac{(\omega-\omega_p)^2}{2\sigma^2\omega_p^2}\right)$$

$$\sigma = \begin{cases} \sigma_a & \text{if } \omega \leq \omega_p \\ \sigma_b & \text{if } \omega > \omega_p \end{cases}$$

Ochi-Hubble and **Torsethaugen** spectrums allow to model sea states where both wind and swell play an important role [25, sec. 3.5.2.4]. These spectrums define a spectral density function with two peaks [22, 23, 25]. These do not, however, make place for a wave directional spreading.

The **Ochi-Hubble** spectrum is a linear combination of two Gamma distributions. The original paper [22] introduces two different ways of specifying the spectrum - Wajac uses only one of them.

The first method (the one available in Wajac) is based on three parameters for each of the parts of the spectrum, that is: significant wave height $H_{s,j}$, period of the peak $T_{p,j}$ and shape parameter λ_j, where index j refers to one of the two parts of the spectrum, i.e. $j = 1, 2$. Usually $j = 1$ refers to the lower and $j = 2$ to the higher frequency components.

The second method takes as input the significant wave height H_s relevant to the entire spectrum and then the most probable spectral wave parameters are determined, this option is not available in Wajac.

Definition of spectral density function for Ochi-Hubble spectrum [25, sec. 3.5.7.5]:

$$S_{OH}(\omega) = \sum_{j=1}^{2} E_j \cdot G_j \cdot \Gamma_j \tag{2.20}$$

Where:

$$\Gamma_j = \omega_{n,j}^{-4(\lambda_j+\frac{1}{4})} \cdot e^{-(\lambda_j+\frac{1}{4})\cdot\omega_{n,j}^{-4}}$$

$$G_j = \frac{4\cdot(\lambda_j+\frac{1}{4})}{\Gamma(\lambda_j)}$$

$$E_j = \frac{H_{s,j}^2 \cdot T_{p,j}}{32\pi}$$

$$\omega_{n,j} = \frac{\omega}{\omega_{p,j}}$$

The **Torsethaugen** two-peaked spectrum is based on fitting JONSWAP functions to averaged measured spectra from the Norwegian Continental Shelf [25, 23, 24].

There are two versions of the spectrum available in Wajac, the original one [23], which represents the full specification, and the simplified version [24], which, as the name suggests, makes some assumptions, to limit the number of dependent parameters.

Contrary to the definition of Ochi-Hubble, the relations for Torsethaugen are rather lengthy and will not be presented here. It is advised to refer to Appendix A of [25].

Both versions of the Torsethaugen spectra are defined by specifying the period of the peak T_p, and the significant wave height H_s, both relevant to the entire spectrum.
One should note that the Full version of the Torsethaugen spectrum implemented in Wajac is energy-normalized along the specified frequency range. This means that one will always obtain the predefined significant wave height H_s based on the 0th moment of the spectrum using the following relation:

$$H_s = 4 \cdot \sqrt{m_{0,e}}$$

$$m_{0,e} = \int_0^{\omega_e} S(\omega) \cdot d\omega$$

Where: ω_e - low-pass angular frequency, i.e. end value of angular frequency range considered.

In all above equations the following definitions are used:

$H_s{}^*$	significant wave height
$T_z{}^*$	zero up-crossing period
α	Philips' constant ($= 0.081$ for a fully developed sea)
ω_p	angular frequency of the spectral peak
T_p	period relevant to frequency of the spectral peak
γ	peak enhancement factor (JONSWAP spectrum)
σ_a	spectrum left width (JONSWAP spectrum)
σ_b	spectrum right width (JONSWAP spectrum)
$\Gamma()$	Gamma function

* in case of double-peaked spectra, this quantity relates to entire spectrum.

In Wajac the following parametrisation of the JONSWAP spectrum is used:

$$\alpha = f_1(H_s, T_z, \sigma_a, \sigma_b, \gamma) \tag{2.21}$$

$$\omega_p = f_2(H_s, T_z, \sigma_a, \sigma_b, \gamma) \tag{2.22}$$

where the functions f_1 and f_2 are computed using numerical integration.

Profiles of the Pierson-Moskowitz and the JONSWAP spectrum are given in Figure 2.23.

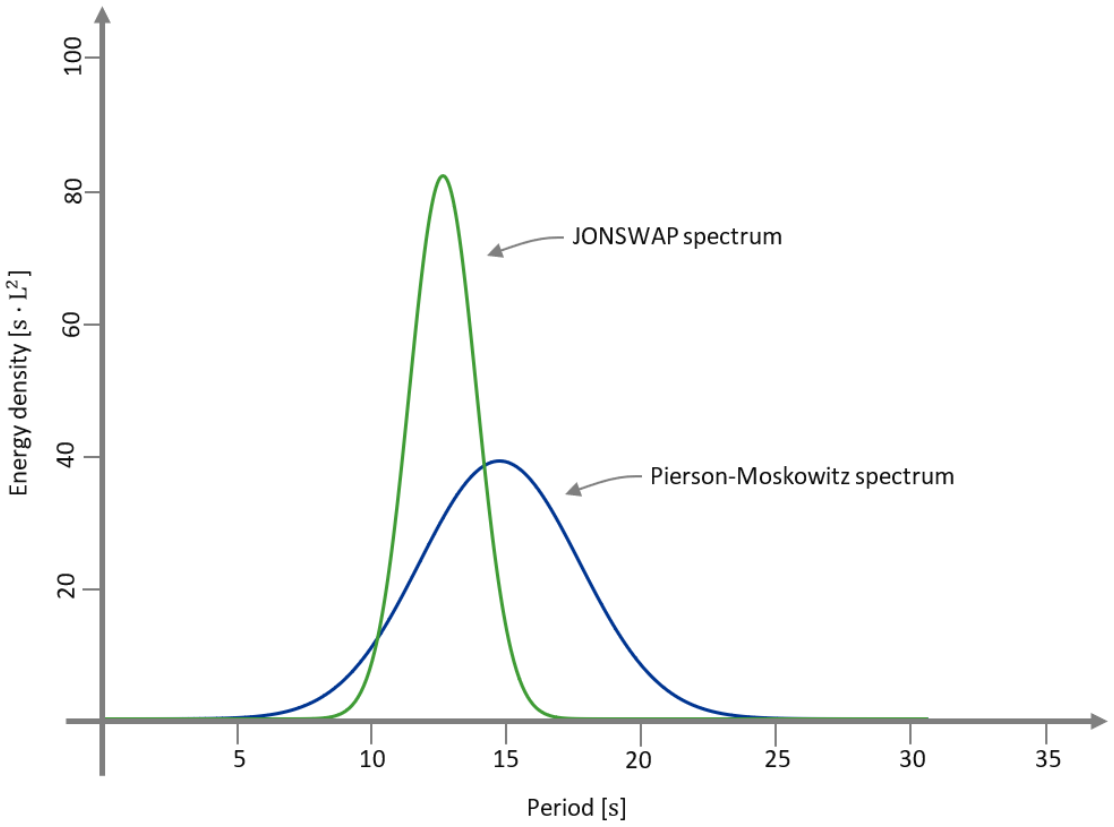


Figure 2.23: Pierson-Moskowitz and JONSWAP wave energy spectra

2.3.8 Wave Spreading Function

For the seastate simulation option in Wajac short crested seastates may be specified through wave spreading. This is done by specifying a fraction (a value between 0.0 and 1.0) of the energy for each component wave direction. Fractions for five directions with intervals of 45 degrees are specified.

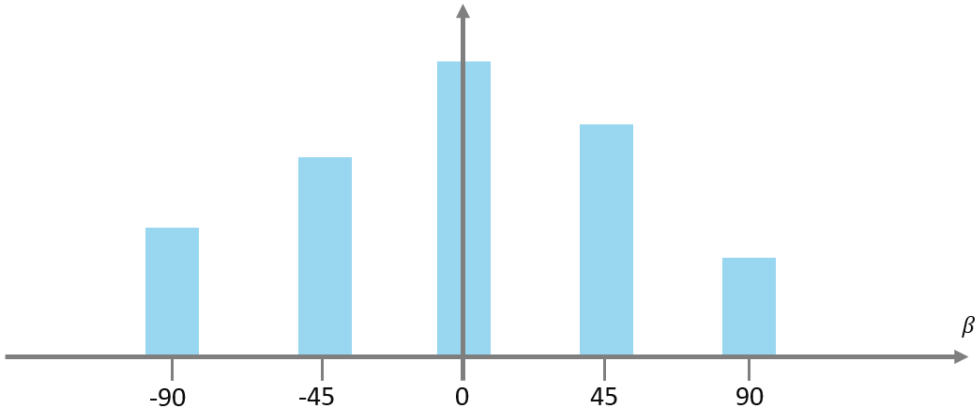


Figure 2.24: Energy for component wave directions

2.3.9 Current Profiles

A current may be superimposed on the wave particle velocity both for deterministic wave load calculation and when performing a time simulation of seastates (time domain calculations). When calculating transfer functions (frequency domain) current may also be superimposed and will affect the drag loads through the linearisation process (described in Section 2.4.2 and Section 2.4.3).

The current velocity is specified for a set of vertical levels. It is given as X-, Y- and Z-components referring to the global coordinate system, or as a horizontal velocity and direction. In the latter case the direction of the current velocity may be given relative to the global X-axis or specified to be parallel with the wave directions.

If Wheeler stretching is applied to linear waves in a deterministic load calculation any specified current will also be stretched according to the procedure described in Section 2.3.2.

2.3.10 Wind Profiles

A stationary wind field independent of the horizontal coordinates may be defined in order to calculate wind loads separately or in combination with a deterministic wave load calculation. The wind profile is given as a function of the global vertical coordinate, see Section 2.4.9.

2.3.11 Diffracted Waves around a Cylindrical Tank

Wajac may calculate diffracted kinematics due to a circular cylindrical tank and use the modified kinematics when calculating loads. The current profile may also be modified according to the potential flow solution. The calculation of the diffracted wave field is based on the MacCamy-Fuchs solution. See Ref. [4] for a description of the theory.

2.3.12 Multiple Depths

In deterministic load calculations (see Section 2.1.1), and frequency domain load calculations (see Section 2.1.2), more than one depth may be specified. The depth is defined as the distance from mudline to the still water level, as shown in Figure 2.1. For each depth specified loads will be calculated for all given seastates or correspondingly specified seastate(s). See more details in DPTH command.

When loads are calculated in an irregular sea (see Section 2.1.3) only specification of one single depth is possible.

2.4 Force Calculation

Wave and current forces are calculated according to Morison's equation, Ref. [12]. This is a semi-empirical formula in which it is assumed that the force may be divided into a sum of an inertia component due to the fluid acceleration and a drag component due to the fluid velocity.

For waves shorter than five times the member diameter the use of inertia force coefficients independent of the wave frequency, as in Morison's equation, will not give good results. When calculating transfer functions (frequency domain) the inertia forces may in such cases be calculated by the MacCamy-Fuchs formula, a simplified 2-dimensional potential theory. See Section 2.4.4.

Forces per unit length (force intensities) are calculated at the load calculation points of each member with components in the local or member coordinate system defined in Figure 2.20.

The distributed transverse components of the forces are approximated by linearly varying force intensities as shown in Figure 2.25.

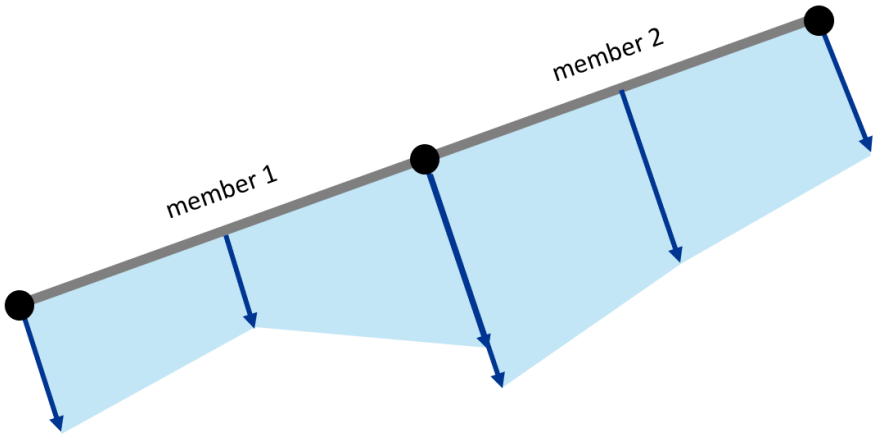


Figure 2.25: Linearly varying force intensities

Buoyancy forces are calculated according to the cross section areas defined either on the Input Interface File or through BUOA command and, as a general rule, added to the hydrodynamic forces. By default, longitudinal components are applied to the ends of the member. A more detailed description is given in Section 2.4.8.

The Morison's equation cannot be applied directly for the calculation of force transfer functions. The nonlinear drag term, the superposition of current and members with variable degree of submergence during a wave cycle will lead to nonharmonic response. To be able to use the concept of transfer functions approximations must be made. With respect to the drag term the user may choose between two different approaches, linearisation with respect to the wave height and equivalent linearisation with respect to a wave energy spectrum. The total loads, including maximum base shear and overturning moment, are reported in the Print File. The distributed loads are transferred to the Loads Interface File, see Section 2.6.3.

2.4.1 Morison's Equation

Morison's equation assumes that the pressure gradient across a member diameter is roughly constant and that the diffraction (scattering of the wave) is negligible. For engineering purposes the Morison's equation thus gives adequate results for member diameters smaller than approximately 1/5 of the wave length. For larger members compared to the waves other wave force calculation methods must be used to give accurate results.

According to the Morison's equation as applied in Wajac the force intensity calculated at the load calculation points may be written as (only the transverse components are included in this equation)

$$\mathbf{F}_n(\mathbf{r},t) = \rho\frac{\pi D^2}{4}\mathbf{C}_m \cdot \mathbf{a}_n(\mathbf{r},t) + \frac{1}{2}\rho D\mathbf{C}_d \cdot \mathbf{v}_n(\mathbf{r},t)|\mathbf{v}_n(\mathbf{r},t)| \tag{2.23}$$

where

ρ	is the water density,
D	is the member diameter at the load calculation point,
$\mathbf{C}_m$	is the inertia coefficient matrix,
$\mathbf{C}_d$	is the drag coefficient matrix,
$\mathbf{v}_n$	is the undisturbed velocity component of the fluid normal to the member at the time and point in question (including both wave and current),
$\mathbf{a}_n = \frac{\mathrm{d}\mathbf{v}_n}{\mathrm{d}t}$	is the undisturbed acceleration component of the fluid normal to the member at the time and point in question,
$\lvert\mathbf{v}_n\rvert$	is the absolute value of $\mathbf{v}_n$,
$\mathbf{r}$	is the global coordinate of the load calculation point, and
t	is the time.

The coefficient matrices are defined by:

$$\mathbf{C} = \begin{bmatrix} C_x & 0 & 0 \\ 0 & C_y & 0 \\ 0 & 0 & C_z \end{bmatrix}$$

where C represents the hydrodynamic inertia or drag force coefficient in the member local coordinate system as specified in the Wajac Analysis Control Data.

Normally only the force intensities normal to the members are calculated. When the inertia and drag coefficients are specified as a function of depth, as a function of diameter for fouled/non-fouled members or for individual members (Section 2.2.7) longitudinal components may also be calculated. These components may be written as

$$\mathbf{F}_l(\mathbf{r},t) = \rho\frac{\pi D^2}{4}\mathbf{C}_m \cdot \mathbf{a}_l(\mathbf{r},t) + \frac{1}{2}\rho D\mathbf{C}_d \cdot \mathbf{v}_l(\mathbf{r},t)|\mathbf{v}_l(\mathbf{r},t)| \tag{2.24}$$

where the subscript l indicates the longitudinal components of the fluid velocity and acceleration. Note that the longitudinal component is only included in the total forces integrated over the entire structure (thus, the longitudinal component is not written to the Loads Interface Files), and longitudinal wave loads are not calculated when frequency domain load calculations are performed. When calculating the total moments the longitudinal components are applied at the member ends.

The terms $|\mathbf{v}_n|$ and $|\mathbf{v}_l|$ may optionally be replaced by the total velocity $|\mathbf{v}|$.

2.4.2 Linearisation of Drag with respect to Wave Heights

This is relevant for calculation of force transfer functions only.

Linearisation with respect to wave heights is based on the selection of a characteristic or linearisation wave height H_ω , for each wave frequency. The drag force intensity is then linearised with respect to the maximum fluid velocity at the point in question during one wave cycle with the selected wave height. Members with a variable degree of submergence are treated conservatively. That is, for each member breaking the still water level the maximum degree of submergence during one wave cycle is determined using the wave height specified for that frequency. The inertia force and linearised drag force intensities are then calculated and applied up to this point. Fluid kinematics is assumed constant above the still water level. See Section 2.3.2 and Figure 2.22.

The transverse drag force intensity linearised with respect to wave heights may be expressed as

$$\mathbf{F}_{d_n}(\mathbf{r},t) = \frac{1}{2}\rho D\mathbf{C}_d \cdot \mathbf{v}_n(\mathbf{r},t)|\mathbf{v}_{n_{max}}(\mathbf{r})| \tag{2.25}$$

where

$\mathbf{v}_n$	is the undisturbed velocity of the fluid normal to the member at the time and point in question,
$\|\mathbf{v}_{n_{max}}\|$	is the absolute value of the maximum velocity normal to the member at the point in question during one cycle of a wave with the specified linearisation wave height H_ω .

If a current profile is superimposed on the wave the velocities in the above expressions are the sum of the velocities due to the wave and the current velocity. The constant mean value of the nonlinear drag force over one wave cycle is calculated and printed in the Wajac Print File for each load calculation point. The total drag force due to the current is also reported. These constant forces are calculated for each given wave period with corresponding wave height.

2.4.3 Equivalent Linearisation of Drag with respect to a Wave Energy Spectrum

This is relevant for calculation of force transfer functions only.

As an alternative to the linearisation with respect to wave height the nonlinear drag force in Equation (2.23) may be replaced by an equivalent linear force. The equivalent linearisation procedure applied in Wajac is based on the fact that the ocean waves and the corresponding fluid kinematics are Gaussian processes. The nonlinear drag force intensity in a given load calculation point,

$$\mathbf{F}_{d_n}(t) = \frac{1}{2}\rho D\mathbf{C}_d \cdot \mathbf{v}_n(t)|\mathbf{v}_n(t)| \tag{2.26}$$

is for a given seastate replaced by the linear equivalent force intensity

$$\mathbf{F}^*_{d_n}(t) = \alpha(\mathbf{u}_n - \mathbf{U}) + E[\mathbf{F}_{d_n}] \tag{2.27}$$

where

$$\alpha = \frac{E[\mathbf{F}_{d_n} \cdot (\mathbf{u}_n - \mathbf{U})]}{\Sigma} \tag{2.28}$$

Furthermore:

$E[x]$ is the expected or mean value of the variable x,
$\mathbf{u}_n$ is the total fluid velocity normal to the member including current,
$\mathbf{U}$ $= E[\mathbf{u}_n]$
Σ is the covariance $\mathrm{cov}(u_{n_i}, u_{n_i})$

The expressions implemented in Wajac assume circular cross section of the members.

The expected values and the co-variance matrix is calculated by numerical integration of the particle velocity spectrum at a given vertical position for the given seastate. Two types of standard wave spectra are available, the Pierson-Moskowitz spectrum and the JONSWAP spectrum. A short description of these are given in Section 2.3.7.

When applying the equivalent linearisation of drag forces, loads are calculated up to the still water level. The time dependent part of the drag force intensities are written to the Loads Interface File as transfer functions. The constant forces are printed in the Wajac Print File.

2.4.4 MacCamy-Fuchs Force Calculation

When requested through OPT4 parameter on OPTI command, the inertia forces may be calculated by a simplified two-dimensional potential theory, the MacCamy-Fuchs formula for wave forces on a vertical tube. This formula may be applied for the inertia part of the force intensities. The formula representing modified inertia coefficient used in Wajac is presented below in Eq. (2.29).

$$C_m = \frac{4}{\pi \cdot (k \cdot r)^2 \cdot \sqrt{J_1'^2(k \cdot r) + Y_1'^2(k \cdot r)}} \tag{2.29}$$

The two derivatives are determined using relations presented below.

$$\begin{aligned} J_1^{'}(x) &= J_0(x) - \frac{1}{x} \cdot J_1(x) \\ Y_1^{'}(x) &= Y_0(x) - \frac{1}{x} \cdot Y_1(x), \end{aligned} \tag{2.30}$$

Where:

k wave number,
r member radius,
$J_N(x)$ Bessel function of first kind and order N,
$Y_N(x)$ Bessel function of second kind and order N,
$J_1^{'}(x)$ derivative with respect to x of Bessel function of first kind and first order,
$Y_1^{'}(x)$ derivative with respect to x of Bessel function of second kind and first order.

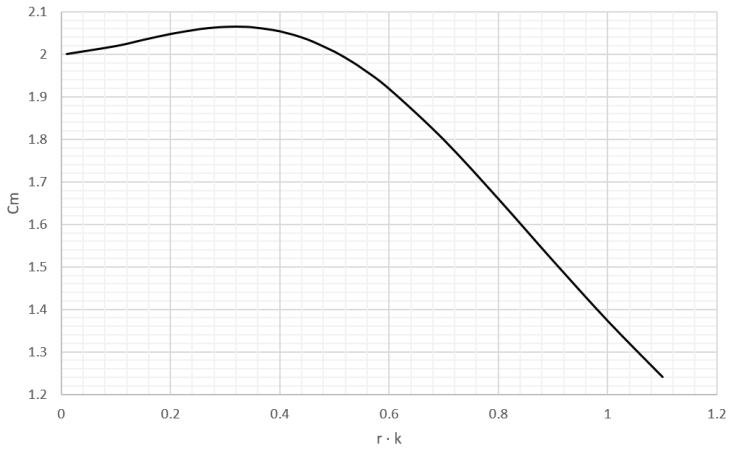


Figure 2.26: Plot of dependency of inertia coefficient on wave number and member radius according to MacCamy-Fuchs.

The modification may be applied in deterministic analysis, frequency domain analysis and irregular-sea analysis - including constrained wave analysis, however there are some minor differences between frequency domain analysis and time domain analyses, see more comments below.

Frequency domain analysis

The formula is applied only to members for which inertia coefficient C_m is set to 0 and for which inclination is less than 30 degrees. The formula may be applied without or with phase shift. In other words, the force may be applied in phase with the wave (in phase with the horizontal fluid particle acceleration at the load calculation point in question as in Morison's equation), or with a phase lag between the wave and the inertia force as given by potential theory.

Time domain analyses (deterministic, irregular sea, constrained wave)

The formula will be applied to members with inclination up to 10 degrees. Additionally, user may select members by specifying minimum diameter for which MacCamy-Fuchs should be applied using MFPR command, all members with diameter lower than the one specified will not be affected by MacCamy-Fuchs modification. Also, only option without phase shift is available for time domain analyses, meaning that there will be no phase shift between acceleration field and force. In deterministic analysis, the modification is reflected by change in value of inertia hydrodynamic coefficient - values from other definitions will be overridden if member is accepted for the modification. For irregular-sea analysis the horizontal acceleration field is modified, main reason behind it is that Wajac uses FFT for kinematics calculation. This is available both for pure irregular sea analysis and constrained wave. For constrained wave analysis, only the irregular background-sea part will be modified, i.e. the quantities relevant to constrained wave will not be modified.

It must be noted that the MacCamy-Fuchs formula is developed for a single, vertical and circular cylinder with constant diameter and which stands on the sea bottom and extends through the sea surface. Application outside these should be made with care.

For a detailed description of the MacCamy-Fuchs formula see Ref. [9].

2.4.5 Added Mass

Added mass components per unit length may be calculated at each load calculation point. These mass components are written to the Loads Interface File for use in subsequent dynamic structural analysis. This feature is available for all analysis types, deterministic load calculation, calculation of transfer functions and seastate simulation.

In all cases the hydrodynamic added mass is calculated up to the still water level and down to the mudline. The internal water of flooded members is included only up to still water level. The internal water may be

neglected for flooded members. The mass of marine growth over the still water level is also included in deterministic analysis and for pure added mass calculation. Additionally for deterministic analysis and pure added mass calculation user may select which of the two approaches for added mass calculation should be used by specifying proper value of 3rd parameter of MASS command. The difference between these two approaches is included in the description of MASS card.

The contribution to added mass components per unit length are given by

$$m_a = \left[\rho\frac{\pi D^2}{4}(C_m - 1)\right] + \left[\rho\left(\frac{\pi}{4}(D - 2t_g)^2 - \sigma\right)(1 - I)\right] + [\rho_g\pi(Dt_g - t_g^2)] \tag{2.31}$$

where the first, second and third term on the right hand side are contributions from added mass, internal water and mass of marine growth respectively, and

C_m is the inertia coefficient specified by one of the options described in Section 2.2.7 except for options two, six, seven (as function of KC and Rn numbers), and option eight (global wave direction or seastate dependent) ,

ρ is the fluid density,

ρ_g is the marine growth density,

D is the member diameter including marine growth. In the first term on the right hand side as applied when calculating the inertia forces by Morison's equation, Equation (2.23), and in the second and third term the equivalent diameter read from the Input Interface File,

σ is the member cross section steel area depending only on geometrical data from the Input Interface File,

t_g is the thickness of marine growth,

$I = 1$ for members where any internal water is not to be included, and

$I = 0$ for all members where internal water is to be included.

Note that for beams with general cross sections defined on the Input Interface File, no contributions from internal water or marine growth will be calculated.

An extra option through MASS card can be used to include both normal and longitudinal contribution of added mass. Longitudinal added mass triggered by non-zero longitudinal added mass coefficient and mass of marine growth and internal water in longitudinal direction will be included together with transverse added mass both in the Input Interface Files and output listing files. A more detailed description is given in MASS card for this option.

If frequency dependent inertia coefficients are specified either as a function of the Keulegan-Carpenter number or the Reynolds number, use of MacCamy-Fuchs formula, by API or by CGWD cards (wave-direction or seastate dependent coefficients), the value $C_m = 2.0$ is used when calculating the added mass according to Equation (2.31). This value is applied in all directions, also the longitudinal one. Value of $C_m = 2.0$ will also be used in all directions by default, i.e. when no coefficients are assigned to the member.

The total added mass is reported in the Print File.

2.4.6 Damping

Damping components b per unit length normal to the members may be calculated at each load calculation point and written to the Loads Interface Files. The calculation is based on the user specified constant drag coefficients and the damping components are calculated from the mudline up to the still water level by

$$b = \frac{1}{2}\rho D C_d \tag{2.32}$$

An extra option through MASS card can be used to include both normal and longitudinal contribution of damping. Longitudinal damping is triggered by a non-zero longitudinal damping coefficient and is included

together with normal damping in the Input Interface Files. A more detailed description is given in MASS card for this option.

If frequency dependent drag coefficients are specified either as a function of the Keulegan-Carpenter number or the Reynolds number, by API or by CGWD cards (wave direction/seastate dependant coefficients), the value $C_d = 0.7$ is used when calculating the damping according to Equation (2.32).

2.4.7 Weight of Marine Growth

Weight of marine growth is calculated from the following expression

$$\mathbf{F}_g = -(\rho_g - \rho)g\pi(Dt_g - t_g^2)\mathbf{i}_3 \tag{2.33}$$

where

- ρ is the fluid density,
- ρ_g is the marine growth density,
- t_g is the thickness of marine growth,
- D is the member equivalent diameter obtained from the Input Interface File. The thickness of marine growth is included,
- $\mathbf{i}_3$ is a unit vector normal to global horizontal plane.

In time domain (deterministic load calculation or seastate simulation), weight of marine growth is calculated from mudline and up to the free surface elevation. The dry weight (weight excluding buoyancy) of marine growth over the free surface elevation is also included for deterministic analysis. The calculation is done for each member at each time instant. The loads are included in the load written to the Print File, and the loads are written to the Loads Interface File as line loads. The weight of marine growth for the horizontal beams located at mudline can optionally be included by setting OPT12 as 1.

For member being identified as leg, weight of marine growth can additionally be reduced or not included at all. This is controlled by a LEG command.

In frequency domain, weight of marine growth is calculated from mudline to SWL. The loads are included in the load written to the Print File, but not written to the Loads Interface File.

2.4.8 Buoyancy Forces

By default buoyancy forces are determined using so called rational method, OPT11=0 on OPTI command. In this method the components of the buoyancy force normal to the member are applied as constant force intensities along the member. The longitudinal components, by default, are applied as nodal forces at both member ends pointing into the member and include contribution from marine growth area for deterministic load calculation. This will induce compression forces in the member.

The transverse buoyancy force, $\mathbf{F}_{b_n}$, and the longitudinal buoyancy forces at the member ends and their sum, components, $\mathbf{F}_{b_{l1}}$, $\mathbf{F}_{b_{l2}}$ and $\mathbf{F}_{b_l}$ respectively, are given by

$$\mathbf{F}_{b_n} = \rho g\sigma l \cos\alpha \mathbf{n} \tag{2.34}$$

$$\begin{aligned} \mathbf{F}_{b_{l1}} &= \rho g(-Z_1 + \eta)\sigma \mathbf{l} \\ \mathbf{F}_{b_{l2}} &= -\rho g(-Z_2 + \eta)\sigma \mathbf{l} \\ \mathbf{F}_{b_l} &= \rho g(-Z_1 + Z_2)\sigma \mathbf{l} = \rho g\sigma l \sin\alpha \mathbf{l} \end{aligned} \tag{2.35}$$

where

- σ is a member cross section area depending on either geometrical data from the Input Interface File or through card BUOA. For flooded members σ is the cross section steel area. For non-flooded members the cross section area of the inner volume is added. See Figure 2.17.
- l is the member length,
- α is the inclination defined in Figure 2.28,
- Z is the vertical position relative to the still water level,
- η depends on the analysis type as described below,
- $\mathbf{l}$ is the unit vector along the member, and
- $\mathbf{n}$ is the unit vector normal to the member in the plane spanned by $\mathbf{l}$ and $\mathbf{i}_3$.

In a **deterministic load calculation** the intensities of marine growth buoyancy by default vary along member axis according to marine growth variation. When marine growth thickness does not vary along member axis then there are only normal components of these intensities. On the other hand when marine growth thickness varies along member axis then we should also expect axial components. In addition to distributed loads, concentrated loads may also appear due to sudden change of marine growth, these forces are located along member axis.

For members partly below the mudline the buoyancy at the lower end, $\mathbf{F}_{b_{l1}}$, is calculated at the mudline and applied at the node below the mudline.

There are two other choices available for OPT11 parameter, namely OPT11=1 and OPT11=2, the latter one is only available for deterministic analysis.

OPT11=1 refers to so called marine method. In this method all components of buoyancy intensities act in global vertical direction ($+z$). There will be no nodal forces at both member nodes if this option is selected. This option is only relevant for time domain (deterministic load calculation or seastate simulation).

OPT11=2 is a mix of rational and marine method. It uses the rational method for non-flooded members (non-flooded space and steel). For flooded members the marine method is used (steel). Buoyancy of marine growth, both for flooded and non-flooded members is calculated using the marine method. The three available options are presented in Figure 2.27. Note that when marine growth thickness varies along a member, axial components of distributed line load will be present.

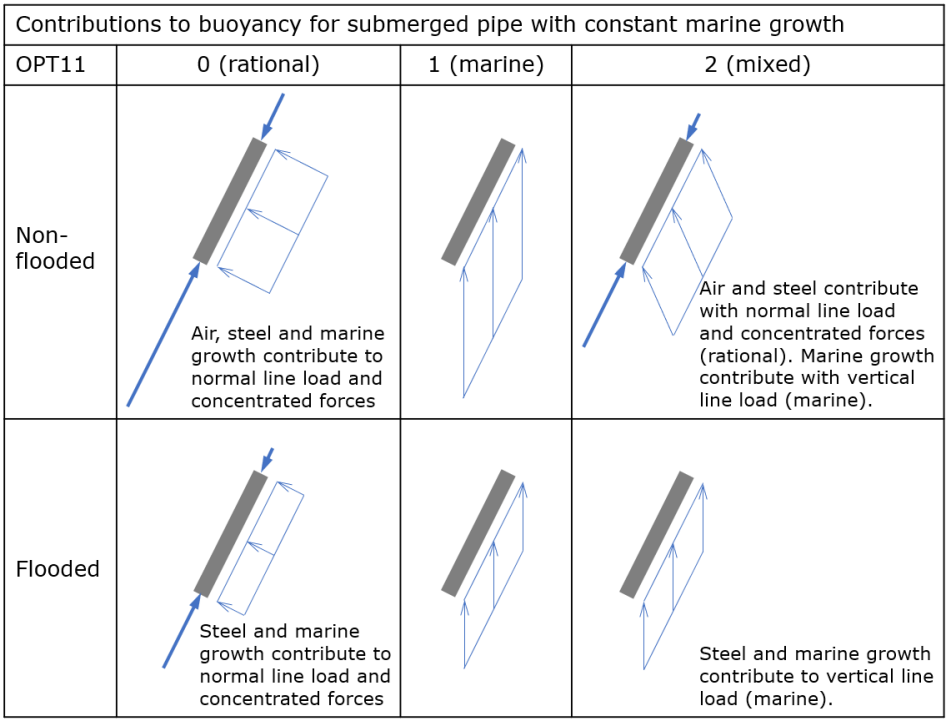


Figure 2.27: Load distribution for different values of OPT11 parameter

By default, no buoyancy will be calculated for members or parts of members below the mudline. However, the buoyancy of legs sinking into the mudline may be adjusted through the specification of soil permeability, see Section 2.2.5. Buoyancy of marine growth attached to a leg can additionally be reduced or excluded via one of the parameters specified on LEG command. Members may also be flooded, see Section 2.2.4. The buoyancy of horizontal beams located at mudline can optionally be included by setting OPT12 as 1.

In time domain (deterministic load calculation or seastate simulation) the buoyancy of each member is calculated at each time instant and added to the wave and current forces.

Buoyancy areas based on geometry data can be overridden through card BUOA.

Members may be defined as flooded resulting in contribution from the steel cross sectional area only to the buoyancy, see section 2.2.4. For flooded members buoyancy of *all members* may optionally be switched off by setting OPT7=1.

A non-horizontal surface elevation will give horizontal components of the buoyancy forces on non-vertical members due to the different surface elevation for the two member ends. This is avoided in Wajac by using the larger of the two surface elevations when calculating the buoyancy loads, that is

$$\eta = \max(\eta_1, \eta_2) \tag{2.36}$$

See Figure 2.28. User may choose to use actual surface elevation by setting OPT6 to 1.

In a **deterministic load calculation** the buoyancy loads may be excluded from the load calculation by specifying proper value of LOAD parameter on SEAOPT command.

In a **frequency domain calculation** only a total static buoyancy load is calculated. The buoyancy is calculated up to the still water level, i.e. $\eta = 0.0$, when linearisation with respect to a wave energy spectrum is used. The buoyancy is calculated for the maximum degree of submergence during the wave cycle when linearisation with respect to wave heights is used. Neither the buoyancy due to the steel area of pipe members nor any other members contribute to this total load and no buoyancy loads are included in the distributed member loads written to the Loads Interface Files.

The buoyancy of marine growth, the buoyancy of steel area and the buoyancy of air in non-flooded members for the part of the structure between the mudline and SWL are reported in the Print file. Besides, the centre

of buoyancy with/without contribution of marine growth is also reported in the Print file. The coordinates printed are relative to the origin of the global coordinate system.

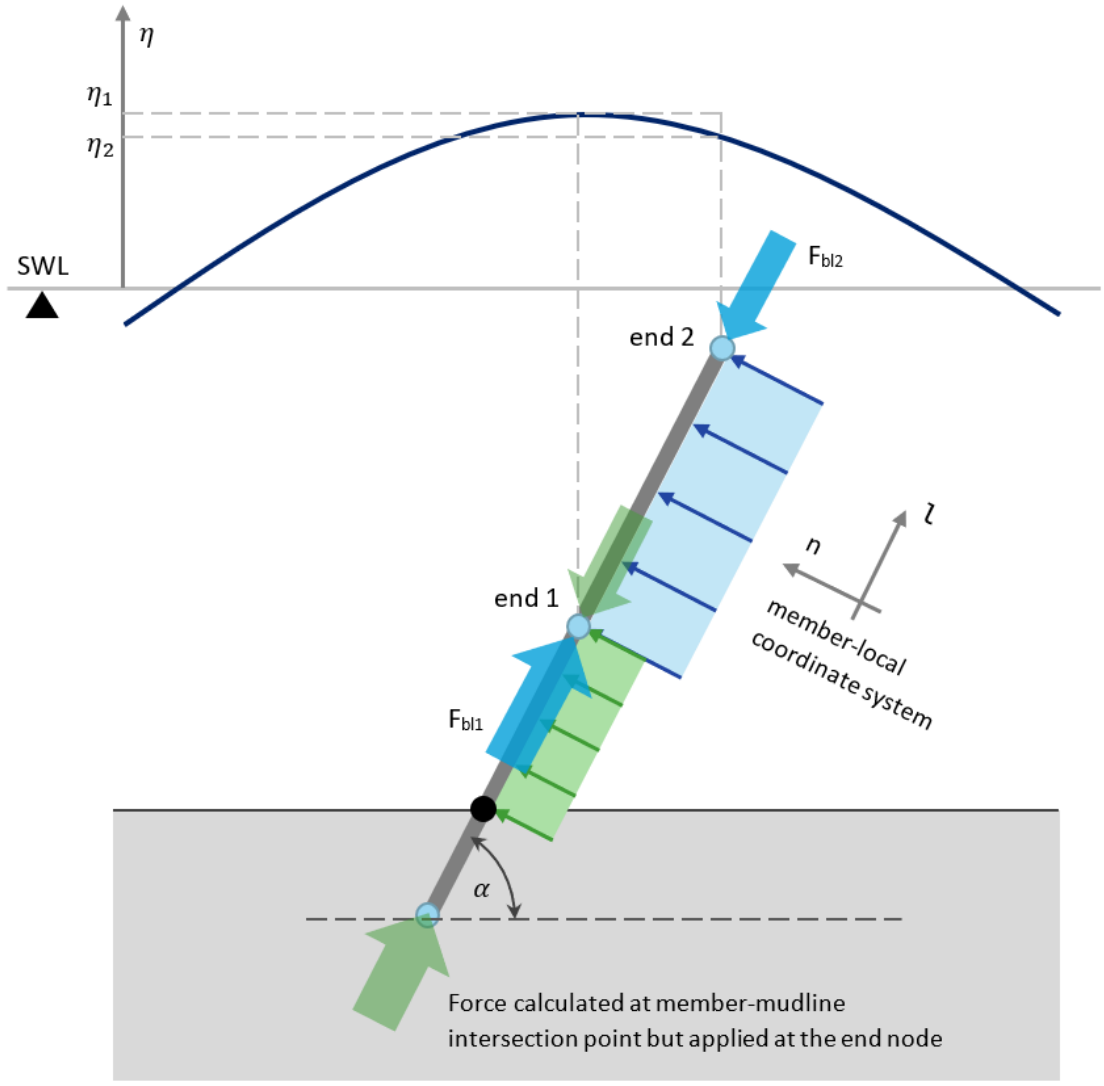


Figure 2.28: Buoyancy force calculation

2.4.9 Wind Loads

Wind loads due to a stationary wind field independent of the horizontal coordinates may be calculated and optionally added to linear or nonlinear periodic wave loads in a deterministic wave load calculation. The program will evaluate the wind drag force normal to each element of the jacket above the instantaneous water. However, the part of element exposed to wind but under still water level will not receive any wind load.

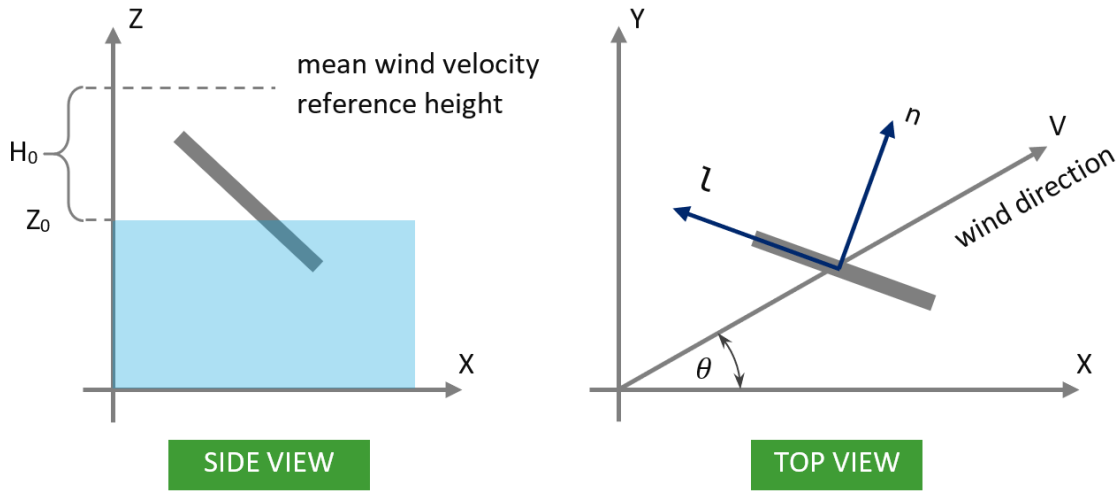


Figure 2.29: Sketch of an element in a wind field

Figure 2.29 shows an element of a jacket in a wind field. In the (X, Y, Z) coordinate system the wind direction is at an angle θ to the X-axis. The velocity of the wind is independent of time and horizontal coordinates and is given by one of the following expressions:

$$\mathbf{v} = Vf\left(\frac{Z - Z_0}{H_0}\right)^P (\mathbf{i}_1 \cos\theta + \mathbf{i}_2 \sin\theta) \tag{2.37}$$

$$\mathbf{v} = V\left[1 + 0.137 \ln\left(\frac{Z - Z_0}{H_0}\right) - 0.047 \ln\left(\frac{T_a}{T_{a0}}\right)\right](\mathbf{i}_1 \cos\theta + \mathbf{i}_2 \sin\theta) \tag{2.38}$$

$$\begin{aligned} \mathbf{v} &= V\left[1 + C \ln\left(\frac{Z - Z_0}{H_0}\right)\right]\left[1 - 0.41 I_u(Z) \ln\left(\frac{T_a}{T_{a0}}\right)\right](\mathbf{i}_1 \cos\theta + \mathbf{i}_2 \sin\theta) \\ C &= 0.0573(1 + 0.15V)^{0.5} \\ I_u(Z) &= 0.06(1 + 0.043V)\left(\frac{Z - Z_0}{H_0}\right)^{-0.22} \end{aligned} \tag{2.39}$$

$$\begin{aligned} \mathbf{v} &= V\left[1 + C \ln\left(\frac{Z - Z_0}{H_0}\right)\right]\left[1 - 0.41 I_u(Z) \ln\left(\frac{T_a}{T_{a0}}\right)\right](\mathbf{i}_1 \cos\theta + \mathbf{i}_2 \sin\theta) \\ C &= 0.0573(1 + 0.0457V)^{0.5} \\ I_u(Z) &= 0.06(1 + 0.0131V)\left(\frac{Z - Z_0}{H_0}\right)^{-0.22} \end{aligned} \tag{2.40}$$

where

V	is the mean wind velocity at reference height at H_0,
Z_0	is the position of the still water level SWL,
H_0	is the distance from SWL to the mean wind velocity reference level H_0=10m (32.8 ft),
f	is the gust factor,
P	is the height exponent, and
T_a/T_{a0}	is the mean period ratio.

The wind formulae given in Equation (2.38) and Equation (2.39) are according to Ref. [13] and Equation (2.39) is also according to 21st edition of API RP2A (Ref. [2]). Equation (2.40) also according to 21st edition of API RP2A (Ref. [2]) in fact is the same formulation as Equation (2.39) but in English units.

The following wind formualtion given in Equation (2.41) is according to ABS guide Ref. [18].

$$\mathbf{v} = V\left(\frac{Z - Z_0}{H_0}\right)^P (\mathbf{i}_1 \cos\theta + \mathbf{i}_2 \sin\theta) \tag{2.41}$$

where

V is the mean wind velocity at reference height at H_0,
Z_0 is the position of the still water level SWL,
H_0 is the distance from SWL to the mean wind velocity reference level H_0=10m (32.8 ft),
P = 0.09 - 0.16 for 1-minute average wind,
= 0.125 for 1-hour average wind .

Vector $\mathbf{n}$ in Figure 2.29 is the unit normal to the element in the plane spanned by the velocity vector and the y-axis in the local coordinate system. The normal component of the velocity is then denoted $\mathbf{v}_n = v_n\mathbf{n}$ and for each part of the jacket above the still water level the normal wind force is calculated by the drag term in Morison's equation with this "Velocity Component Approach", see B8.3.3 in Ref. [19], i.e.

$$\mathbf{F_n} = \frac{1}{2}\rho_a D\mathbf{C}_a \cdot \mathbf{v}_n v_n \tag{2.42}$$

where ρ_a is the density of air, D the equivalent diameter (including marine growth thickness) and $\mathbf{C}_a$ the air drag coefficient matrix given by

$$\mathbf{C}_a = \begin{bmatrix} C_{ax} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & C_{az} \end{bmatrix}$$

The alternative approach is to calculate the wind force normal to the member using the normal component of wind pressure projected along the length of the member. For this "Projected Pressure Approach", see B8.3.3 in Ref. [19], the normal wind force is calculated by the drag term in Morison's equation as

$$\mathbf{F_n} = \frac{1}{2}\rho_a D\mathbf{C}_a \cdot \mathbf{v}_n v \tag{2.43}$$

The air drag coefficients may be a function of the Reynolds number using CDWR command or for a selection of members using CDWN command.

Reynolds number is defined by Equation (2.44).

$$\mathrm{Rn} = \frac{v_n D}{\nu_a} \tag{2.44}$$

where ν_a is the viscosity coefficient for air.

By default, the air drag coefficients are assumed to be a known function of the Reynolds number (see Equation 2.45) and the built-in function used corresponds to the elements being pipes.

Default air drag coefficients as functions of the Reynolds number:

$$\begin{aligned} C_a &= 1.2 && 0 < \mathrm{Rn} \leq 2.5 \times 10^5 \\ C_a &= 7.2426 \times 10^{10} / \mathrm{Rn}^{1.9972} && 2.5 \times 10^5 < \mathrm{Rn} \leq 3.8 \times 10^5 \\ C_a &= \mathrm{Rn}^{0.2557} / 51.392 && 3.8 \times 10^5 < \mathrm{Rn} \end{aligned} \tag{2.45}$$

Gust wind induced fatigue in Framework

An alternative wind force model may be used in order to prepare for gust wind induced fatigue analysis in Framework. In this case, the wind force is split into three components. The first component represents wind force due to wind in the main wind direction. The second component represents wind force due to gust wind in the horizontal plane in direction normal to the main wind direction. The third component represents wind force due to gust wind in Z-direction. See Appendix 9 in the Sesam Theory Manual Framework Wind Fatigue Design for description of theory.

2.4.10 Design Loads

In deterministic load calculations, parameter DLOAD on SEAOPT command allows to transfer of design loads to structural analysis. For each seastate, Wajac generates and transfers loads for either maximum base shear, maximum overturning moment, or both. Alternatively, user may decide to transfer minimum values of these quantities. The characteristic values are selected among the time steps specified.

The minimum base shear force is used with the following sign convention:

- $+$ load in the wave direction
- $-$ load opposite to the wave direction (180 degree off)

In order to find the minimum base shear force or overturning moment, a SIGN ($+$ or $-$) is introduced to identify whether this force or moment is in the considered wave direction ($+$) or opposite ($-$) to the considered wave direction.

Thus for base shear force, at current seastate, base shear force and overturning moment at each phase angle will be respectively defined as

$$\text{base shear force}|_{\text{at phase } \delta} = \frac{(L_x \cos\beta + L_y \sin\beta)}{|L_x \cos\beta + L_y \sin\beta|}\Big|_{\text{at phase } \delta} \cdot \sqrt{L_x^2 + L_y^2} \tag{2.46}$$

$$\text{over turning moment}|_{\text{at phase}\delta} = \frac{(-M_x \sin\beta + M_y \cos\beta)}{|-M_x \sin\beta + M_y \cos\beta|}\Big|_{\text{at phase } \delta} \cdot \sqrt{M_x^2 + M_y^2} \tag{2.47}$$

where

- L_x is the base shear force projected on x-direction
- L_y is the base shear force projected on y-direction
- M_x is the over turning moment projected on x-direction
- M_y is the over turning moment projected on y-direction
- δ is the phase angle
- β is the wave direction

Figure 2.30 shows the distribution of base shear force without/with sign ($+$ or $-$) relative to the phase angle. Minimum base shear force / over turning moment is therefore found at the minimum point of the curve and

then is reported as a value with a sign. In order to properly find this minimum, users should cover the full range of phase angle, i.e. 0-360 degree.

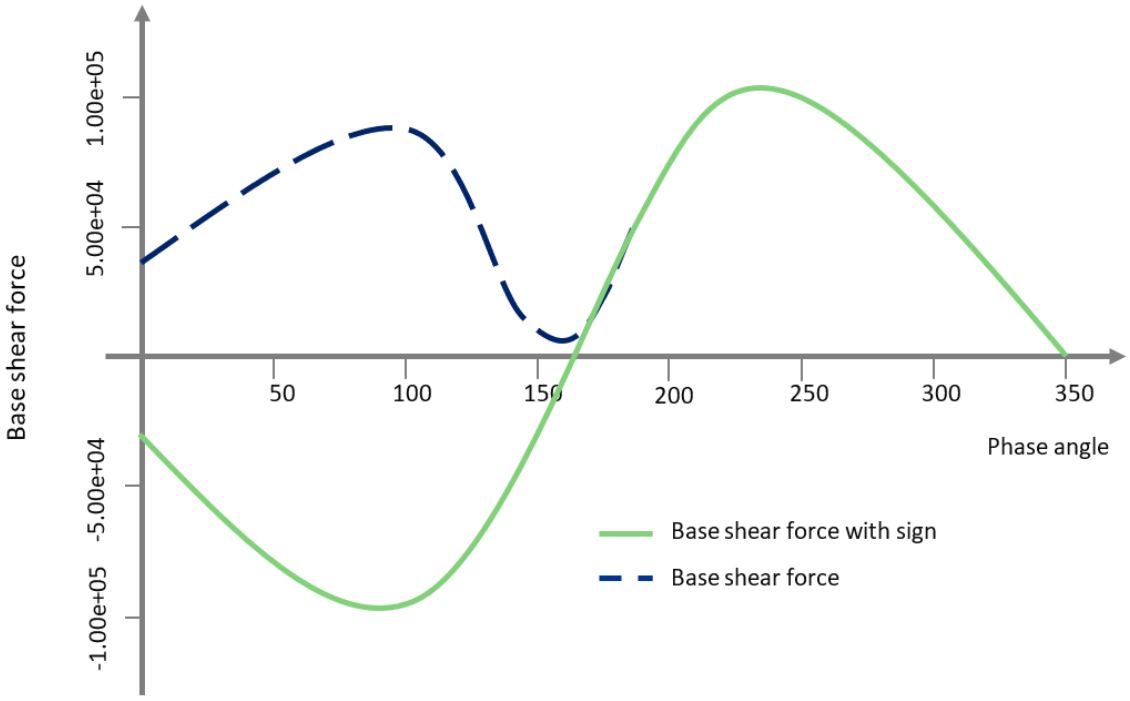


Figure 2.30: Base shear force distribution without/with sign

This function works properly for typical JU analyses, because in such analyses:

1 Large waves are combined with current **in** the wave direction.

2 Leg distance is relatively short vs. actual wave lengths, thus the 3 legs get max loaded for wave crest in the centre of three legs.

3 The 9 chords (3 legs) are vertical and will always get load in or opposite to the wave direction. Major part of load is from the chords.

However, for non-typical load situations for JU, the selected phase angle should always be checked by engineering judgement. Therefore an additional information of base shear force and overturning moment at each phase angle, such as vector length with sign (+ or −) and angle relative to the wave direction can be printed in the Print File (WAJAC.LIS) to improve the verification possibilities of the chosen values. This additional information will only be printed when users have set DLOAD as 4, 5 or 6 in SEAOPT card.

Note that this maximum load is not necessarily in the wave direction. Users thus might end up with both maximum and minimum base shear force and/or over turning moment at the same phase angle. Such situation can be detected by Wajac and a warning message will be reported in the Print File (WAJAC.LIS) file.

2.5 Calculation of Loads According to API

2.5.1 Overview of API Features

When specified through API command in the Analysis Control Data for Wajac the program will calculate static forces for all identified members with known cross section according to the procedure described in Sections 2.3.1b and C2.3.1b of the API RP, Ref. [2]. The load calculation is also according to Section c3.2 of Ref. [1] (Ref. [1] and Ref. [2] are identical wrt. load calculation procedures in Wajac.)

This involves that the following procedure is used for calculating loads for given wave, wave theory, current and depth conditions:

1 Estimate apparent wave period to account for Doppler effect due to wave/current interaction.

2 Calculate two dimensional wave kinematics according to specified wave model for apparent wave period.

3 Reduce the wave kinematics due to wave spreading or irregular waves (wave kinematics factor).

4 Reduce specified current velocity due to the existence of the structure (current blockage factor).

5 Calculate combined current and wave kinematics using linear stretching of the current profile.

6 Assign pre-defined steady-flow drag coefficients depending on member roughness and cross section to members with known cross sections.

7 Assign inertia coefficients dependent on member orientation, half-wave-cycle Keulegan-Carpenter number and steady-flow drag coefficients.

8 Modify relevant member's half-wave-cycle Keulegan-Carpenter number due to wave/current interaction effects.

9 Calculate wake encounter amplification factor based on the modified Keulegan-Carpenter number.

10 Modify the wake encounter amplification factor due to inline and normal current.

11 Multiply steady-flow drag coefficients of nearly vertical members by the wake encounter amplification factor.

12 Reduce drag and inertia coefficients for conductor arrays due to shielding effects (conductor shielding factor).

13 Calculate linearly varying normal force intensities using Morison's equation.

Required input

The following minimum set of information must be specified by the user in order to apply loads according to the API procedure:

1 Specification of *Loads according to API RP2A*

2 The load conditions including

- wave height
- corresponding wave period
- wave direction
- current profile

3 Prescribed phase angles of the incident wave at which loads will be calculated

4 Specification of automatic design loads

5 Wave model to be applied

6 Wave kinematics reduction factor

7 Current blockage factor

8 Identification of members for which conductor shielding is to be applied including centre to centre distance to use for each conductor array

9 Mean water level above mudline

10 Mudline

Options

The user will be able to adjust the load calculation procedure through the following options:

1 Option for automatic transfer of design loads to structural analysis. Loads may be generated for either

- maximum base shear

- maximum overturning moments
- both maximum base shear and overturning moment
- minimum base shear
- minimum overturning moments
- both minimum base shear and overturning moment

2 The Doppler effect may be neglected, that is, coefficients and loads will be calculated using the actual wave period. This can be controlled individually for the seastates, for more information regarding this option see description for the SEAOPT card.

3 The dependency of wake encounter (Keulegan-Carpenter) may be applied to all members within 15° of orbital plan of the wave kinematics (EPR modifications to API, see Ref. [15]).

4 The effect of wake encounter may be turned off.

5 Coefficients for individual members (to be used unmodified in Morison's equation) may be specified. Additional Analysis Control Data specifying hydrodynamic coefficients as described in Section 2.2.7 will overwrite coefficients calculated according to the described API procedure.

Limitations

The API feature has the following notable limitations:

1 Lift and slam forces are not calculated.

2 Froude-Krylov forces are neglected.

3 Only linear stretching of current profiles will be available.

4 The current implementation is not applicable to frequency domain analysis since coefficients are calibrated for a time domain analysis with time dependant adjustment of the empirical coefficients.

5 Non-pipe members are treated as pipe members using the equivalent diameter as defined in Section 2.2.1. If other values are required individual coefficients must be specified for these members.

6 Forces due to longitudinal coefficients are only included in the total force and moment reported in the Wajac Print File and not included in detailed loads transferred to the structure. These forces will be included in the total forces and moments from which automatic design loads are calculated. Longitudinal coefficients should therefore not be specified when using the automatic design load option.

7 If the API procedure is specified requested for subsequent dynamic structural analysis will be written to the Loads Interface files using the default value of 2.0 for the C_m unless other constant values are specified by additional commands.

8 No influence on the wind load calculation.

2.5.2 List of Symbols

Below is a list of symbols that is not previously defined and which is used in the following description of the API load calculation.

ϕ	angle between member axes and vertical
C_{ds}	steady flow drag coefficient
C_{mc}	wake dependant inertia coefficient for circular members
C_{m0}	theoretical limit for C_m as $\mathrm{KC} \to 0$
D_c	cross section with of clean members
e	relative roughness height $= h_g/D$
K_c	Keulegan-Carpenter number based on wave only and adjusted for inline current component
K_w	Keulegan-Carpenter number based on wave only $= 2U_{mo}T_2/D$
S	centre to centre spacing of conductors in wave direction
T_{app}	apparent wave period modified due to Doppler effects from wave/current interaction
T_2	duration of half-wave cycle based on original wave period T
V_I	current component in wave direction (inline current velocity) at load calculation point
V_N	current component normal to wave direction at load calculation point
r	V_I/U_{mo} (for current in the wave direction $r > 0$ at wave crests and $r < 0$ at troughs)
R_s	conductor shielding factor
R_w	wake amplification factor $= C_d/C_{ds}$
U_{mo}	maximum wave-induced orbital velocity for wave period T_{app} at the load calculation point

2.5.3 Apparent Wave Period

To account for the Doppler effect due to wave/current interaction apparent wave period is used when calculating wave kinematics. Apparent wave period is calculated by solving the simultaneous equations given in C2.3.1b1 of API, Ref. [1].

2.5.4 Two-Dimensional Wave Kinematics

Appropriate wave theory must be specified by the user. Available options will be:

1 Airy wave theory with constant kinematics above still water level.

2 Airy wave theory with linear (Wheeler) stretching of wave kinematics.

3 A 5th order Stokes wave theory.

4 Dean's stream function wave theory.

2.5.5 Wave Kinematics Factor

Appropriate spreading factor must be specified by the user. Horizontal velocities and accelerations from the selected wave theory and apparent wave period will be multiplied by this factor.

2.5.6 Current Blockage Factor

Appropriate current blockage factor must be specified by the user. The total current profile will be multiplied by this factor after calculation of apparent wave period and before combination with wave kinematics.

2.5.7 Current Stretching

Linear (Wheeler) stretching will be applied to the reduced current profile when combined with the wave kinematics.

2.5.8 Marine Growth and Roughness

Marine growth and roughness is specified by the user for all members as a function of depth. The effective member diameter used in Morison's equation (cross-sectional width of non-circular members) is $D = D_c + 2t_g$ where D_c is the clean outer diameter and t_g is the specified thickness of marine growth.

2.5.9 Drag and Inertia Coefficients

Dependency on surface roughness

The steady flow drag coefficient, C_{ds}, for circular members is a function of relative roughness, $e = h_g/D$, as indicated by Figure C2.3.1-4 of API RP2, Ref. [1]. This curve is approximated by the piece-wise linear curve defined by Equation (2.37). The curve is shown in Figure 2.31.

$$\begin{aligned}
C_{ds} &= 0.60 && e_* < 0 \\
C_{ds} &= 0.60 + 0.02e_* && 0 \le e_* < 1 \\
C_{ds} &= 0.62 + 0.06(e_* - 1) && 1 \le e_* < 2 \\
C_{ds} &= 0.68 + 0.157(e_* - 2) && 2 \le e_* < 2.699 \\
C_{ds} &= 0.79 + 0.300(e_* - 2.699) && 2.699 \le e_* < 3.398 \\
C_{ds} &= 1.00 + 0.0927(e_* - 3.398) && 3.398 \le e_* < 4.477 \\
C_{ds} &= 1.10 && 4.477 \le e_*
\end{aligned} \tag{2.48}$$

where $e_* = log_{10}e + 6$. C_{ds} for non-circular members is assumed independent of roughness and given by DNV Ref. [8]. C_m is assumed to be independent of roughness in steady flow.

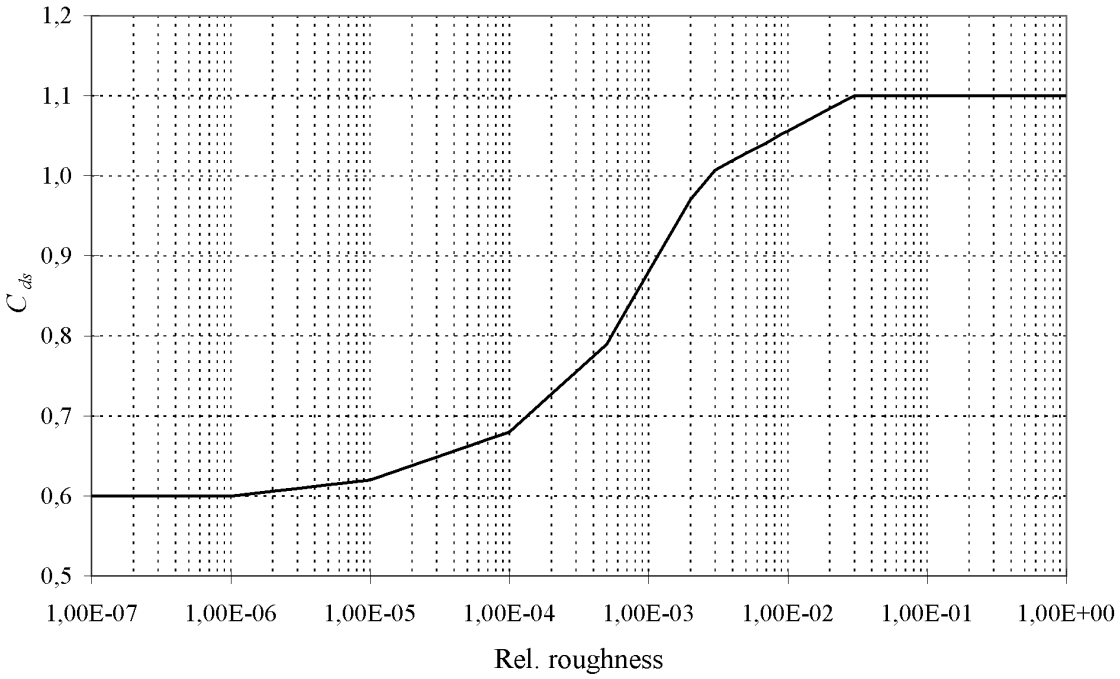


Figure 2.31: Steady flow drag coefficient as function of relative surface roughness (API Fig. C2.3.1-4)

Dependency of Reynolds number

Reynolds numbers are assumed to be post-critical for all members, thus all coefficients are by default assumed to be independent of the Reynolds number.

Dependency of Keulegan-Carpenter number

For nearly vertical members (within 15° of vertical) drag coefficients are given by Equation (2.49).

$$C_d = R_w C_{ds} \tag{2.49}$$

where R_w is the wake amplification factor for drag coefficients and

- R_w is given according to Figure C2.3.1-5 of API RP2, Ref. [1], for $\mathrm{KC} \geq 12$
- R_w is given according to Figure C2.3.1-6 for $\mathrm{KC} < 12$

The curves are approximated by the piece-wise linear function defined by

$$
\begin{aligned}
\frac{C_d}{C_{ds}} &= 1.50 - 0.024\left(\frac{\mathrm{KC}}{C_{ds}} - 10\right) && 10 \le \frac{\mathrm{KC}}{C_{ds}} < 20, \quad \mathrm{KC} \ge 12 \\
\frac{C_d}{C_{ds}} &= 1.26 - 0.008\left(\frac{\mathrm{KC}}{C_{ds}} - 20\right) && 20 \le \frac{\mathrm{KC}}{C_{ds}} < 40, \quad \mathrm{KC} \ge 12 \\
\frac{C_d}{C_{ds}} &= 1.10 - 0.003\left(\frac{\mathrm{KC}}{C_{ds}} - 40\right) && 40 \le \frac{\mathrm{KC}}{C_{ds}} < 60, \quad \mathrm{KC} \ge 12 \\
\frac{C_d}{C_{ds}} &= 1.04 - 0.001\left(\frac{\mathrm{KC}}{C_{ds}} - 60\right) && 60 \le \frac{\mathrm{KC}}{C_{ds}} < 100, \quad \mathrm{KC} \ge 12 \\
\frac{C_d}{C_{ds}} &= 1.00 && 100 \le \frac{\mathrm{KC}}{C_{ds}}, \quad \mathrm{KC} \ge 12 \\
\frac{C_d}{C_{ds}} &= C_\pi + 0.10(\mathrm{KC} - 12) && 2 \le \mathrm{KC} < 12 \\
\frac{C_d}{C_{ds}} &= C_\pi - 1.00 && 0.75 \le \mathrm{KC} < 2 \\
\frac{C_d}{C_{ds}} &= C_\pi - 1.00 - 2.00(\mathrm{KC} - 0.75) && \mathrm{KC} < 0.75
\end{aligned}
\tag{2.50}
$$

Here $C_\pi = 1.50 - 0.024(12/C_{ds} - 10)$. The curves are shown in Figure 2.32 through Figure 2.34.

Inertia coefficients are given by

- $C_m = 2.0$ for $\mathrm{KC} < 3$ and circular cross section
- C_m is defined according to API RP2, Ref. [1], Figure C2.3.1-7 for $3 \le \mathrm{KC} < 12$ and circular cross section
- C_m is defined according to API RP2, Ref. [1], Figure C2.3.1-8 for $\mathrm{KC} > 12$, $C_{ds} = 0.66$ and $C_{ds} = 1.1$, and circular cross section

For $\mathrm{KC} \ge 3$ these curves are approximated by the relation in Equation (2.51). This relation will also be used for intermediate values of C_{ds}. Results of this equation are shown in Figure 2.35 and Figure 2.36.

$$
C_m = \max\left\{\begin{matrix} 2.0 - 0.044(\mathrm{KC} - 3) \\ 1.6 - 0.9(C_{ds} - 0.66) \end{matrix}\right\} \tag{2.51}
$$

For non-circular cross section we have $C_m = C_{mc}C_{m0}/2$ where C_{m0} is the theoretical value of the inertia coefficient of the non-circular member as $\mathrm{KC} \to 0$ as given by DNV Ref. [8].

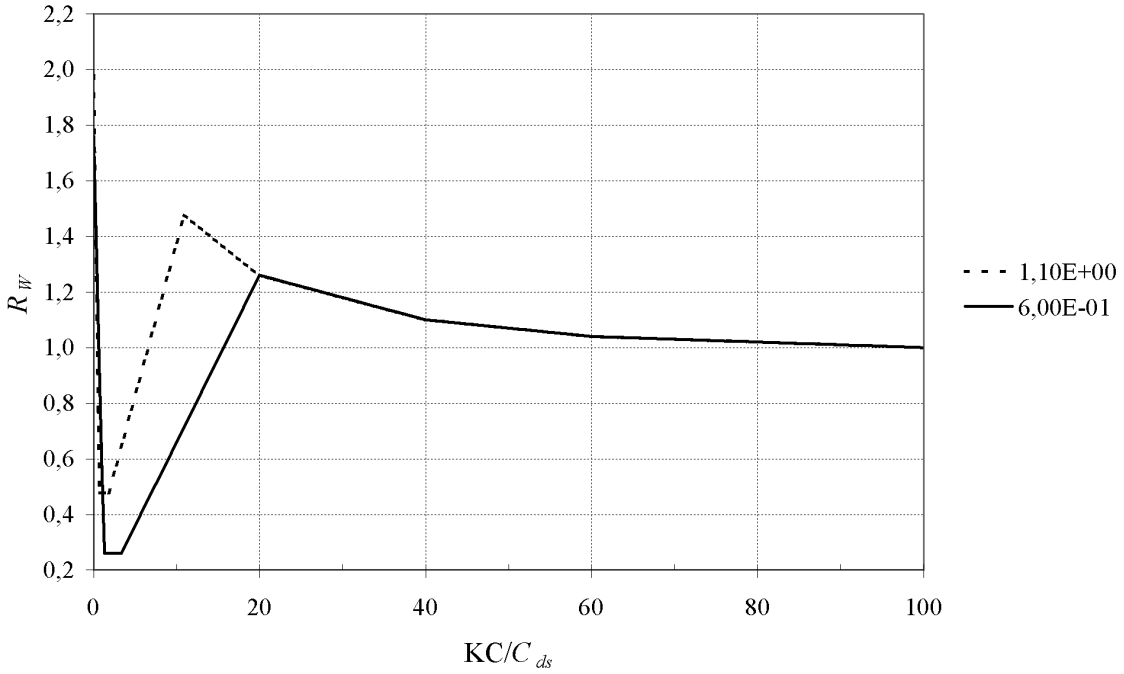


Figure 2.32: Wake amplification factor for drag coefficient as function of KC/Cds (API Fig. C2.3.1-5)

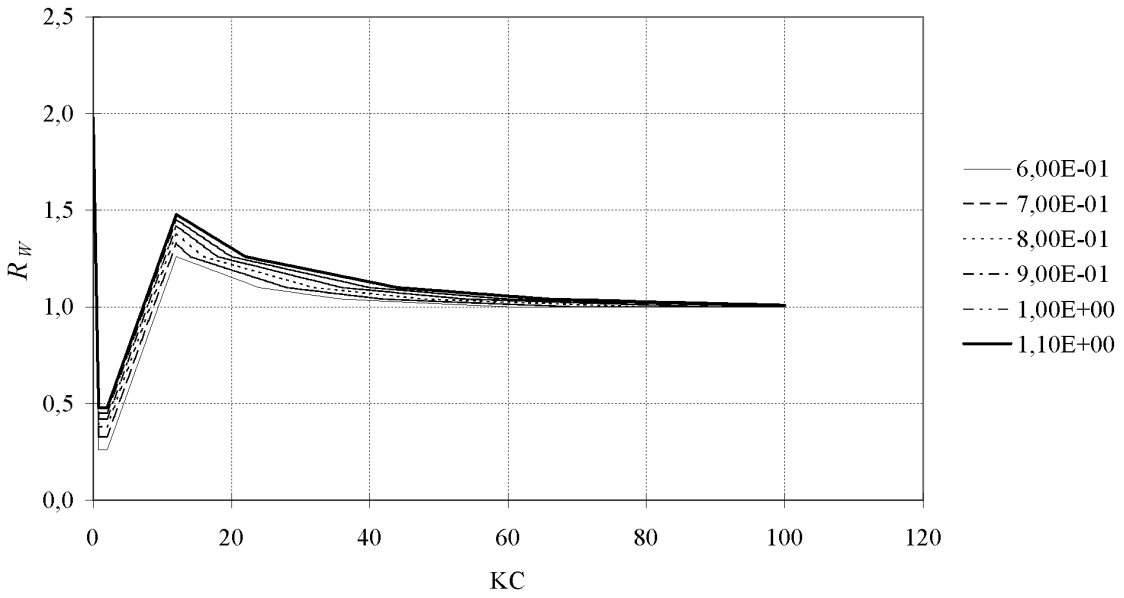


Figure 2.33: Wake amplification factor

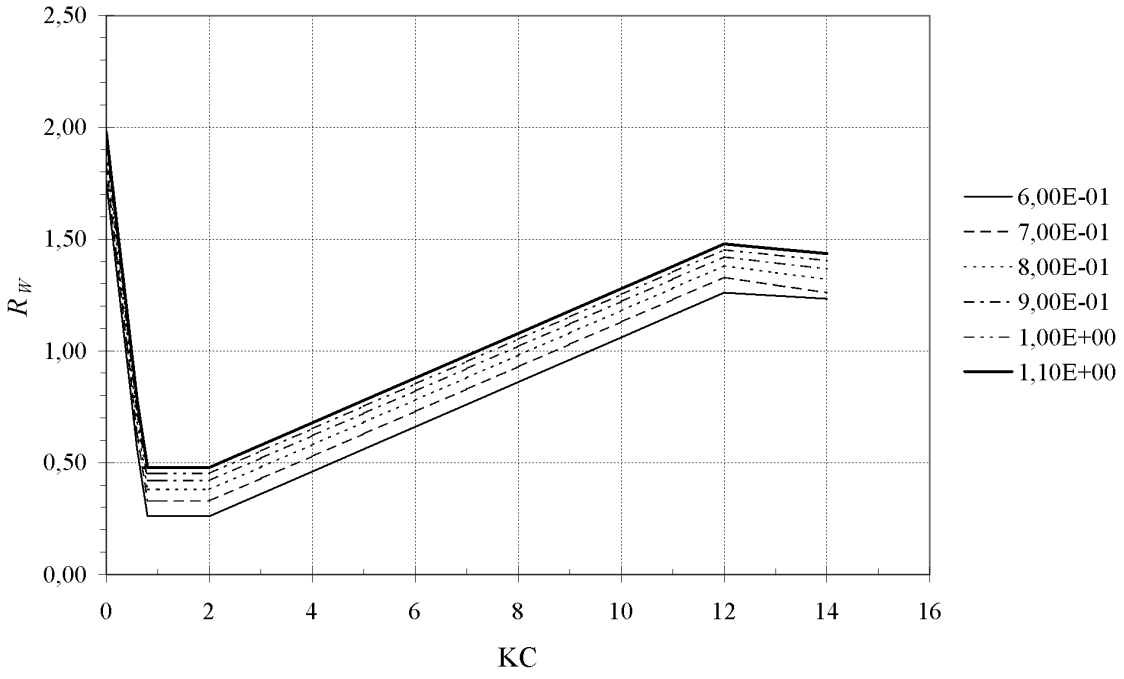


Figure 2.34: Wake Amplification factor for drag coefficient as a function of KC (API Fig. C2.3.1-6)

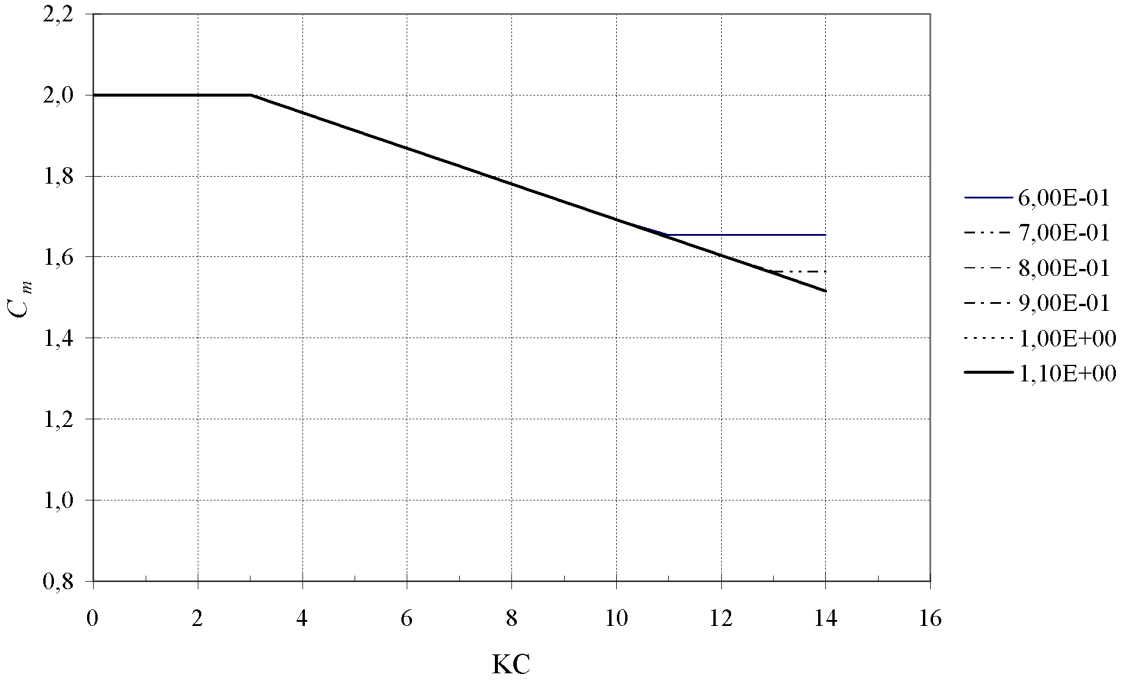


Figure 2.35: Inertia coefficient as a function of KC (API Fig. C2.3.1-7)

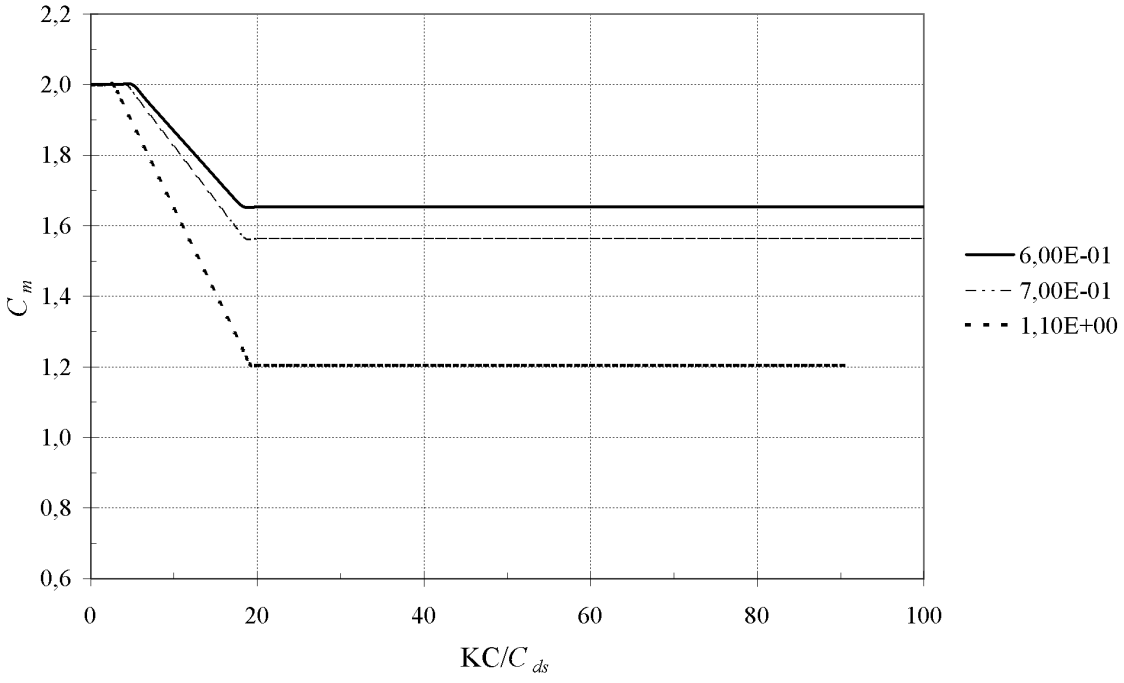


Figure 2.36: Inertia coefficient as a function of $\mathrm{KC}/\mathrm{C_{ds}}$ (API Fig. C2.3.1-8)

Dependency on current/wave velocity ratio

The recommendations given by API, Ref. [1], and formulated in Equation (2.52) and Equation (2.55) below are not complete with respect to the effect of inline and normal current on wake encounter. We have

$$\begin{aligned} C_d &= C_{ds} && \text{for } r > 0.4 \\ C_d &= C_d(K_c) && \text{for } r \ll 0.4 \end{aligned} \tag{2.52}$$

where $C_d(K)$ is given by Equation (2.49) and K_c by Equation (2.54) below, and

$$\begin{aligned} C_d &= C_{ds} && \text{for } \frac{V_N T_2}{C_{ds} D} > 4 \\ C_d &= R_w C_{ds} && \text{for } \frac{V_N T_2}{C_{ds} D} < 0.5 \end{aligned} \tag{2.53}$$

and

$$K_c = K_w(1+r)2\theta_*/\pi \qquad \text{for } |r| \le 1.0 \tag{2.54}$$

where $\theta_* = \text{atan}(\sqrt{1-r^2}, -r)$

To cover all values of inline and normal current the formulations in Equation (2.55) and Equation (2.57) will be used. The corrections for inline and normal current, K_i and K_n, are shown in Figure 2.38.

$$\begin{aligned} C_d &= C_{ds} && \text{for } |r| > 1.0 \\ C_d &= f_d C_{ds} && \text{for } |r| < 1.0 \end{aligned} \tag{2.55}$$

where $f_d = 1 + (R_w(K_c) - 1) K_i K_n$

$$K_i = \begin{cases} 0 & \text{for } r > 0.4 \\ -2.5r + 1 & \text{for } -0.3 < r \le 0.4 \\ 2.5r + 2.5 & \text{for } -1 < r \le -0.3 \end{cases}$$

$$K_n = \begin{cases} 0 & \text{for } \dfrac{V_N T_2}{C_{ds} D} \ge 4 \\ -\dfrac{2}{7}\dfrac{V_N T_2}{C_{ds} D} + \dfrac{8}{7} & \text{for } 0.5 \le \dfrac{V_N T_2}{C_{ds} D} \le 4 \\ 1 & \text{for } \dfrac{V_N T_2}{C_{ds} D} \ge 0.5 \end{cases} \tag{2.56}$$

$$\begin{aligned} C_m &= C_m(\text{KC} \to \infty) && \text{for } |r| > 1.0 \\ C_m &= C_m(K_c) && \text{for } |r| < 1.0 \end{aligned} \tag{2.57}$$

In the last equation $C_m(K)$ is given by Equation (2.51) and K_c is given by Equation (2.54). The above formulations are consistent with the API recommendations for $r < 0.4$ and $r = 0.0$ (which means that $r \ll 0.4$) and for $V_N T_2 / C_{ds} D > 4$ and $V_N T_2 / C_{ds} D < 0.5$.

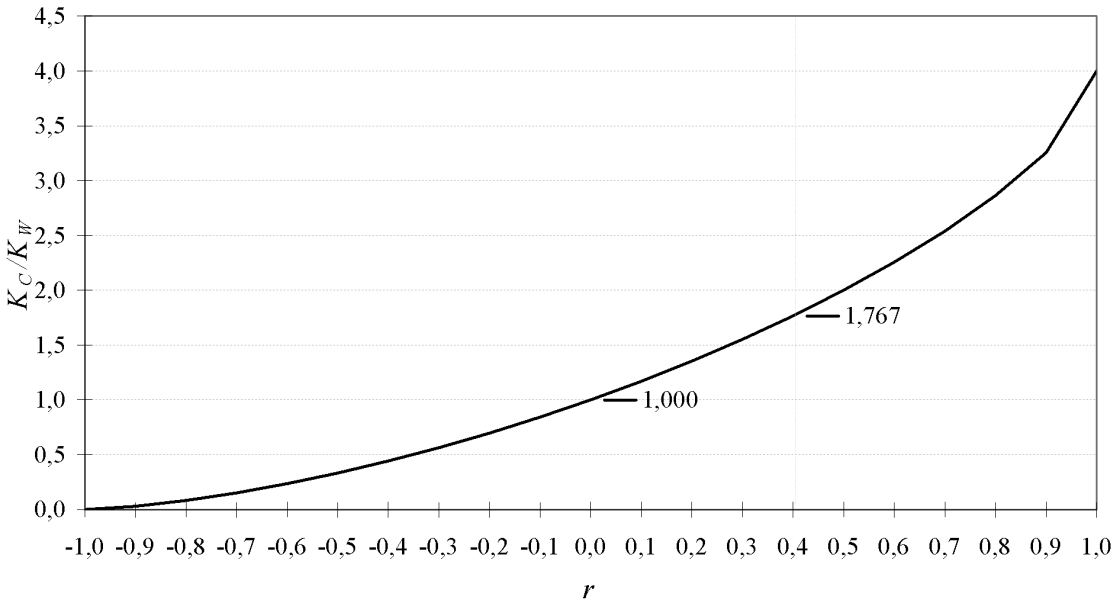


Figure 2.37: Adjustment of KC due to inline current

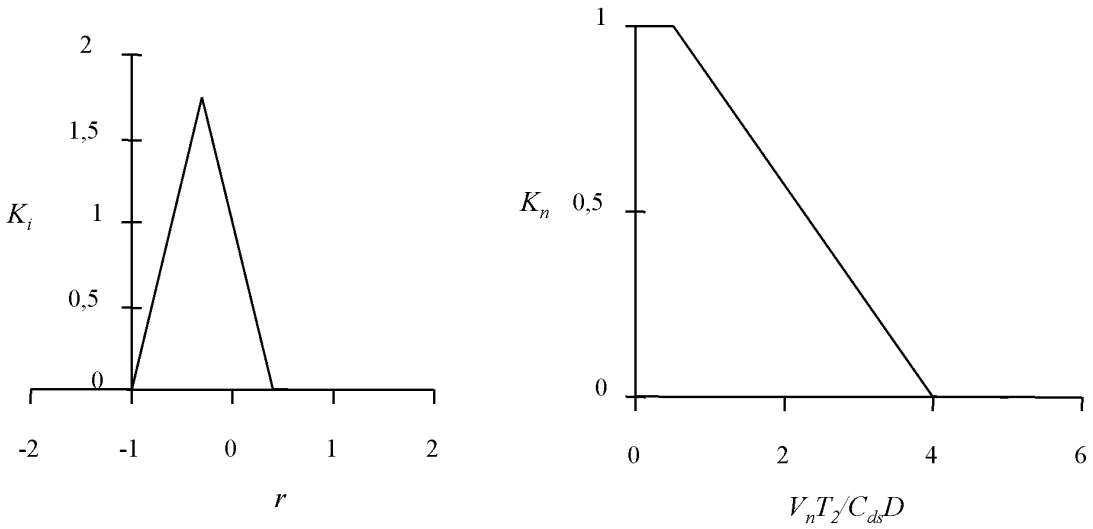


Figure 2.38: $\mathbf{K_i}$ and $\mathbf{K_n}$

Dependency on member orientation

For not nearly vertical members (more than 15° out of vertical) the following values will be used:

- $C_d = C_{ds}$ (the theoretical limit for $KC \to \infty$)
- $C_m = C_{m0}$ (the theoretical limit for $\mathrm{KC} \to 0$)

Summary of coefficient formulation

The above interpretations may be summarized as follows.

Drag coefficients are given by

$$C_d = RC_{ds}$$

where

$$R = f_d(g(K_c, C_{ds}), r, V_n, T_2, C_{ds}, D)$$

provided that

$$\begin{aligned} \phi &\leq 15^\circ \\ |r| &\leq 1.0 \\ \frac{V_n T_2}{C_{ds} D} &\leq 4.0 \end{aligned}$$

else

$$R = 1.0$$

Here

- $f_d(g) = 1 + (g(\mathrm{KC}, C_{ds}) - 1)K_i K_n$
- C_{ds} is given by Equation (2.48) for circular members and by DNV, Ref. [8], for non-circular members
- $g(\mathrm{KC}, C_{ds}) = C_d/C_{ds}$ as defined by Equation (2.50).
- K_i ad K_n are given by Equation (2.56)

Inertia coefficients are given by

$$C_m = C_{m0} C_{mc}/2$$

where

if $\phi > 15^\circ$ then

$$C_{mc} = C_{mc}(\mathrm{KC} \to \infty) = 2.0$$

else if $|r| \leq 1$ then

$$\begin{aligned} C_{mc} &= f_i(K_c, C_{ds}) \quad \text{for} \quad K_c \geq 3 \\ C_{mc} &= 2.0 \quad \text{for} \quad K_c < 3 \end{aligned}$$

else if $|r| > 1$ then

$$C_{mc} = f_i(\mathrm{KC} \to \infty, C_{ds})$$

Here $f_i(\mathrm{KC}, C_{ds}) = C_m(\mathrm{KC}, C_{ds})$ as defined by Equation (2.51).

Conductor shielding factor

Calculated drag and inertia coefficients are reduced for specified members (clusters of conductors) to account for conductor shielding effects. The reduction factor R_s , in two perpendicular $X-$ or $Y-$ directions is estimated as follows.

$R_s = 1$ for $\frac{U_{m0}T_{app}}{2\pi S} \leq 0.5$ or $\frac{S}{D} > 4$

$R_s = \frac{S}{4D}$ for $\frac{U_{m0}T_{app}}{2\pi S} \geq 2.5$ or $\frac{S}{D} \leq 4$

R_s from linear interpolation for $0.5 < \frac{U_{mo}T_{app}}{2\pi S} < 2.5$ and $\frac{S}{D} \leq 4$

Between the two perpendicular directions (e.g. for headings between 0 and 90 degrees) the shielding reduction factor is computed by elliptical interpolation. In other words, the factor is the radius in an ellipse having shielding reduction factor in X as one axis and shielding reduction factor in Y as the other axis.

Morison's equation

Forces will be calculated using Morison's equation as described in API RP2, Ref. [1], except that $\pi D^2/4$, where D is the effective diameter, is used instead of displaced volume per unit length for non-circular cylinders.

2.6 Comments on the Results Calculated by Wajac

2.6.1 Units

When performing an analysis with Sesam the user must apply a set of consistent units. The same units must be used in all programs throughout the analysis procedure.

The basis for determining a set of consistent units is the fundamental equation:

$$\mathbf{F} = m\mathbf{a} \tag{2.58}$$

In terms of the fundamental units of mass $[\mathrm{M}]$, length $[\mathrm{L}]$ and time $[\mathrm{T}]$, this equation may be written:

$$\left[\mathrm{F} = \frac{\mathrm{ML}}{\mathrm{T}^2}\right] \tag{2.59}$$

Force, stress, density, etc. are *not* fundamental units and must be derived in terms of the units of mass, length and time. Whenever possible, it is simplest to use S.I. units:

[L] length in meters (m)

[M] mass in kilograms (kg)

[T] time in seconds (s)

Force will then be in Newton (N):

$$1N = 1\frac{kg \cdot m}{s^2} \tag{2.60}$$

The units used in Wajac is controlled by input values of time $[\mathrm{T}]$ (given through the wave period), acceleration of gravity $\left[\frac{\mathrm{L}}{\mathrm{T}^2}\right]$ and the fluid density $\left[\frac{\mathrm{M}}{\mathrm{L}^3}\right]$. All other input data must be expressed in terms of these units.

For example:

fluid kinematic viscosity, $\nu \sim \left[\frac{\mathrm{L}}{\mathrm{T}^2}\right]$

fluid velocity, $v \sim \left[\frac{\mathrm{L}}{\mathrm{T}}\right]$

2.6.2 Global Results

Global results calculated by Wajac, i.e. forces and moments related to entire structure, are written to the Print File and when calculating transfer functions optionally to the Hydrodynamic Results Interface File. These global results are the total integrated forces and moments from current, wave, wind and buoyancy loading. Note that wind loads are not currently calculated for frequency domain analysis, thus will not be present in the Hydrodynamic Results Interface File.

The moment reference point about which the overturning moments are calculated are by default at the mud line directly below or above the origin of the global coordinate system. An alternative point may be specified by the user through MOMT command.

2.6.3 Load Distribution and Load Case Numbers

While files like a Print File contain global data presented per entire structure, Loads Interface File(-s) contains information about distribution of the loads. This section gives an overview of type of loads written to the Loads Interface Files(-s) while details on the force calculation methodology are described in Section 2.4.

Loads Interface File(-s) may be generated for the first level superelements (see Section 2.2.2) for use in a subsequent structural analysis. The generation of the Loads Interface Files must be requested through MODE command. Description of Loads Interface Files can be found in section 4.1. The data contained in these files is listed below.

Deterministic load calculation:

- Linearly varying line loads due to:
  - hydrodynamic forces from Morison's equation,
  - wind forces,
  - buoyancy of both member itself and marine growth applied to the member.
- Simulated concentrated loads due to hydrostatic pressure acting on a marine growth surface when sudden change in marine growth thickness appears - only when marine growth is defined by constant intervals,
- Nodal forces at each member node due to the longitudinal components of buoyancy are included by default, i.e. for OPT11=0. If this option is set as 1, there will be no nodal forces at each member node.

The loads are calculated for each time step specified for each 'seastate' (given by the wave period, wave height, wave direction and current profile). Load case numbers will be assigned to each time step.

Note that when hydrodynamic coefficients along member axial direction are set as non-zero, the hydrodynamic loads along axial direction will also be non-zero, however axial components will not be written to the Loads Interface Files.

Calculation of transfer functions:

- Linearly varying line loads including transverse components of complex, linearised hydrodynamic forces from Morison's equation due to linear waves of unit wave amplitude.

The loads are calculated for each wave frequency and each wave direction.

Seastate simulation:

- Linearly varying line loads due to transverse components of hydrodynamic forces from Morison's equation with irregular waves and a stationary current. The transverse components of the buoyancy are also included by default, i.e. OPT11=0. If this option is set as 1, the buoyancy in global vertical direction ($+z$) or the weight of displaced fluid will be included.
- Nodal forces at each member node due to the longitudinal components of buoyancy are included by default, i.e. OPT11=0. If this option is set as 1, there will be no nodal forces at each member node.

The loads are calculated for each time step of the specified simulation time.

It is possible to switch off generation of Loads Interface Files by altering value of MEMCON parameter on LOASIM command.

Notes:

The load case numbers for each individual superelement type will be subsequent to the highest load case number detected on the Input Interface File, for that superelement. Optionally, the lowest load case number to be used by Wajac for all superelement types may be specified using LONO command.

When the superelement technique is used loads for the first level superelements must be combined for higher level superelements by using the superelement assembler Presel.

In addition to loads calculation, added mass and damping calculation can be requested through MASS command. In such a case Loads Interface File will also contain transverse or all components of added mass and damping, as selected through the option on MASS command.

2.7 Limitations in Features

The following are important limitations related to the features of Wajac. They are mainly related to the theory implemented in the program. For size dependent limitations see Section 4.3.

- The structure is assumed to be rigid and fixed in space.
- The structure is assumed to have no influence on the fluid, that is no diffraction effects are included.
- Due to the above, the theory should only be applied to structural elements with diameters less then 1/5 of the wave length. For vertical pipe members MacCamy-Fuchs' formula may be applied for members with large diameters but diffraction effects are still not included.
- In general, the hydrodynamic coefficients are specified as frequency independent. Some dependency on the wave frequency may be included by specifying the coefficients as functions of the Keulegan-Carpenter number or the Reynolds number or by use of MacCamy-Fuchs' formula.
- The water depth is assumed to be constant.
- The current profile is stationary. Stretching of the current profile will, however, be performed when applying Wheeler stretching on an Airy wave.

3 USER'S GUIDE TO WAJAC

The first section of this guide contains definitions — or reference to definitions of phrases commonly used in connection with Wajac.

In the subsequent sections small examples are used to illustrate the most common ways of using Wajac. A complete set of Analysis Control Data necessary to run the specific analysis is listed together with explanations of the characteristics and limitations of each example. The three first sections illustrate simple usage of the three different analysis types available including short explanations of the content of the Print File for each analysis type. The remaining sections give examples of use of frequently used options available in the program. All examples are executed under the Windows 7 operating system.

3.1 Definitions

cross section	The cross section obtained by a section normal to the longitudinal axis of a beam and the data related to this section (e.g. outer diameter, wall thickness etc.).
depth	Distance from mudline to the still water level.
direct input	Input given directly to the program = Analysis Control Data.
eccentricity	The beam element ends may be offset from the nodes in direction of the beam axis. This is a property connected to the element which shortens the flexible part of the beam.
equivalent diameter	The diameter defined as the maximum dimension of the beam element's cross section, see Figure 2.14.
flooded member	Members with an internal volume filled with water.
frequency domain	Phrase expressing that the results are given as complex numbers (i.e. the calculation of transfer functions).
global coordinate system	The coordinate system used in Wajac in which all coordinates and all results are given if not explicitly defined otherwise. If the position of the mudline is not specified the mudline is at the origin of the global coordinate system.
global load case number	The load case number assigned to each load case defined by the user independently of the number of occurrences of individual superelement types. This number is not necessarily the same as the load case number written to the Loads Interface File, see Section 3.5.12.
Hydrodynamic Results Interface File	See Section 2.6.2.
Input Interface File	See Section 2.2.1.
instantaneous water surface	See Figure 2.3.
load calculation point	See Section 2.2.3 and Figure 2.16.
Loads Interface File	See Section 2.6.3.
local coordinate system	See Figure 2.20 and Section 2.2.7.
member	Beam elements for which loads are calculated by Wajac.
member diameter	Diameter or equivalent diameter of a member as defined by the cross section data in the Input Interface File or by the SPEC or SPEX command.
mudline elevation	Position of mudline sea floor relative to the origin of the global coordinate system.
Print File	See Section 4.1.5.
Simulation Result File	See Section 4.1.5.
steel area	Area of the steel of a cross section.

time domain	Phrase expressing that the results are given as real numbers for time series (i.e. the deterministic load calculation and seastate simulation analysis).

3.2 Deterministic Load Calculation

Example 3.1 Minimum Analysis Control Data for Deterministic Load Calculation

In this example the loads are due to a single wave with a period of 13 seconds, a wave height of 12.5 meters and a direction of propagation of 45 degrees. The water depth is 43.5 m. The wave theory used is Stokes' fifth order and constant inertia (=2.0) and drag (=0.7) coefficients are specified for all members. The model is read from the Input Interface File T1.FEM and distributed loads are written to the Loads Interface File L1.FEM. No distributed results are written to the Print File. Units are Newtons and metres.

The deterministic loads are calculated for 25 phase angles of the incident wave starting at phase -60.0 degrees and stepping 5.0 degrees, i.e. covering the interval from -60.0 to 60.0 degrees.

Analysis Control Data:

```
WAJAC
TITL DETERMINISTIC LOADS INCLUDING CURRENT
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
HYDR
C
C   Hydrodynamic Coefficients as Function of Vertical Position
C                 Z1        Z2       CDN       CDL       CMN
COEF             0.0     100.0       0.7       0.0       2.0
LOAD
DPTH            43.5
C
C   Deterministic Load Calculation
C      OPT CTNO HEIG.   PERIOD      PHIO        TO      STEP     NSTEP     BETA
SEA    5.0  0.0 12.5      13.0     -60.0       0.0       5.0     -25.0     45.0
END
```

Input files:

WAJAC.INP, containing the Analysis Control Data

T1.FEM, the Input Interface File from GeniE containing geometry and structural data.

Output files:

WAJAC.LIS, Print File. For comments see Example 3.2.

L1.FEM, the Loads Interface File.

S1.FEM, the S-file, additional Analysis Control Data for Sestra.

Example 3.2 Linear Wave Theory and Current in Deterministic Load Calculation

In this example linear wave theory with constant fluid kinematics above the still water level is used. In addition, a current profile acting in the direction of the waves is applied. The drag force coefficients are specified to vary linearly with the member diameter. Units are Newtons and millimetres.

Distributed loads are written to the Loads Interface File and for selected members also to the Print File for timestep numbers 9, 11, 14 and 20. The input and output files are as for Example 3.1.

Analysis Control Data:

```
WAJAC
TITL DETERMINISTIC LOADS INCLUDING CURRENT
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
C
C   Units and Constants Definition
C              UNITS   GRAVITY        RO      VISC
CONS             1.0    9806.6  1.025E-9
HYDR
C
C   Hydrodynamic Coefficients as Function of Member Diameter
C               DIA1      CDN1      CMN1      DIA2      CDN2      CMN2
CDIA             0.0       1.0       2.0    2000.0       0.5       2.0
LOAD
DPTH         43500.0
C
C   Definition of Current Profiles, variant 3.
C     CTNO                                        Z         V               OPT
CRNT   1.0       0.0       0.0       0.0       0.0       0.0       0.0       1.0
CRNT   1.0       0.0       0.0       0.0   20000.0     100.0       0.0       1.0
CRNT   1.0       0.0       0.0       0.0   60000.0     500.0       0.0       1.0
C
C   Deterministic Load Calculation
C      OPT CTNO HEIG.   PERIOD      PHI0        T0      STEP     NSTEP     BETA
SEA    1.1 1.0 12000       8.0    -180.0       0.0      10.0     -21.0      0.0
SEA    1.1 1.0 12000       8.0    -180.0       0.0      10.0     -21.0     45.0
C
C   Members Force Print-out Specification
C                N1        NN      STEP     STYPE     INDEX      ISEA    ISTEP
MPRT         56220.0   67220.0   11000.0       1.0       1.0       1.0      9.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       1.0     11.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       1.0     14.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       1.0     20.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       2.0      9.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       2.0     11.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       2.0     14.0
MPRT         56220.0   67220.0   11000.0       1.0       1.0       2.0     20.0
END
```

Examples from the Print File WAJAC.LIS for this example are given below with some comments. (The numbers refer to the Print File.)

1) Information on program, computer and user

The first page contains information about the Wajac version, computer, user and time of execution.

2) Limitations in this version of Wajac

This list reflects the size limitations in the specific version of Wajac. See also Section 4.3.

3) Echo of the specified Analysis Control Data from the Wajac input processor

The given Analysis Control Data. The given commands are listed for each data set.

4) Analysis type description and summary of input specification

This part of the Print File contains information about the analysis to be performed including the interpretation of the specified options.

4a) Nothing is printed since no name for the Loads Interface File is specified. The name will be similar to the Input Interface File.

4b) These data define the basic units in millimetres (mm), kilograms (kg) and seconds (s), which again give the forces in Newton (N). The zero viscosity has no effect since this only affects the Reynolds number (not used in this example) and not the calculation of viscous drag.

4c) The default value of CPERM is 1.0.

4d) The 'WAVE BUOYANCY FLAG' is the 'X' part of the wave theory parameter OPT in the SEA command. In this example both current and buoyancy is to be included in the loads.

5) Names of Input Interface Files read

This section lists all Input Interface Files that have been read by Wajac including any text cards found on the files. This text gives the following information:

- The file is generated at 06:56:50 on 30-Jun-2015.
- The file is generated by the Sesam program GeniE version 7.0-14 (released 21-Mar-2015)
- GeniE was executed on a X86 computer under the operating system Windows.
- GeniE was executed by the user kemar.

6) Loading information

This section of the Print File lists all members not receiving any loads. The loads on individual members specified through the MPRT command is also listed here. The data is listed for each superelement.

Member (or element) number 12110 of superelement type number 1, index 1 has not received any load since it is completely below (or with the upper most node at) the mudline. Member number 78110 has not received any load because it is above the water surface at all time instances of all analysed waves.

The forces FX, FY and FZ are components in the global coordinate system of the total integrated force on the member in question, that is including hydrodynamic loads, buoyancy and forces due to the current. The other data are:

DIAI	the average diameter at the load calculation points used when calculating the inertia forces,
DIAD	the average diameter used when calculating viscous drag forces,
CDN	the average longitudinal drag force coefficient,
CDL	the average transverse inertia coefficient,
CML	the average longitudinal inertia coefficient.

7) Total load summary

This section reports the sum of all forces and moment contribution integrated over the linearly varying line loads and the nodal forces calculated for each member. The moments are calculated relative to the origin of the global coordinate system since no MOMT command is given in the Analysis Control Data. The maximum base shear (=maximum horizontal force) and maximum overturning moment (=maximum horizontal moment about the specified moment reference point) are reported for each wave.

The minimum base shear force and minimum overturning moment with a sign (+ or -) are reported for those sea states where users choose to transfer the minimum loads.

8) Load case summary

This table gives an overview of the loads generated and the global load case number assigned to the individual loads. Note that each time step is identified by the time and not the phase angle of the wave as specified in the Analysis Control Data.

Examples from the Print File of Example 3.2.

1)

```
              Program id   : 6.7-09                          Computer          : 586
              Release date : 03-JUN-2015                     Impl. update      :
              Access time  : 30-JUN-2015 11:05:06            Operating system : Win NT 6.1 [7601]
              User id      : kemar                           CPU id            : 0699697368
                                                             Installation      : , OSLLP110401



              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway
```

2)

```
 LIMITATIONS IN THIS VERSION OF WAJAC :
 -------------------------------------

    MAXIMUM SIZE OF ONE SUPERELEMENT
    -  NUMBER OF NODES          :    600000
    -  NUMBER OF BASIC ELEMENTS :     60000


    MAXIMUM NUMBER OF LOADCASES
    -  DISCRETE WAVE            :     20000
    -  FREQUENCY DOMAIN         :       960
           ( MAX. FREQUENCIES :        60 )
    -  TIME DOMAIN SIMULATION (3D GRID)  :      8192
    -  TIME DOMAIN SIMULATION (DIRECT)   :    262144


    MAXIMUM NUMBER INPUT CARDS
    -  CARD TYPE SELI           :       100
    -  CARD TYPE ELIM           :     20000
    -  CARD TYPE FLOO           :     20000
    -  CARD TYPE LEG            :        50
    -  CARD TYPE SPEC           :     20000
    -  CARD TYPE CDIR           :     20000
    -  CARD TYPE MPRT           :     20000
```

```
 SIZE OF COMMON SCRATCH ARRAYS :
 -------------------------------

 /IWORK/ IWORK( 500000) /WORK/ WORK(1201000 )
 /IWORK4/ IARR(1800000) /WORK4/ ARR(1800120)
 TOTAL SIZE: /IWORK4/=4200068 /WORK4/=4931781
```

3)

```
W A J A C   I N P U T   P R O C E S S O R :

               *** DATA SET WAJAC ***


               CARD NO       2    TITL DETERMINISTIC LOADS INCLUDING CURRENT
../..
               CARD NO       9    MODE                        1.0       1.0
../..
               CARD NO      13    CONS             1.0    9806.6  1.025E-9
               *** END OF DATA SET  13 CARDS READ ***



               *** DATA SET HYDR ***

../..

               *** END OF DATA SET   5 CARDS READ ***



               *** DATA SET LOAD ***

../..

               *** END OF DATA SET  24 CARDS READ ***


          ***** END OF DATA INPUT   43 CARDS READ *****
```

4)

```
 ***************************************************************************************************
 *                                                                                                 *
 *      DETERMINISTIC LOADS INCLUDING CURRENT                                                      *
 *                                                                                                 *
 ***************************************************************************************************


 S U M M A R Y   O F   I N P U T   S P E C I F I C A T I O N S :

 PROGRAM EXECUTION:
 ------------------
../..
```

4a)

```
    THE NAME WHICH WILL BE USED FOR THE DEFAULT PART OF
          THE LOAD FILE NAMES IS:
```

4b)

```
 UNITS:
 ------

    THE UNITS ARE USER DEFINED:

    GRAVITY                   = 9.8066E+03
    WATER SPECIFIC MASS       = 1.0250E-09
    WATER KINEMATIC VISCOSITY = 0.0000E+00
    AIR SPECIFIC MASS         = 0.0000E+00
    AIR KINEMATIC VISCOSITY   = 0.0000E+00

../..
```

4c)

```
 LEG PERMEABILITY FACTORS:
 -------------------------

    DEFAULT VALUES FOR CPERM IS USED.
    ALL LEGS ARE ASSUMED TO HAVE FULL BUOYANCY.
```

../..

4d)

DETERMINISTIC SEASTATES DEFINITION:

THE FOLLOWING SEASTATES WILL BE ANALYSED:

SEA-STATE NO.	WAVE THEORY	WAVE HEIGHT	WAVE PERIOD	PHASE /TIME	INITIAL PHASE/TIME	PHASE/TIME INCREMENTS	NUMBER OF STEPS	WAVE HEADING	WAVE KINEMATICS FACTOR	WAVE BUOY FLAG	DESIGN LOADS
1	AIRY CONS	0.1200E+05	8.000	PHASE	-180.0	10.00	21.	0.0000	1.000	0	0
2	AIRY CONS	0.1200E+05	8.000	PHASE	-180.0	10.00	21.	45.00	1.000	0	0

SEA-STATE NO.	CURRENT TAB.NO	CURRENT BLOCKAGE	CURRENT STRETCH	WIND INDEX	WIND LOAD CALC.METH
1	1	1.000	-1	0	0
2	1	1.000	-1	0	0

SEASTATE NO.: 1 WAVE/BUOYANCY FLAG = 0 (LOADS ARE CALCULATED FOR WAVE, CURRENT, WIND , BUOYANCY AND WEIGHT OF MARINE GROWTH)

SEASTATE NO.: 2 WAVE/BUOYANCY FLAG = 0 (LOADS ARE CALCULATED FOR WAVE, CURRENT, WIND , BUOYANCY AND WEIGHT OF MARINE GROWTH)

D A T A C H E C K I N G F I N I S H E D

5)

NAMES OF INPUT INTERFACE FILES READ:

```
Direct file opened: kemar4996R1.SIN
(IUINP,NWS,IUIDNT,MXPHYS,STATUS) :          10      1024     3                    0   SCRATCH
File is native
    MD-FILE    1 OPENED ON UNIT  10 WITH INDEX   1 MAX LENGTH=     2147483640 WORDS AND BLOCKSIZE=  1024
                 NAME   R1.SIN
                 STATUS SCRATCH
    MD-FILE    1 ALLOCATION ACCOUNT OPENED

T1.FEM

        DATE:     11-SEP-1998         TIME:         13:49:21
        PROGRAM:  SESAM PREFRAME      VERSION:      6.6-01 20-MAR-1998
        COMPUTER: 586 WIN NT 4.0 [1381INSTALLATION: DNVS OSLPCN20
        USER:     TTAN                ACCOUNT:


D E T E R M I N I S T I C   W A V E   C H A R A C T E R I S T I C S :


                WAVE     WAVE                              DEPTH TO    WAVE HEIGHT TO    WAVE       WAVE      HALF WAVE    HALF WAVE
WAVE   WAVE     PERIOD   PERIOD    WAVE       WAVE      WAVE LENGTH    WAVE LENGTH    CREST      TROUGH      DURATION     DURATION
 NO    THEORY   ACTUAL   APPARENT  HEIGHT     LENGTH       RATIO          RATIO      ELEVATION  ELEVATION     CREST        TROUGH

  1    AIRY       8.00           0.1200E+05  0.9909E+05  0.4390        0.1211       0.4950E+05  0.3750E+05   4.000        4.000
```

6)

```
W A V E / C U R R E N T   L O A D I N G :


STRUCTURE LOADS:
----------------


SUPERELEMENT TYPE  :         1

   THE HIGHEST LOAD CASE NUMBER ON THE FEM INTERFACE FILE IS :         0
   THE INITIAL LOAD CASE NUMBER ON THE LOAD FILE IS          :         1
```

```
 SUPERELEMENT TYPE NO   1   INDEX  1  (      69 BASIC ELEMENTS,      69 MEMBERS AND       38 NODES,  1 ACTUAL SUPERELEMENTS OF THAT TYPE )

    MEMBER        NO   12110  RECEIVES NO   LOADS

    MEMBER        NO   78110  RECEIVES NO   LOADS

../..

    MEMBER        NO   56220  SEA-STATE NO   1

       STEP NO    PHASE      FX          FY          FZ       DIAI      DIAD     CDN  CDL  CMN  CML  A/D

           9     -100.0 -2.0641E+03  2.2460E+03  3.4770E+04 1.600E+03 1.600E+03 0.60 0.00 2.00 0.00
          11      -80.0  8.0464E+03  3.3571E+03  5.2590E+04 1.600E+03 1.600E+03 0.60 0.00 2.00 0.00
          14      -50.0  4.6793E+04  4.1112E+03  1.0085E+05 1.600E+03 1.600E+03 0.60 0.00 2.00 0.00
          20       10.0  7.5022E+04 -2.2859E+03  1.2192E+05 1.600E+03 1.600E+03 0.60 0.00 2.00 0.00

../..
```

7)

```
 T O T A L   L O A D   S U M M A R Y :


    SEASTATE NO   1

       STEP    PHASE      LX            LY            LZ            MX            MY            MZ
       ----    -----      ----------    ----------    ----------    ----------    ----------    ----------

          1   -180.0     -1.9646E+05     3.6088E+03     6.0632E+06    -6.9570E+08     3.5282E+08     3.3272E+08
          2   -170.0     -4.8507E+04     8.3203E+03     6.1561E+06    -1.1402E+09     5.6437E+09     3.4325E+08

../..

         21     20.0      2.8160E+05    -1.9039E+04     5.4924E+06     5.0352E+08     8.2304E+09    -1.8073E+08

       MAXIMUM BASE SHEAR         = 1.0100E+06  AT PHASE =  -70.0
```

```
       MAXIMUM OVERTURNING MOMENT = 3.4225E+10  AT PHASE =  -80.0

../..
```

8)

```
SUMMARY OF ADMINISTRATIVE DATA TRANSFERRED TO STRUCTURAL ANALYSIS PROGRAM :
 ------------------------------------------------------------------------


 ---------------------------------------------------------------------------------------------------------------------------
 : SEASTATE  /   : WAVE     : WAVE     : WAVE     : WATER    : MUDPLANE :  WIND    : GUST WIND: TIME STEPS                  :
 : IDENTIFICATION: DIRECTION: HEIGHT   : PERIOD   : DEPTH    : ELEVATION:  PROFILE : INDUCED  : LOAD CASE NUMBERS           :
 : NUMBER        :          :          :          :          :          :  INDEX    : FATIGUE  :                             :
 ---------------------------------------------------------------------------------------------------------------------------
 :    1  /    1  :    0.0000:0.1200E+05: 8.000    :0.4350E+05:    0.0000:          :          :          :          :          :
 :               :          :          :          :          :          :          :          :    -4.000:    -3.778:    -3.556:
 :               :          :          :          :          :          :          :          :    -3.333:    -3.111:    -2.889:
 :               :          :          :          :          :          :          :          :    -2.667:    -2.444:    -2.222:
 :               :          :          :          :          :          :          :          :    -2.000:    -1.778:    -1.556:
 :               :          :          :          :          :          :          :          :    -1.333:    -1.111:    -0.889:
 :               :          :          :          :          :          :          :          :    -0.667:    -0.444:    -0.222:
 :               :          :          :          :          :          :          :          :     0.000:     0.222:     0.444:
 :               :          :          :          :          :          :          :          :       1.:        2.:        3.:
 :               :          :          :          :          :          :          :          :       4.:        5.:        6.:
 :               :          :          :          :          :          :          :          :       7.:        8.:        9.:
 :               :          :          :          :          :          :          :          :      10.:       11.:       12.:
 :               :          :          :          :          :          :          :          :      13.:       14.:       15.:
 :               :          :          :          :          :          :          :          :      16.:       17.:       18.:
 :               :          :          :          :          :          :          :          :      19.:       20.:       21.:
 ---------------------------------------------------------------------------------------------------------------------------
 :    2  /    2  : 45.00    :0.1200E+05: 8.000    :0.4350E+05:    0.0000:          :          :          :          :          :
 :               :          :          :          :          :          :          :          :    -4.000:    -3.778:    -3.556:
 :               :          :          :          :          :          :          :          :    -3.333:    -3.111:    -2.889:
 :               :          :          :          :          :          :          :          :    -2.667:    -2.444:    -2.222:
 :               :          :          :          :          :          :          :          :    -2.000:    -1.778:    -1.556:
 :               :          :          :          :          :          :          :          :    -1.333:    -1.111:    -0.889:
 :               :          :          :          :          :          :          :          :    -0.667:    -0.444:    -0.222:
 :               :          :          :          :          :          :          :          :     0.000:     0.222:     0.444:
 :               :          :          :          :          :          :          :          :       22.:       23.:       24.:
```

```
:              :         :         :         :         :         :         :         :  25.:       26.:       27.:
:              :         :         :         :         :         :         :         :  28.:       29.:       30.:
:              :         :         :         :         :         :         :         :  31.:       32.:       33.:
:              :         :         :         :         :         :         :         :  34.:       35.:       36.:
:              :         :         :         :         :         :         :         :  37.:       38.:       39.:
:              :         :         :         :         :         :         :         :  40.:       41.:       42.:


CPU TIME CONSUMPTION: 0.1100


P R O G R A M   N O R M A L   E N D
```

3.3 Calculation of Transfer Functions

Example 3.3 Minimum Analysis Control Data for Calculation of Transfer Functions

In this example transfer functions are calculated for a zero degree wave direction containing wave periods of 2.0, 3.0, 5.0 and 12.5 seconds. Linearisation with respect to wave height is specified using linearising wave heights of 0.5, 1.0, 2.3 and 8.5 meters for respective wave periods. Constant inertia (=2.0) and drag (=0.7) coefficients are specified for all members. The model is read from the Input Interface File T1.FEM and distributed loads are written to the Loads Interface File L1.FEM. No distributed results are written to the Print File.

Analysis Control Data:

```
WAJAC
TITL CALCULATION OF TRANSFER FUNCTIONS, MINIMUM EXAMPLE
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
HYDR
C
C   Hydrodynamic Coefficients as Function of Vertical Position
C                 Z1        Z2       CDN       CDL       CMN
COEF             0.0      60.0       2.0       0.0       2.0
LOAD
DPTH            43.5
C
C   Calculation of Transfer Functions
C      OPT      CTNO       BETA
SEAFRQ 2.0       0.0        0.0
C
C   Wave Periods for Calculation of Transfer Functions, given explicitly.
C               NPER
C                 T1        T2   . . .          T4
FRQ              4.0
FRQ              2.0       3.0       5.0      12.5
C
C   Wave Heights for linearisation
C                 H1        H2                 HN
AMP              0.5       1.0       2.3       8.5
END
```

Input files:

WAJAC.INP

T1.FEM

Output files:

WAJAC.LIS

L1.FEM

S1.FEM

Example 3.4 Analysis Control Data for Calculation of Transfer Functions

In this example the viscous drag is linearised using equivalent linearisation (see Section 2.4.3) with respect to a Pierson-Moskowitz wave energy spectrum with $T_z = 5.0$ seconds and $H_s = 8.5$ meters. Transfer functions of the global forces and moments are written to the Hydrodynamic Results Interface File. In addition to the

dynamic loads added mass including internal water of flooded members are written to the Loads Interface File for use in a subsequent dynamic structural analysis.

Analysis Control Data:

```
WAJAC
TITL CALCULATION OF TRANSFER FUNCTIONS, EQUIVALENT LINEARISATION
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
C
C   Units and Constants Definition
C              UNITS   GRAVITY        RO      VISC
CONS             1.0    9806.6  1.025E-9
C
C   Special options
C               OPT1      OPT2      OPT3      OPT4      OPT5      OPT6     OPT7
OPTI             0.0       0.0       1.0
HYDR
C
C   Hydrodynamic Coefficients as Function of Vertical Position
C                 Z1        Z2       CDN       CDL       CMN
COEF             0.0   60000.0       0.7       0.0       2.0
C
C   Added mass to Loads Interface File
C                OPT
MASS             2.0
LOAD
DPTH         43500.0
C
C   Calculation of Transfer Functions
C      OPT      CTNO      BETA
SEAFRQ 1.0       0.0       0.0
SEAFRQ 1.0       0.0      45.0
SEAFRQ 1.0       0.0      90.0
SEAFRQ 1.0       0.0     135.0
C
C   Wave Periods for Calculation of Transfer Functions, given explicitly.
C               NPER
C                 T1        T2   ...            T4
FRQ              4.0
FRQ              2.0       3.0       5.0      12.5
C
C   Definition of Wave Energy Spectrum for equivalent linearisation
C                 HS        TZ    SIGMAA    SIGMAB    blank    GAMMA   ISPECT
SPECTR        8500.0       5.0       0.0       0.0                0.0      1.0
C
C   Members Force Print-out Specification
C                 N1        NN      STEP     STYPE     INDEX      ISEA    ISTEP
MPRT         56220.0   67220.0   11000.0       1.0       1.0       1.0      3.0
END
```

Input files:

WAJAC.INP

T1.FEM

Output files:

WAJAC.LIS

L1.FEM

S1.FEM

G1.SIF, Hydrodynamic Results Interface File (G-file)

Data on the Print File deviating from the Print File described in Example 3.2 are listed below.

1) Loading information

No added mass has been calculated for member (or element) number 12110. Added mass without internal water has been calculated and written to the Loads Interface File for member 23110. Internal water is not included since the member is not specified as flooded.

The following data are printed for members specified by the MPRT command:

T	the average diameter at the load calculation points used when calculating the inertia forces,
OMEGA	The wave angular frequency (radians per unit time).
DIST1	Distance from end 1 to start of distributed load.
DIST2	Distance from end 2 to end of distributed load.
HARMONIC FORCE	Real and imaginary part of the hydrodynamic forces per unit wave amplitude. The components are given in the global coordinate system.
CONSTANT FORCE	Real and imaginary part of the hydrodynamic forces per unit wave amplitude. The components are given in the global coordinate system. would also have been included here. These constant forces are not transferred to the Loads Interface File.
DIAI	The average diameter at the load calculation points used when calculating the inertia forces.
DIAD	The average diameter used when calculating the viscous drag forces.
CDN	The average transverse drag force coefficient.
CDL	The average longitudinal drag force coefficient.
CMN	The average transverse inertia coefficient.
CML	The average longitudinal inertia coefficient.

2) Total load summary

Also for the total loads the forces are split into the harmonic forces due to the waves and constant forces due to buoyancy (and current if specified).

3) Total added mass

This section reports the sum of distributed added mass written to the Loads Interface File. The printed total added mass is split into three values:

1. Total added mass without contribution from internal water (A_{EX}),
2. contribution from additional diameter accounting for marine growth ($A_{EX} - A_D$, where A_D is the added mass based on the member diameter), and
3. contribution from internal water (A_I).

The total added mass is then given by $A_{EX} + A_I$. In this example no marine growth is specified and no members are flooded.

4) Load case summary

Again this table gives an overview of the loads generated and the global load case number assigned to the individual loads. Note that each load case is identified by the frequency and not the wave period as specified in the Analysis Control Data.

Examples from the Print File of Example 3.4.

```
 ********************************************************************************************
 *                                                                                          *
 *      CALCULATION OF TRANSFER FUNCTIONS, EQUIVALENT LINEARISATION                         *
 *                                                                                          *
 ********************************************************************************************

../..

 FREQUENCY DOMAIN SEASTATES DEFINITION:
 --------------------------------------

    LOAD TRANSFER FUNCTIONS WILL BE CALCULATED FOR THE FOLLOWING SEASTATES (HEADINGS):

    SEASTATE    WAVE     CURRENT TABLE
     NUMBER    HEADING        NO.

        1        0.0          0
        2       45.0          0
        3       90.0          0
        4      135.0          0


    WAVE SPECTRUM TYPE:   PIERSON-MOSKOWITZ WITH PARAMETERS:
    HS=    8500.000   TZ=  5.00

    TRANSFER FUNCTIONS WILL BE CALCULATED FOR THE FOLLOWING WAVE PERIODS:

    PERIOD NO.       PERIOD

         1            2.000
         2            3.000
         3            5.000
         4           12.500

    STATISTICAL LINEARIZATION WILL BE USED TO LINEARIZE THE DRAGFORCES.
```

```
 D A T A C H E C K I N G   F I N I S H E D

../..
```

1)

```
 W A V E / C U R R E N T   L O A D I N G :


 STRUCTURE LOADS:
 ----------------


 SUPERELEMENT TYPE  :         1

    THE HIGHEST LOAD CASE NUMBER ON THE FEM INTERFACE FILE IS :         0
    THE INITIAL LOAD CASE NUMBER ON THE LOAD FILE IS          :         1



 SUPERELEMENT TYPE NO   1   INDEX  1  (      69 BASIC ELEMENTS,      69 MEMBERS AND       38 NODES,  1 ACTUAL SUPERELEMENTS OF THAT TYPE )

    MEMBER        NO   12110  RECEIVES NO ADDED MASS

 ADDED MASS CALCULATIONS:

       MEMBER        INTERNAL WATER     DIAMETER      CM
       ------        --------------     --------      -----

        23110        WITHOUT            0.160E+04     2.000

../..

    MEMBER        NO   12120  RECEIVES NO ADDED MASS

../..

    MEMBER        NO   56220  HEADING NO   1

       PERIOD NO  3   T= 5.00   OMEGA=1.2566
```

```
          DIST1=0.000E+00 DIST2=0.000E+00   DIAI=1.600E+03 DIAD=1.600E+03  CDN=0.70 CDL=0.00 CMN=2.00 CML=0.00

                                 REAL        IMAG           REAL        IMAG           REAL        IMAG
          HARMONIC FORCE:  X -1.0055E-01 -2.0840E+01  Y  2.5649E+00 -1.2376E-02  Z  3.2061E-01 -1.5470E-03
          CONSTANT FORCE:  X  0.0000E+00              Y  1.9531E-03              Z  1.2221E+05
```

../..

2)

```
 T O T A L   L O A D   S U M M A R Y :


    HEADING NO. 1   BETA=  0.0

       PERIOD NO. 1   T= 2.00   OMEGA=3.1416   WAVE LENGTH =    6243.075

              HARMONIC FORCE      CONSTANT FORCE      HARMONIC MOMENT      CONSTANT MOMENT

             REAL        IMAG                          REAL        IMAG
       X  2.0198E+01  1.1608E+02    7.8125E-03     6.3176E+04  1.4542E+05   -1.6855E+09
       Y  1.6193E-01 -9.4590E-02    2.0966E-02     9.2586E+05  4.9719E+06    1.3929E+09
       Z -4.9606E+00 -7.6403E+00    5.9323E+06     1.2850E+04  2.1987E+04   -9.6000E+01
```

../..

3)

```
 T O T A L     A D D E D    M A S S :

   ( DECOMPOSED IN X, Y AND Z COMPONENTS )


   COMP  ADDED MASS     CONTRIBUTION   CONTRIBUTION   TOTAL
         USING EXTERN.  FROM MASS      FROM MASS      ADDED
         DIAMETER INC.  OF MARINE      OF INTERNAL    MASS
         MARINE GROWTH  GROWTH         WATER
   ----  -------------  -------------  -------------  ------------

   X     5.0316E+02     0.0000E+00     0.0000E+00     5.0316E+02
```

```
  Y     5.0536E+02     0.0000E+00     0.0000E+00     5.0536E+02
  Z     2.0135E+02     0.0000E+00     0.0000E+00     2.0135E+02


 W E I G H T   A N D   B U O Y A N C Y   S U M M A R Y :

../..


 WRITING GLOBAL RESPONSE INTERFACE FILE
 ======================================
    FILE NAME               : G1.FEM
    BODY IDENTIFICATION     :    1
    DATA SET IDENTIFICATION :    1
    PROGRAM IDENTIFICATION  : 1436
```

4)

```
 SUMMARY OF ADMINISTRATIVE DATA TRANSFERRED TO STRUCTURAL ANALYSIS PROGRAM :
 --------------------------------------------------------------------------


 ------------------------------------------------------------------------------------------------------------------------
 : SEASTATE  /    : WAVE     : WAVE     : WAVE     : WATER    : MUDPLANE : FREQUENCIES (HZ)                             :
 : IDENTIFICATION: DIRECTION: HEIGHT   : PERIOD   : DEPTH    : ELEVATION: LOAD CASE NUMBERS                            :
 : NUMBER        :          :          :          :          :          :                                                 :
 ------------------------------------------------------------------------------------------------------------------------
 :    1  /    1  :    0.0000:    0.0000:    0.0000:0.4350E+05:    0.0000:          :          :          :          :
 :               :          :          :          :          :          :   0.50000:   0.33333:   0.20000:   0.08000:
 :               :          :          :          :          :          :        1.:        2.:        3.:        4.:
 ------------------------------------------------------------------------------------------------------------------------
 :    2  /    2  : 45.00    :    0.0000:    0.0000:0.4350E+05:    0.0000:          :          :          :          :
 :               :          :          :          :          :          :   0.50000:   0.33333:   0.20000:   0.08000:
 :               :          :          :          :          :          :        5.:        6.:        7.:        8.:
 ------------------------------------------------------------------------------------------------------------------------
 :    3  /    3  : 90.00    :    0.0000:    0.0000:0.4350E+05:    0.0000:          :          :          :          :
 :               :          :          :          :          :          :   0.50000:   0.33333:   0.20000:   0.08000:
 :               :          :          :          :          :          :        9.:       10.:       11.:       12.:
 ------------------------------------------------------------------------------------------------------------------------
 :    4  /    4  : 135.0    :    0.0000:    0.0000:0.4350E+05:    0.0000:          :          :          :          :
```

```
:              :          :          :          :          :          :   0.50000:   0.33333:   0.20000:   0.08000:
:              :          :          :          :          :          :       13.:       14.:       15.:       16.:


CPU TIME CONSUMPTION: 0.1000


P R O G R A M   N O R M A L   E N D
```

3.4 Time Simulation of Wave Loads in a Short-Term Seastate

Example 3.5 Minimum Analysis Control Data for a Short-Term Seastate Simulation

In this example a seastate described by a Pierson-Moskowitz wave energy spectrum with $H_s = 8.5$ meters and $T_z = 10$ seconds is simulated by a unidirectional, irregular sea. The irregular sea is generated by superposition of linear waves with random phase and wave periods varying from 4.0 to more than 3600 seconds.

Time series of loads are calculated in the simulated seastate for a time interval of 3600 seconds and with waves propagating along the global X-axis. Loads are calculated with a time interval of 2 seconds.

Constant inertia (=2.0) and drag (=0.7) coefficients are specified for all members. The model is read from the Input Interface File T1.FEM and time series of distributed loads are written to the Loads Interface File L1.FEM. No distributed results are written to the Print File.

The kinematics of the irregular sea is calculated in a 3 dimensional grid within a vertical cylinder with a radius of 30 meter. No data is saved for later re-use.

```
WAJAC
TITL CALCULATION OF TRANSFER FUNCTIONS, MINIMUM EXAMPLE
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
HYDR
C
C   Hydrodynamic Coefficients as Function of Vertical Position
C                 Z1        Z2       CDN       CDL       CMN
COEF             0.0      60.0       0.7       0.0       2.0
LOAD
DPTH            43.5
C
C   Horizontal Extremity of Simulation Grid
C             RADMAX
GRID            30.0
C
C   Seastate Simulation Directions
C             LISGEN    ISPECT    NEDLDIR    blank  SIMLEN    SEED     TCUT
SEASIM           0.0       1.0        1.0            3600.0     47.0      4.0
C
C   Time Simulation of Wave Loads in a Seastate
C                 T0       TIM       DELT      CTNO    BETA   LOACON   MEMCON
LOASIM           0.0    3600.0        4.0       0.0     0.0      0.0      1.0
C
C   Definition of Wave Energy Spectrum
C                 HS        TZ     SIGMAA    SIGMAB   blank    GAMMA
SPECTR           8.5      10.0
END
```

Input files:

WAJAC.INP

T1.FEM

Output files:

WAJAC.LIS L1.FEM

S1.FEM

Example 3.6 Analysis Control Data for Simulation of Wave Loads in a Short-Term Seastate

In this example a seastate described by a JONSWAP wave energy spectrum with standard spectral characteristics and $H_s = 8.5$ meters and $T_z = 10$ seconds is simulated by a short crested irregular sea. Loads are calculated with a main wave direction of 45 degrees to the left of the global X-axis. A stationary current with varying direction is also imposed on the structure. The kinematics of the irregular sea is calculated in a 3 dimensional grid within a vertical cylinder with a radius of 34 metre.

Time series of distributed loads are written to the Loads Interface File L1.FEM and the time series of the total loads are stored on Simulation Result Files.

```
WAJAC
TITL SIMULATION OF WAVE LOADS IN A SEA STATE
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C        1         2         3         4         5         6         7         8
C
C   Model Identification
C             IGFSAV    ILFSAV    ISETOP
MODE                       1.0       1.0
C
C   Units and Constants Definition
C              UNITS   GRAVITY        RO      VISC
CONS             1.0    9806.6  1.025E-9
HYDR
C
C   Hydrodynamic Coefficients as Function of Vertical Position
C                 Z1        Z2       CDN       CDL       CMN
COEF             0.0   60000.0       0.7       0.0       2.0
LOAD
DPTH         43500.0
C
C   Horizontal Extremity of Simulation Grid
C             RADMAX
GRID         34000.0
C
C   Percentages of Energy for Component Wave Directions
C             EPART1    EPART2    EPART3    EPART4    EPART5
ERG              0.0       0.3       0.4       0.3       0.0
C
C   Seastate Simulation Directions
C             LISGEN    ISPECT    NELDIR    blank   SIMLEN      SEED      TCUT
SEASIM           0.0       2.0       5.0              3600.0       5.0       5.0
C
C   Definition of Current Profiles, variant 1.
C     CTNO        VX        VY        VZ         Z
CRNT   1.0       0.0       0.0       0.0       0.0
CRNT   1.0     200.2     100.0       0.0   20000.0
CRNT   1.0     300.3     300.0       0.0   60000.0
C
C   Time Simulation of Wave Loads in a Sea State
C                 T0       TIM      DELT       CTNO     BETA    LOACON    MEMCON
LOASIM           0.0    3600.0       4.0        1.0     45.0       3.0       1.0
C
C   Definition of Wave Energy Spectrum
C                 HS        TZ    SIGMAA    SIGMAB    blank    GAMMA
SPECTR        8500.0      10.0       0.0       0.0                0.0
END
```

Input files:
WAJAC.INP
T1.FEM

S1030.SER	Simulation Result File with time series of the surface elevation at origin of the global coordinate system.
S1031.SER	Simulation Result File with time series of the total force FX.
S1032.SER	Simulation Result File with time series of the total force FY.
S1033.SER	Simulation Result File with time series of the total force FZ.
S1034.SER	Simulation Result File with time series of the total moment MX.
S1035.SER	Simulation Result File with time series of the total moment MY.
S1036.SER	Simulation Result File with time series of the total moment MZ.

Data on the Print File deviating from the Print Files described in Example 3.2 and Example 3.4 are given below.

1) Simulation time

Only 3600 seconds were specified as the total simulation time for the generated irregular sea but due to the applied algorithm this time is increased to a multiple of two of the cut-off period which is specified to 4.0 seconds.

2) Main wave direction

The generated irregular sea may be rotated any angle with respect to the structure. It is not necessary to recalculate the kinematics when analysing an other main direction for the same seastate.

3) Distributed load

No print is made of loads on individual members. Only members not receiving any loads are listed. The individual loads are only stored on the Loads Interface File. Time series of loads on selected members may optionally be written to Simulation Result Files, see the LOASIM command. In this run only global results and the surface elevation above origin of the global coordinate system are stored on Simulation Result Files.

Examples from the Print File of Example 3.6.

```
 ********************************************************************************************
 *                                                                                          *
 *      SIMULATION OF WAVE LOADS IN A SEA STATE                                             *
 *                                                                                          *
 ********************************************************************************************

../..

 SEASTATE TO BE SIMULATED IN THE TIMEDOMAIN:
 ------------------------------------------

../..
```

1)

```
    THE ACTUAL SIMULATION LENGTH WILL BE:
    SIMLEN=    5120.000 (SECONDS)

../..

 WAVE LOADS SIMULATION IN THE TIMEDOMAIN:
 ---------------------------------------

../..
```

2)

```
    THE ROTATION ANGLE BETWEEN THE THE SIMULATION COORDINATE SYSTEM
    AND THE STRUCTURE COORDINATE SYSTEM WILL BE =  45.0

../..

 D A T A C H E C K I N G   F I N I S H E D

../..

 T I M E S I M U L A T I O N   O F   W A V E   K I N E M A T I C S :
```

```
 GENERATION, SAVING OR RESTORING:
 --------------------------------


    INPUT SEED GIVEN BY THE USER :               5
    OUTPUT SEED AFTER SIMULATION :        46106016


    JONSWAP (JW) SPECTRUM (COMPUTED) :

       HS    = 8500.00  TZ    =   10.01  ALPHA =  0.0091  TP    =   12.78
       GAMMA =    3.30  SIGMAA=  0.0700  SIGMAB=  0.0900


 W A V E / C U R R E N T   L O A D I N G :

 SAVING SEA SURFACE ELEVATION FOR TIME SERIES ANALYSIS :
 -------------------------------------------------------

     AT POINT :   ORIGIN =    0.000E+00   0.000E+00   0.000E+00


       FILE NAME :  S1030
       CONTENTS  :  SEA SURFACE ELEVATION AT ORIGIN
```

3)

```
 STRUCTURE LOADS:
 ----------------


 SUPERELEMENT TYPE  :         1

../..

 SUPERELEMENT TYPE NO   1   INDEX  1  (      69 BASIC ELEMENTS,      69 MEMBERS AND       38 NODES,  1 ACTUAL SUPERELEMENTS OF THAT TYPE )

    MEMBER        NO   12110  RECEIVES NO   LOADS
```

../..

T O T A L L O A D S U M M A R Y :

SEASTATE NO 1

STEP	TIME	LX	LY	LZ	MX	MY	MZ
1	0.0	3.1571E+05	-1.1101E+05	6.0146E+06	1.6309E+09	1.0456E+10	-7.7958E+07
2	4.0	-2.3531E+04	1.7184E+04	5.9130E+06	-2.5837E+09	9.8107E+08	-3.7052E+08

../..

SAVING TOTAL LOAD HISTORY FOR TIME SERIES ANALYSIS :

SEASTATE NO 1

FILE NAME : S1031
CONTENTS : FX TOTAL FORCE IN X - DIR

FILE NAME : S1032
CONTENTS : FY TOTAL FORCE IN Y - DIR

FILE NAME : S1033
CONTENTS : FZ TOTAL FORCE IN Z - DIR

FILE NAME : S1034
CONTENTS : MX TOTAL MOMENT IN X - DIR

FILE NAME : S1035
CONTENTS : MY TOTAL MOMENT IN Y - DIR

FILE NAME : S1036
CONTENTS : MZ TOTAL MOMENT IN Z - DIR

SUMMARY OF ADMINISTRATIVE DATA TRANSFERRED TO STRUCTURAL ANALYSIS PROGRAM :

SEASTATE / IDENTIFICATION NUMBER	WAVE DIRECTION	WAVE HEIGHT	WAVE PERIOD	WATER DEPTH	MUDPLANE ELEVATION	TIME STEPS LOAD CASE NUMBERS
1 / 1	45.00	8500.	10.00	0.4350E+05	0.0000	FROM 0.000 STEP 4.000 TO 3596.000
						FROM 1. STEP 1. TO 900.

CPU TIME CONSUMPTION: 2.870

P R O G R A M N O R M A L E N D

Example 3.7 Analysis Control Data for regeneration of random sea.

In typical time simulation analysis Wajac uses predefined wave spectrum to obtain wave amplitudes, additionally random phases are generated. SEAIN command presents an alternative to SEASIM command. It allows to specify seastate using two different approaches, specifying:

a) time series of surface elevation. Wave components are determined based on time series data.

b) data related to individual wave components random wave is based on. The final wave is a sum all components specified in the input file. Single component is defined by its amplitude, frequency and phase.

In both cases components are used for kinematics calculation based on Airy wave theory. From this moment on everything is exactly the same as in case of typical time simulation analysis. The only difference is in how we obtain wave components parameters.

```
WAJAC
C
TITL  Time simulation of wave loads in a seastate.
C
C         PREFIX (left adjusted)
FMOD      X270R
C
C     Prefix for Loads Interface Files:
C         PREFIX (left adjusted)                  FORM (Unformatted is default)
FWAVE     X270R                                   FORMATTED
C
C
FCOMP     X270R
C                        ILFSAV    ISETOP
MODE                        1.        1.
C
C               OPT1      OPT2      OPT3      OPT4      OPT5      OPT6      OPT7
OPTI              0.        0.        0.        0.        0.        0.        1.
                  0.        0.        0.
C
C              UNITS   GRAVITY       RHO      VISC    RHOAIR   VISCAIR
CONS              1.   9.80665     1025. 1.19e-006     1.226  1.462e-5
C
C         *************************** GEOM Section ****************************
GEOM
C
C                  Z
MUDP           -31.2
C
C         *************************** HYDR Section ****************************
HYDR
C               TYPE
CPRI      FEM
CPRI      SPEC
CPRI      CDIR
C
C         *************************** LOAD Section ****************************
LOAD
C              DEPTH
DPTH            31.2
C
C             RADMAX
GRID            30.0       4.3
C
C         --- 10---|--- 20---|--- 30---|--- 40---|--- 50---|--- 60---|--- 70---|--- 80---|
```

```
C          123456789|123456789|123456789|123456789|123456789|123456789|123456789|1234567890
C               FNAME                                      FTYPE     RSTART       REND
SEAIN       myfile_time_SER_102d4_DT0d1.dat                  0.         1.      1024.
              102.40        0.1        0.0
C              TIMEL      TSTEP       HEPS
C
C                 TO         TIM       DELT       CTNO       BETA     LOACON     MEMCON    WHEESTR
LOASIM           0.0       102.4       0.10        0.0       45.0        3.0        1.0         0.
C
C                  X          Y          Z
MOMT              0.         0.       -31.2
C
END
```

In the listing file presented above seastate is about to be regenerated through time series of surface elevation, we can recognize that by value of FTYPE parameter which for time series data needs to be specified as ≤ 10.

In the original input file first and last row are specified as the first one and the last one available. However user may select the data to be analysed by narrowing range of rows.

```
C          123456789|123456789|123456789|123456789|123456789|123456789|123456789|1234567890
C               FNAME                                      FTYPE     RSTART       REND
SEAIN       myfile_time_SER_102d4_DT0d1.dat                  0.         2.       500.
              102.40        0.1        0.0
C              TIMEL      TSTEP       HEPS
```

If no data specified for RSTART and REND, Wajac will start from first row and read until end of file.

```
C          123456789|123456789|123456789|123456789|123456789|123456789|123456789|1234567890
C               FNAME                                      FTYPE     RSTART       REND
SEAIN       myfile_time_SER_102d4_DT0d1.dat                  0.
              102.40        0.1        0.0
C              TIMEL      TSTEP       HEPS
```

If user would like to use wave components instead of time series of surface elevation file type flag FTYPE should be modified. According to description of SEAIN command it is possible to introduce wave components as a function of angular frequency, period or frequency. The corresponding values of FTYPE are 11, 12 and 13.

```
C          123456789|123456789|123456789|123456789|123456789|123456789|123456789|1234567890
C               FNAME                                      FTYPE     RSTART       REND
SEAIN       myfile_comp.dat                                  11.         1.       100.
              102.40        0.1        0.0
C              TIMEL      TSTEP       HEPS
```

In this example user wants to analyse only one component specified on the 5th row of the input file. Wave components are specified as a function of period.

```
C          123456789|123456789|123456789|123456789|123456789|123456789|123456789|1234567890
C               FNAME                                      FTYPE     RSTART       REND
SEAIN       myfile_comp.dat                                  12.         5.         5.
              102.40        0.1        0.0
C              TIMEL      TSTEP       HEPS
```

Below valid input data for both specification method is presented. Please note that in case of specification by wave components first column contains ids of wave components, followed by amplitudes, angular frequency

(or period or frequency) and phases. When input file contains time series of surface elevation, first column should contain time data, second one corresponding surface elevation data.

Data given by wave components

First example presents basic input structure without any comments.

```
1       1.39541226E-06       0.00000000E+00       0.00000000E+00
2       1.04414028E-06       6.13592342E-02       2.30046439E+00
3       6.69837789E-07       1.22718468E-01       1.42687464E+00
4       1.89107743E-06       1.84077710E-01       2.70051074E+00
5       1.16885212E-06       2.45436937E-01       1.19924277E-01
```

First rows can be used to introduce comments. In such case user should specify correct value of RSTART parameter. In this case RSTART should be specified at least as 3 and cannot be blank. Note that this time 3rd column contain period instead of frequency, thus values are stored in decreasing order.

```
This file contains few rows with comments.
   id                  amp               period                phase
    1       1.39541226E-06       0.10000000E+00       0.00000000E+00
    2       1.39541226E-06       0.09000000E+00       0.00000000E+00
    ...
```

Data given by time-series of surface elevation

The same rules apply here regarding comments, i.e. first few lines does not have to contain valid numerical data but proper value of RSTART parameter should be used.

```
This file contains few rows with comments.
                  time            elevation
        0.00000000E+00       0.05000000E+00
        0.10000000E+00       0.10000000E+00
        0.20000000E+00       0.16000000E+00
        0.30000000E+00       0.16700000E+00
        ...
```

3.5 Additional Options

3.5.1 Modification of Member Diameters

The diameters applied in Morison's equation may be modified. There are two ways of doing this. The user may specify a marine growth as function of the vertical position of the load calculation points (see Section 3.5.6) or he may specify member diameter for individual members by the SPEC/SPEX command:

	1	2	3	4	5	6	7	8	9	10	11
SPEC				STYPE	INDEX	DIAM	CDN	CDL	CMN	CML	IGWD
	N1	NN	STEP								
	SETNAM										

3.5.2 Elimination of Members and Superelements

Parts of the structure may be eliminated from the load calculations by the commands ELIM which removes members and SELI which removes superelement types. Note that by default all members with both end-node z-coordinates below value of 1e-6 will be eliminated. For deterministic analysis horizontal (and nearly horizontal) members lying at sea bottom (within some tolerance) may be included in the calculation using OPT12 option.

	1	2	3	4	5	6	7	8
ELIM				STYP	INDEX			
	N1	NN	STEP					
	SETNAM							

	1	2	3	4	5	6	7	8
SELI		STYP						

3.5.3 Member Segmentation

To achieve a better resolution of the distributed forces on a structure the segmentation of the members may be controlled by the SEGM or the MSEG commands:

	1	2	3	4	5	6	7	8
SEGM		Z1	Z2	SEG	SLMIN	SLMAX		

	1	2	3	4	5	6	7	8
MSEG		SEG						

3.5.4 Mudline Elevation

The mudline elevation is specified relative to the global coordinate system by the MUDP command:

	1	2	3	4	5	6	7	8
MUDP		Z						

3.5.5 Soil Permeability, Reduced Buoyancy

The buoyancy of a platform leg consisting of non-flooded pipe members may be reduced by a factor specified through CPERM parameter the LEG command. Buoyancy and weight of marine growth attached to a leg can be controlled via BAWMG parameter.

	1	2	3	4	5	6	7	8
LEG	BAWMG	CPERM	NODBOT	NODTOP	STYPE	INDEX		

3.5.6 Marine Growth

The diameters applied in Morison's equation may be modified to account for marine growth. There are two ways of doing this. The user may specify member diameter for individual members (see Section 3.5.1) or specify marine growth as function of the vertical position of the load calculation points by using the MGRW command. If multiple marine growth profiles are required this may be specified by using the IMEM parameter on MGRW and connecting the different profiles to parts of the structure by the MEMGRW command:

	1	2	3	4	5	6	7	8
MGRW		Z1	Z2	HMGRW	HROUGH	OPT	IMEM	

	1	2	3	4	5	6	7	8
MEMGRW				STYPE	INDEX	IMEM		
	N1	NN	STEP					
	SETNAM							

A specification of multiple marine growth profiles in a Wajac simulation may be as follows:

```
C   - For load calculation in the range [10,20>, HMGRW=0.06 for
C     CLEANED members and HMGRW=0.03 for all other members.]
C   - For all load calculation points in the range [20,50>, HMGRW=0.03
C
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C                 Z1        Z2     HMGRW    HROUGH       OPT  IMEM
MGRW               0.       50.      0.03     0.010       1.0
MGRW               0.       10.      0.05     0.010       1.0    1.
MGRW              10.       20.      0.06     0.011       1.0    1.
MGRW               0.       10.      0.15     0.010       1.0    2.
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C                                 SETNAM STYP INDX IMEM
MEMGRW                           CLEANED  11    1.   1.
MEMGRW                           CLEANED  12    1.   1.
MEMGRW                           NOTCLEA  11.   1.   2.
```

3.5.7 Specification of Hydrodynamic Coefficients

There are six different options for specifying hydrodynamic coefficients in Wajac. These are described in Section 2.2.7. For the different options the relevant commands are the following:

	1	2	3	4	5	6	7	8
COEF		Z1	Z2	CDN	CDL	CMN		

2) As function of the member diameter:

	1	2	3	4	5	6	7	8
CDIA		DIA1	CDN1	CMN1	DIA2	CDN2	CMN2	

	1	2	3	4	5	6	7	8	9
		for fouled members				for non-fouled members			
CDFN	DIA	CDN	CDL	CMN	CML	CDN	CDL	CMN	CML

3) As function of the roughness number and the Reynolds number (Rn):

	1	2	3	4	5	6	7	8
CDRG	OPT	ROUGH	NU1	CDN1	NU2	CDN2	NU3	CDN3

and

	1	2	3	4	5	6	7	8
CMAS	OPT	ROUGH	NU1	CMN1	NU2	CMN2	NU3	CMN3

with OPT $= 1.0$.

4) As function of the roughness number and Keulegan-Carpenter (KC) number:

	1	2	3	4	5	6	7	8
CDRG	OPT	ROUGH	NU1	CDN1	NU2	CDN2	NU3	CDN3

and

	1	2	3	4	5	6	7	8
CMAS	OPT	ROUGH	NU1	CMN1	NU2	CMN2	NU3	CMN3

with OPT $= 2.0$.

5) Specified for individual members assuming uni-directional coefficients, and global wave direction and/or seastate dependent coefficients:

	1	2	3	4	5	6	7	8	9	10	11
SPEC / SPEX				STYPE	INDEX	DIAM	CDN	CDL	CMN	CML	IGWD
	N1	NN	STEP								
	SETNAM										

	1	2	3	4	5	6	7	8	9
CGWD	IGWD	CD1	CD2	CD3	CM1	CM2	CM3	DIR	ISEA

6) Directional coefficients specified for individual members:

	1	2	3	4	5	6	7	8	9	10	11
CDIR				STYPE	INDEX	CD1	CD2	CD3	CM1	CM2	CM3
	N1	NN	STEP								
	SETNAM										

3.5.8 Current Profiles

Current may be added to the wave during any analysis type by the CTNO parameter on the seastate definition commands:

	1	2	3	4	5	6	7	8	9
SEA	OPT	**CTNO**	HEIGHT	PERIOD	PHI0	T0	STEP	NSTEP	BETA

	1	2	3	4	5	6	7	8
SEAFRQ	OPT	**CTNO**	BETA					

	1	2	3	4	5	6	7	8
LOASIM		T0	TIM	DELT	**CTNO**	BETA	LOACON	MEMCON

The CTNO parameter identifies the current profile to be applied. Up to five different current profiles may be defined in the Analysis Control Data by the CRNT command. This command has three different forms. The current at each level may be specified by either the velocity components in the global coordinate system, (var. 1)

or by horizontal velocity and direction relative to the X-axis in the global coordinate system, (var. 2)

or specified to go in the direction of the wave (OPT=1.0), (var. 3)

	1	2	3	4	5	6	7	8
CRNT	CTNO							
	var.1	VX	VY	VZ	Z			
	var.2				Z	V	THETA	
	var.3				Z	V		OPT

3.5.9 Equivalent Linearisation

When calculating transfer functions the viscous drag forces may be linearised through equivalent linearisation (OPT=1.0 on the SEAFRQ command). The linearisation is then performed with respect to a wave energy spectrum specified through the SPECTR command:

	1	2	3	4	5	6	7	8
SPECTR		HS	TZ	SIGMAA	SIGMAB		GAMMA	ISOECT

The type of spectrum is chosen by the ISPECT parameter:

ISPECT = 1.0 gives Pierson-Moskowitz spectrum

ISPECT = 2.0 gives JONSWAP spectrum

3.5.10 Use of MacCamy-Fuchs' Formula

The MacCamy-Fuchs formula for inertia loads on a cylindrical pile may be applied. This is done by specifying zero inertia coefficients ($C_m = 0.0$) at the load calculation points in question and setting the OPT4 parameter in the OPTI command equal to 1.0 or 2.0:

	1	2	3	4	5	6	7	8
OPTI		OPT1	OPT2	OPT3	OPT4	OPT5	OPT6	OPT7

See the command description in Section 5.5.

3.5.11 Added Mass to the Loads Interface File

Constant added mass may be written to the Loads Interface File. This is done by giving the MASS command:

	1	2	3	4	5	6	7	8
MASS		ADMAS	DAMP	IMET				

where the ADMAS parameter controls whether additional mass due to internal water of flooded members should be included or not. ADMAS parameter also controls whether longitudinal added mass should be included or not. See also the OPT2 parameter of the OPTI command. IMET parameter is valid only for pure added mass calculation or when added mass calculation is performed alongside with deterministic calculation and controls which of two available added mass calculation approaches should be used.

3.5.12 Load Case Numbers and Load Combinations

As can be seen from the examples in Section 3.2, Section 3.3 and Section 3.4 the load case numbers assigned to each load case written to the Loads Interface File will be subsequent to any load cases already defined on the Input Interface File for the individual superelement types. The user may force Wajac to use a specified number as the initial load case number for all first level superelement types by the LONO command:

	1	2	3	4	5	6	7	8
LONO		LN						

The generation of load case numbers is described by Figure 3.1 for deterministic load calculations and frequency domain load calculations. For each given water depth, all the seastates will be calculated.

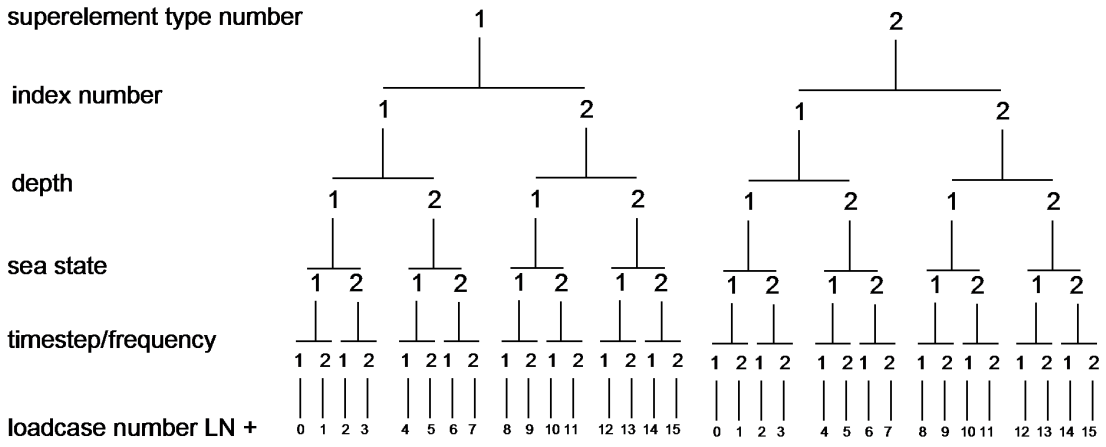


Figure 3.1: Generation of load case numbers for multi-water depths if seastate independent

If seastate is dependent on water depth index, as defined in DPTH command, the generation of load case numbers is described by Figure 3.2. The load case numbers follows the sequence of the seastate indexes defined. This feature is only available for deterministic load calculations.

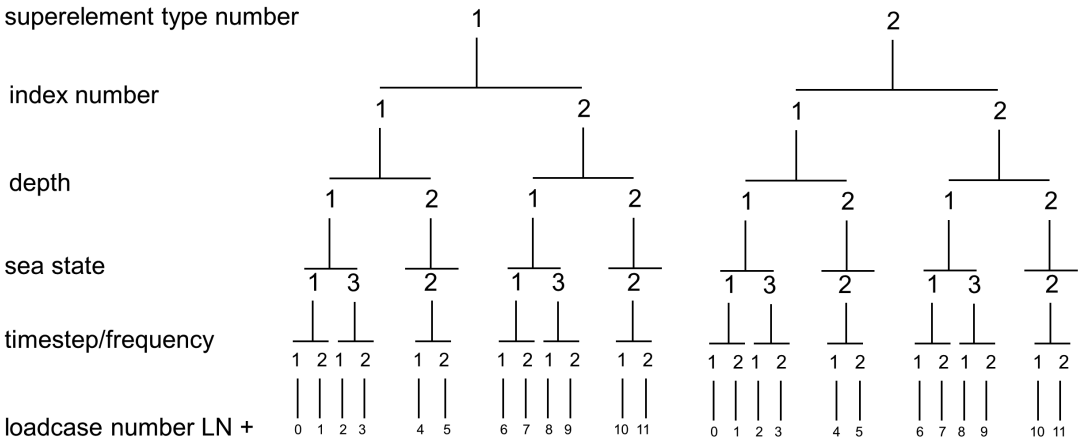


Figure 3.2: Generation of load case numbers for multi-water depths if seastate dependent

For further control of the load case numbering see the SESAM utility program Waloco.

3.5.13 Units

Wajac will by default assume that the units applied are meters, seconds and kilogram. This may be changed by the CONS command:

	1	2	3	4	5	6	7	8
CONS		UNITS	GRAVITY	RO	VISC	ROAIR	VISCAIR	

This command may also be used to specify fluid density different from that of salt water (1025 kg/m^3).

3.5.14 Redefinition of Commands

The command names and their formats as described in Section 5.5 may be redefined through the EQVL command. One purpose of this command is to replace commands with too narrow fields for the data to specify.

	1	2	3	4
EQVL	DSET	OLD	NEW	FORMAT

No commands in the Wajac data set may be redefined.

3.5.15 Hydrodynamic Results Interface File

A Hydrodynamic Results Interface File for transfer of global loads to Postresp may be generated when calculating transfer functions. The option is available through the OPTI command using OPT3=2.0

3.5.16 Wave Kinematics

The fluid kinematics of the applied waves including velocity, acceleration and surface elevation may be calculated in specified points and written to the Print File. This is controlled by the KPRT command:

	1	2	3	4	5	6	7	8
KPRT		X	Y	Z				

Fluid kinematics at all member ends may be written to the Loads Interface File. See the OPT5 parameter in the OPTI command.

3.5.17 Calculation of Loads According to API

Wave load calculation according to Ref. [1] may be specified by using the API command. The user will then be able to control and adjust the calculation by the optional SEAOPT command and, if desired, the CONDCT command may be used to account for shielding effects.

	1	2	3	4	5	6	7	8
API		DOPP	WAKE	ALPH	CURW			

	1	2	3	4	5	6	7	8	9	10	11	12
SEAOPT		ISEA	BETA	WKFAC	CTNO	CBFAC	CSTR	LOAD	DLOAD	WID	WIMET	IDPT

	1	2	3	4	5	6	7	8	9
CONDCT					STYPE	INDEX		DX	DY
		N1	NN	STEP					
		SETNAM							

3.5.18 Wind Loads

Data for wind load calculations is specified by the command WIND (or alternatively by WINX command, which allows higher precision input for the mean period ratio) and SEAOPT which are mandatory. Optionally user may use commands CDWN, CDWR and CONS.

	1	2	3	4	5	6	7	8
WIND	WID	VEL	ANGLE	GUSTF	H0	HEXP	PRAT	IFORM

	1	2	3	4	5	6	7	8
WINX	WID	VEL	ANGLE	GUSTF	H0	HEXP	PRAT	IFORM

	1	2	3	4	5	6	7	8	9	10	11	12
SEAOPT		ISEA	BETA	WKFAC	CTNO	CBFAC	CSTR	LOAD	DLOAD	WID	WIMET	IDPT

	1	2	3	4	5	6	7	8	9
CDWN					STYPE	INDEX	CDX		CDZ
		N1	NN	STEP					
		SETNAM							

	1	2	3	4	5	6	7	8
CDWR	RN1	CDX1		CDZ1	RN2	CDX2		CDZ2

	1	2	3	4	5	6	7	8
CONS		UNITS	GRAVITY	RO	VISC	ROAIR	VISCAIR	

Information about the wind-field such as the wind angle is given by the WIND/WINX command. An arbitrary number of WIND/WINX commands may be given. A minimum of one WIND/WINX command must be given if wind loads are to be evaluated. By default, the air drag coefficients are assumed to be a known function of the Reynolds number, see Section 2.4.9. Optionally, the drag coefficients may be specified as a function of the Reynolds number by the CDWR command or for specified members by CDWN. Information given on CDWN will supersede specifications by CDWR. The Reynolds number is evaluated from Eq. (2.44).

Default values are used for the air density and viscosity coefficients unless they are specified by the CONS command. The default values used are given in the documentation of the CONS command in Section 5.5.

Wind loads are calculated when the deterministic load calculation command SEA is used. This is done by connecting each SEA command with one of the WIND/WINX commands specified (similarly to CRNT). To do this one has to use var.2 of SEA. The reference to the WIND/WINX command is then given on SEAOPT command by the WID parameter. The user may choose between four different wind profile formulae by the parameter IFORM=0,1,2,3. By default, WIMET=0, wind loads are calculated from Equation (2.42) for the part of the jacket above the instantaneous water level and the loads are added to the wave loads for each seastate. By specifying WIMET=1, the wind loads calculated are prepared for gust wind induced fatigue in Framework. In the load calculation and evaluation of the Reynolds number the equivalent diameter D may be redefined by SPEC/SPEX. Additionally whenever specified, marine growth thickness is added to the diameter. If only wind loads are required calm sea condition must be specified on the SEA command and buoyancy loads must be excluded by SEAOPT.

A specification of the WIND and SEA/SEAOPT command in a wind load calculation may be as follows:

```
C   56789 123456789 123456789 123456789 123456789 123456789 123456789 123456789
C
C      WID       VEL       ANGLE      GUSTF        HO      HEXP PRAT IFRM
WIND    1.       10.0       30.0        1.0      10.0      0.11
C
C    Wind loads only
C       OPT ISEA THEO      WHGT     PERIOD     PHIO        TO      STEP    NSTEP
SEA           1.  9.0                                                      1.
C           ISEA BETA WKFC CTNO CBFC CSTR LOAD DLOA  WID WIMT IDPT
SEAOPT        1.                       -1.   1.        1.
C
C    Wind and wave loads
C       OPT ISEA THEO      WHGT     PERIOD     PHIO        TO      STEP    NSTEP
SEA           2.  5.0       5.0       12.0      0.0       0.0       2.0       7.
C           ISEA BETA WKFC CTNO CBFC CSTR LOAD DLOA  WID WIMT IDPT
SEAOPT        2. 45.0                  -1.             1.
```

3.6 Special Options for Comparison

Several options are included in the OPTI command to force the current version of Wajac to perform as earlier versions. See the description of the OPTI command in Section 5.5.

4 EXECUTION OF WAJAC

4.1 Program Environment

4.1.1 Starting Wajac

To run Wajac an input file containing the Analysis Control Data must be prepared. The program is run in batch mode either from Sesam Manager, GeniE or from the command line. When running Wave load analysis from GeniE, Analysis Control Data file for Wajac is generated by GeniE based on user input.

To complete the input file for the actual simulation see Section 3 for user guidance and Section 5 for a complete command reference.

There are several other files associated with a Wajac run. In addition to the Analysis Control Data File (WAJAC.INP file) the Input Interface Files (T-files) are required. Output files consist of Loads Interface Files (L-files), an additional Analysis Control Data File for Sestra (S-file), Hydrodynamic Results Interface File (G-file), Simulation Results Files (SER-files), Print File (WAJAC.LIS file) and Transfer Function Summary File (TRF.out file).

There are also working files containing the internal database which is temporary and normally invisible for the user. The files are described in more detail in the following sections. When using the Sesam Manager or GeniE the files are taken care of in the sense that they are automatically named, read and written.

If Sesam Manager or GeniE is not used Wajac may be started from command line. On Windows by (replace *italics* text by appropriate data):

```
cd drive:\project-directory
drive:\wajac-installation-directory\wajac
```

Please refer to section 4.1.4 for list of command line arguments accepted by Wajac. The input file containing Analysis Control Data must be prepared in advance and its name must be WAJAC.INP. The input files must reside on the project-directory. The Wajac Print File will appear as WAJAC.LIS.

4.1.2 File Overview

An overview of files is given in Figure 4.1 and Table 4.1 below. Detailed description of both, input and output files can be found further in this section.

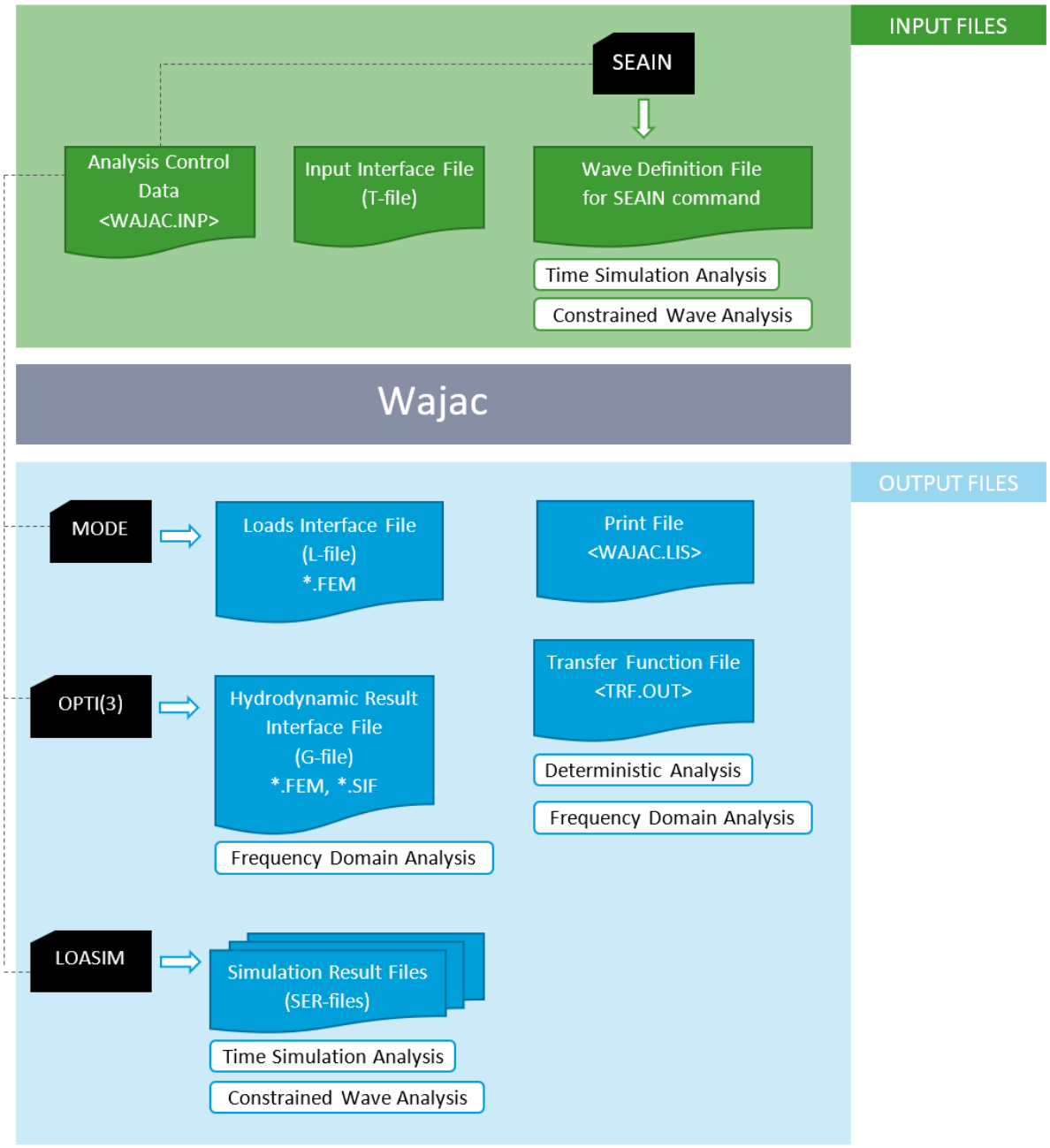


Figure 4.1: Input and output files

Table 4.1: Files associated with a Wajac run

Input / Output	Application	Mandatory / Optional	Default name	Command for giving prefix/name
Input	Analysis Control Data	Mandatory	-[a]	-
Input	Input Interface Files	Mandatory	Tn.FEM[b]	FMOD
Input	Definition of wave surface	Mandatory	USER-SPECIFIED	SEAIN
Output	Loads Interface Files	Optional	Ln.FEM[c]	FWAVE/FMOD
Output	Additional Analysis Control Data	Optional	Sn.FEM	FWAVE/FMOD
Output	Hydrodynamic Results Interface File	Optional	G1.FEM or G1.SIF	FWAVE/FMOD
Output	Print File	Mandatory	-[a]	-
Output	Simulation Result Files	Optional	Sxxxx.SER[d]	-
Output	Transfer Function Summary File	Mandatory[e]	TRF.out	-

a. See Section 4.1.1.
b. n is superelement number.
c. For OPT15>0 more than one Loads Interface File will be generated.
d. xxxx is a four digit number starting at 1030, see description on LOASIM card
e. will not be generated for Seastaete Simulation and Constrained Wave analysis

The Input and Loads Interface Files may be formatted or unformatted. Formatted files are computer independent and may be used for transfer between different computers. Formatted files may be printed and edited. An unformatted file is more compact, occupying about a third of the disk space compared to a formatted file. Unformatted files are computer dependent.

Syntax of Prefix and File Names A prefix can be defined for most files. The prefix is a part of the file name and may include a disk and directory specification. The syntax of the prefix as given in the FMOD and FWAVE commands depends on the operating system. Table 4.2 shows the syntax of the prefix for the Windows operating systems. The table also shows the appearance of file names exemplified by an Input Interface File.

Table 4.2: Prefix for various operating systems

Operating system	Syntax	Example of prefix and resulting Input Interface File for superelement no.12
Windows	`drive:\directory\subdirectory\name` `..\subdirectory\name`	`D:\Alpha\Analyses\Modela` `D:\Alpha\Analyses\ModelaT12.FEM`

4.1.3 Input Files

Analysis Control Data

Control data for the computations in Wajac such as like type of analysis, hydrodynamic coefficients, environmental data etc., called Analysis Control Data, are given directly to Wajac. Analysis Control Data controlling the Wajac analysis is given in the Wajac input file. It must be prepared before the run is started. When Wajac is started from GeniE a template for the input file may be generated by GeniE for deterministic analysis. This template can be edited for the case at hand. Input commands are described in Chapter 5. As already stated in previous section user should remember that the input file containing Analysis Control Data must be prepared in advance and its name must be WAJAC.INP. The input files must reside on the project-directory.

Input Interface Files

The Input Interface Files contain geometrical and structural information for the structure to be analysed, i.e. nodal coordinates, element definitions, cross section definitions and other information related to a structural analysis, e.g. hydrodynamic coefficients, among others. Normally, the user need not be concerned with the contents of the file. The Input Interface Files are formatted files.

One Input Interface File will exist for each superelement type. The files must follow a naming convention in order to be found by Wajac. Names vary slightly for different computer but are in general composed of a <prefix>, the letter T followed by the superelement type number, and the file extension FEM.

The full name will be

<prefix>Tn.FEM

where the <prefix> may contain device, disk and a user defined name, and n is the superelement type number.

See Section 4.1.2 for the syntax of the prefix as well as the appearance of file names under other operating systems.

Two input commands are required for Wajac to find the Input Interface Files:

FMOD	is used for the <prefix>, see Section 5.5. If not given, Wajac will search for the file Tn.FEM at the default directory.
MODE	is used to define the superelement type number of the top level superelement.

4.1.4 Input Arguments

This section describes command line arguments that can be passed to Wajac.exe process. The line below explains the use of `Wajac.exe` with command line arguments. Note that currently Wajac offers only one command line argument.

```
Wajac.exe [/arg[=val] ...]
```

Where `[arg[=val] ...]` is a space-separated list of arguments with optional value selection. Please note the mandatory slash before the argument name. To assign value to the argument = character is used.

Additional information may be found in the description column of Table 4.3 below.

Table 4.3: Command line arguments for process of Wajac.exe

Argument name	*Description*

`LICENSE-WAIT`	This option is only relevant to network license with limited simultaneous users. See description of available options for detailed behavior.
	Available options: `{ON, OFF}`.
	With `/LICENSE-WAIT=OFF` second instance of the process will terminate immediately without actually performing any analysis.
	With `/LICENSE-WAIT=ON`, a second instance of the process will wait for the previous one to terminate.
	
	Examples:
	`Wajac.exe /LICENSE-WAIT=ON`
	`Wajac.exe /LICENSE-WAIT=OFF`

4.1.5 Output Files

Print File

This file will always be named WAJAC.LIS and contrary to other output files will always be generated. The main purpose of this file is to record user input and its interpretation and output summary of the results. In addition the Print File will also contain following type of information:

- echo and interpretation of the Analysis Control Data,
- messages identifying the individual files of the Input Interface File that have been read,
- warning messages,
- error messages from the check of input data in case errors are found,
- a table of calculated wave characteristics for deterministic load calculations,
- a list of superelements on which loads are calculated,
- individual member loads as requested by the user,
- a table summarising the total loads on the structure,
- total added mass written to the Loads Interface File,
- maximum base shear and overturning moment,
- minimum base shear and overturning moment (if requested, i.e. DLOAD = 4, 5, or 6, see SEAOPT command),
- summary of data transferred to the S-file, i.e. file containing analysis control data for Sestra.

Loads Interface Files

Loads from Wajac may be stored on Loads Interface Files, also called L-files here. see Section 2.6.3. Loads Interface Files are generated for the first level superelements only and are in fact subsets of the Input Interface Files. The Loads Interface Files also have the same name convention as the Input Interface Files, only the T is replaced by an L, there is one exception though related to OPT15 . The full name will be

<prefix><L>n.FEM

Where <prefix> is an optional string which equals to the one specified on FMOD command, unless new prefix is provided on FWAVE command. <L> corresponds to string which for OPT15=0 evaluates to letter *L*. For OPT15=1 two Loads Interface Files are generated and <L> equals to *BL* and *WL* for both files respectively. For OPT15=2 three files are generated and <L> equals to *BS*, *WS* and *GS* for all three files respectively. The Loads Interface Files are by default unformatted. The FWAVE command may be used to specify the files to be formatted.

Analysis Control Data for Sestra

In certain cases additional Analysis Control Data for Sestra file (S-file) can be generated. This file is identified by full name of the following form:

<prefix><S>n.FEM

The same rules apply for S-file regarding naming as for L-files. This also includes dependency on OPT15:

- OPT15=0 : one S-file will be produced, <S> evaluates to character *S*,
- OPT15=1 : two S-files will be produced and <S> equals to *BS* and *WS* for both files respectively.
- OPT15=2 : three S-files will be produced and <S> equals to *BS*, *WS* and *GS* for all three files respectively.

This file is formatted and contains ordinary Analysis Control Data for Sestra described in the Sestra user manual.

Note: In Wajac the prefix for the S-file will be the same as the one for the L-files (controlled by FWAVE) whereas in Sestra the prefix for the S-file must be the same as the one used for the T- files. This means that if the prefix given on the FMOD and FWAVE commands differ then the S-file must be renamed after running Wajac and prior to running Sestra.

Depending on the type of structural analysis to do the file is required or it should be deleted prior to the Sestra analysis. See the Sestra user manual for more information on the S-file. (The S-file is not shown in Figure 4.1.)

Hydrodynamic Results Interface File

A Hydrodynamic Results Interface File (G-file) may be generated during calculation of transfer functions and will contain global results such as base shear and overturning moment. This is controlled through third parameter of OPTI command. The Hydrodynamic Results Interface File is a formatted file and the file name is composed of a <prefix>, the letter G followed by a dataset number (the dataset number is currently fixed to 1) and the file extension FEM (old format) or SIF. For a description of the SIF extension file, see the Sesam Interface File description.

The full name will be

- <prefix>G1.FEM or <prefix>G1.SIF

The <prefix> is the same as for the Loads Interface Files.

Simulation Result Files

In addition to results printed in Print File and Loads Interface Files, results from a seastate simulation analysis may be written to Simulation Result Files. These files are formatted files and contain time series of selected quantities. No prefix may be assigned to these files. The file names and kind of data stored in the files are described in the notes to the LOASIM command, see description for LOACON and MEMCON parameters. Additional notes can also be found in Section 5.5. The use of these files is described in Ref. [3].

Transfer Function Summary File

For deterministic and frequency domain analysis Wajac will output TRF.out file which will contain transfer function amplitude of base shear force and over turning moment. For deterministic analysis no values will be printed for calm sea analysis.

4.2 Program Requirements

Execution time and storage space are dependent on the type of analysis, the model and the computer. A simple formula for estimating the execution time cannot be given. Compared with other analysis modules in the Sesam suite Wajac is neither a time nor a space consuming program.

One exception is the simulation of wave loads in a given seastate. In this case both short time steps and small grid spacing may lead to a relatively high execution time and a need for large storage space.

4.3 Program Limitations

Size dependent limitations are listed here. The actual limiting values may vary between different installations. The Status List describes limitations of different installations. A list of the limitations of a specific installations is also printed on the second page of the Wajac Print File. See also Section 2.7 for limitations in features.

The values specified in the limitation list below apply to the standard installations:

Geometry:	Maximum number of elements in one first level superelement	600000
	Maximum number of nodes in one first level superelement	600000
	Maximum number of first level superelement types	100
	Maximum number of hierarchy levels	50
Loads:	Deterministic load calculation:	
	Maximum number of global load cases (total number of time steps)	200000
	Maximum number of specified seastates (wave frequency, height and theory)	3000
	Frequency domain:	
	Maximum number of wave frequencies	196
	Maximum number of wave directions	16
	Simulation of wave loads in a given seastate:	
	Maximum number of seastates	1
	Maximum number of time steps (3D grid) in the generated loads	8192
	Maximum number of time steps (direct) in the generated loads	212644

In addition there is a limit on the number of times a command (of the Analysis Control Data) may be repeated. These restrictions are listed under the detailed description of each command in Section 5.5.

4.4 Warnings and Error Messages

Warnings and error messages may occur on the Print File or on the job log file. An error will immediately halt the execution. Warnings are considered less serious and execution will continue but they may cause error termination at a later stage in the execution. Some of the warning messages may be switched off using OPT13 parameter, i.e. 13th parameter of OPTI command.

Warnings and error messages on the Print File

Problems and errors discovered during check of input data are reported on the Print File.

The input data check includes:

- check of Analysis Control Data,
- check of Input Interface Files.

The checking of the Input Interface Files is, however, not very thorough as it is considered to be a task for the programs that generated them (i.e. the preprocessors) to check their contents.

- Check of model data which cannot easily be checked by preprocessor programs.

Execution errors due to malfunction of a routine gives a short message and a traceback of all routines called.

Messages on the job log file

Computer dependent system error messages may occur on the job log file if such exist. Examples are expiration of the CPU time limit, file protection problems and exceeding of the disk quota.

4.4.1 Error codes

For some cases resulting in error scenario, Wajac.exe process will return an error code. This code can then be caught, e.g. by system console. Table 4.4 lists currently available error codes.

Table 4.4: Error codes returned by process Wajac.exe

Code Id	*Description*
5	Wajac Control Data file (Wajac.inp) could not be found
20	Unable to create file because absolute file path is too long
21	Error during read of file
30	Error during call to Sesam Classic Library method
100	Error during memory allocation

5 WAJAC ANALYSIS CONTROL DATA

The analysis to be performed by Wajac is specified by the Analysis Control Data. The Analysis Control Data consists of a set of commands described in the following sections.

5.1 Alphabetic List of Analysis Control Data

Command	Dataset	Description
AMP	LOAD	Wave Heights for Linearisation
API	HYDR	Load Calculation According to API RP2-WSD, 20th ed.
BUOA	HYDR	Overriding non-flooded and/or flooded buoyancy area
CDFN	HYDR	Hydrodynamic Coefficients as Function of Member Diameter for fouled and non-fouled members
CDIA	HYDR	Hydrodynamic Coefficients as Function of Member Diameter
CDIR/CDIX	HYDR	Directional Hydrodynamic Coefficients
CDRG	HYDR	Drag Coefficients as Function of Roughness and Rn or KC Number
CDWN	HYDR	Air Drag Coefficients for Specified Members
CDWR	HYDR	Air Drag Coefficients as a Function of Reynolds Number
CGWD	HYDR	Global Wave Direction and/or Seastate dependent Hydrodynamic Coefficients
CHCK	WAJAC	Data Check Option
CMAS	HYDR	Inertia Coefficients as Function of Roughness and Rn or KC Number
COEF	HYDR	Hydrodynamic Coefficients as Function of Vertical Position
CONDCT	GEOM	Shielding Effects for Conductor Arrays
CONS	WAJAC	Units and Constants Definition
CPRI	HYDR	Change Priority of Specified Hydrodynamic Coefficients
CRNT	LOAD	Definition of Current Profiles
DENS	LOAD	Energy Density Values in a NEWWAVE Wave Spectrum
DPTH	LOAD	Water Depth
ELIM	GEOM	Members Elimination
END		Last Command in Input Stream
EQVL	WAJAC	Command and Format Redefinition
ERG	LOAD	Fraction of Energy for Wave Directions
FCOMP	WAJAC	Prefix for file in which wave components will be stored (time simulation)
FLOO	GEOM	Definition of Flooded Members
FMOD	WAJAC	Prefix for Input Interface File
FRQ	LOAD	Wave Periods for Calculation of Transfer Functions
FWAVE	WAJAC	Prefix for Loads Interface Files
GEOM	GEOM	Dataset Identification: Geometry Definition

Command	Dataset	Description
GRID	LOAD	Horizontal Extremity of Simulation Grid
HYDR	HYDR	Dataset Identification: Hydrodynamic Properties
KPRT	LOAD	Fluid Kinematics Printout
KSCA	HYDR	Wave Kinematics Adjustment Factor
LEG	GEOM	Soil Permeability Factors for Leg
LOAD	LOAD	Dataset Identification: Loading Conditions
LOASIM	LOAD	Time Simulation of Wave Loads in a Seastate
LONO	WAJAC	Loadcase Numbering
MASS	HYDR	Added Mass to the Loads Interface File
MEMGRW	HYDR	Member Specification of Marine Growth Data
MEMSEG	LOAD	Member Specification of Segmentation Coefficient
MFPR	HYDR	MacCamy-Fuchs parameter
MGRW	HYDR	Marine Growth and Roughness Definition
MODE	WAJAC	Model Identification and Loads Interface File Generation
MOMT	LOAD	Moment Reference Point Definition
MPRT	LOAD	Member Force Printout Specification
MSEG	LOAD	Member Segmentation Definition
MUDP	GEOM	Mudline Elevation
MWIA	WAJAC	Parameters for member-wave intersection in time simulation analysis
NEWWAVE	LOAD	NEWWAVE Theory Parameters
OMEG	LOAD	Frequency Values in a NEWWAVE Wave Spectrum
OPTI	WAJAC	Special Options
SEA	LOAD	Deterministic Load Calculation
SEAFRQ	LOAD	Calculation of Transfer Functions
SEAIN	LOAD	Input File for Time Simulation analysis
SEAOPT	LOAD	Additional Seastate Data for Deterministic Load Calculations
SEASIM	LOAD	Seastate Simulation Directives
SEGM	LOAD	Member Segmentation as Function of Vertical Position
SELI	GEOM	Superelement Type Elimination
SPEC/SPEX	HYDR	Definitions for Special Members
SPECTR	LOAD	Definition of Wave Energy Spectrum
TANK	LOAD	Cylindrical Tank in Vicinity of a Jacket Structure
TITL	WAJAC	Job Identification
TSKI	LOAD	Filtering parameters for time simulation analysis
WAJAC	WAJAC	Dataset Identification: Execution Directives
WAVC	LOAD	Definition of Constrained Wave
WIND	LOAD	Definition of Wind Profiles
WINX	LOAD	Definition of Wind Profiles for smaller mean period ratio

5.2 Detailed Format Description

The Analysis Control Data consists of commands given on records which are eighty characters long.

The first characters are used for the command type identifier or keyword. The identifier may be left blank when the record is a continuation of the previous command.

Several different record formats with different number of data fields are used.

Within each field numerical data must be written in either FORTRAN F-format or E-format, i.e. all values must be entered with punctuation mark. The numbers may be placed anywhere in the format fields except when

E-format is used. In such case the numeric values must be adjusted to the right in the format fields.

Records containing comments may be inserted anywhere within the Analysis Control Data. The comments are preceded with 'C' and three blanks.

Example of F-format: 123.45
Example of E-format: 12.345E+1

Trailing blanks in the format field will be interpreted as zero.

Note: Tabulation marks are not allowed.

Some examples of the formats are given below:

Field:		1		2		3		4	
Column:	4	5	10		20		30		40
CDRG		OPT		ROUGH		NU1		CDN1	

Field:	5		6		7		8	
Column:		50		60		70		80
NU2			CDN2		NU3		CDN3	

Field:		1		2		3		4	
Column:	4		10		20		30		40
MODE						ILFSAV		ISETOP	

Field:		5		6		7		8	
Column:		50		60		70		80	

Field:		1		2		3		4		5	
Column:	3	5	10		15		20		30		40
SEA		OPT		CTNO		HEIGHT		PERIOD		PHI0	

Field:		6		7		8		9	
Column:		50		60		70		80	
T0				STEP		NSTEP		BETA	

Field:		1		2		3		4		5		6	
Column:	4	5	10		15		20		25		30		40
SPEC		N1		NN		STEP		STYPE		INDEX		DIAM	

Field:		7		8		9		10	
Column:		50		60		70		80	
CDN				CDL		CML		CML	

Field:	
Column:	85
IGWD	

Field:		1	
Column:	4		80
TITL	TEXT		

5.3 Sequence of the Analysis Control Data

The input data are grouped in four data sets. Each data set is identified by a command containing one of the keywords listed below. The datasets are:

	Description	KEYWORD
1)	the execution directives	WAJAC
2)	the geometry definition	GEOM
3)	the hydrodynamic properties	HYDR
4)	the loading conditions	LOAD

The following rules applies for the sequence of the Analysis Control Data:

The data must start with the dataset containing the execution directives identified by the keyword WAJAC. The other datasets may be given in any sequence.

All commands within one dataset must be grouped together.

The keyword can be omitted if commands of the same type follow each other. Unless otherwise noted in the command description of Section 5.5, the sequence of commands within one dataset is arbitrary.

Command types which are irrelevant for a particular run will be disregarded.

The command END identifies the end of the Analysis Control Data.

5.4 Application Areas for the Analysis Control Data

Table 5.1 gives an overview of the commands which are relevant for different analyses in Wajac.

Table 5.1: Application Areas for the Analysis Control Data

Command type		Data check	Determ. analysis	Transfer f. waveh. lin.	Transfer f. equiv. lin.	Seastate simulation
dataset	id					
WAJAC	CHCK	*				
WAJAC	CONS		X	X	X	X
WAJAC	EQVL		X	X	X	X
WAJAC	FMOD		X	X	X	X
WAJAC	FWAVE		X	X	X	X
WAJAC	LONO		X	X	X	X
WAJAC	MODE		*	*	*	*
WAJAC	OPTI		X	X	X	X
WAJAC	TITL		X	X	X	X
WAJAC	WAJAC		X	X	X	X
GEOM	CONDCT		X	X	X	X
GEOM	ELIM		X	X	X	X
GEOM	FLOO		X	X	X	X
GEOM	GEOM		*	*	*	*
GEOM	LEG		X	X	X	X
GEOM	MUDP		X	X	X	X
GEOM	SELI		X	X	X	X
HYDR	BUOA		X	X	X	X
HYDR	CDFN		X	X	X	X

Command type		Data check	Determ. analysis	Transfer f. waveh. lin.	Transfer f. equiv. lin.	Seastate simulation
dataset	id					
HYDR	CDIA		X	X	X	X
HYDR	CDIR/CDIX		X	X	X	X
HYDR	CDRG		X	X		
HYDR	CDWN		X			
HYDR	CDWR		X			
HYDR	CGWD		X	X		
HYDR	CMAS		X			
HYDR	COEF		X	X	X	X
HYDR	CPRI		X	X	X	X
HYDR	HYDR		*	*	*	*
HYDR	KSCA		X			
HYDR	MASS		X	X	X	X
HYDR	MEMGRW		X	X	X	X
HYDR	MGRW		X	X	X	X
HYDR	SPEC/SPEX		X	X	X	X
LOAD	AMP			*		
LOAD	API		X			
LOAD	DENS		X			
LOAD	DPTH		*	*	*	*
LOAD	CRNT		X	X	X	X
LOAD	ERG					X
LOAD	FRQ			*	*	
LOAD	GRID					*
LOAD	KPRT		X			X
LOAD	LOAD		*	*	*	*
LOAD	LOASIM					*
LOAD	MEMSEG		X	X	X	X
LOAD	MOMT		X	X	X	X
LOAD	MPRT		X	X	X	X
LOAD	MSEG		X	X	X	X
LOAD	NEWWAVE		X			
LOAD	OMEG		X			
LOAD	SEA		*			
LOAD	SEAFRQ			*	*	
LOAD	SEAOPT		X			
LOAD	SEASIM					*
LOAD	SEGM		X	X	X	X
LOAD	SPECTR				*	*
LOAD	TANK		X			
LOAD	WIND		X			
LOAD	WINX		X			
	END		*	*	*	*

The following symbols are used in the table above:

*	is the mean wind velocity at reference height,
X	These commands may be used in connection with the analysis in question. Some are alternatives of which at least one must be specified in addition to the mandatory commands, for example the specification of hydrodynamic coefficients. For the datacheck only the necessary additional command is identified.
(X)	Only some of the options under the command is allowed in the specified type of analysis.

5.5 Description of the Analysis Control Data in Alphabetic Order

A detailed description of the input commands constituting the Analysis Control Data is given in alphabetic order on the following pages.

AMP — Dataset: LOAD

Wave Heights for Linearisation

Field:	1	2	3	4
Column: 3	10	20	30	40
AMP		H1	H2	...

Field:	5	6	7	8
Column:	50	60	70	80
				HN

PURPOSE:

To specify wave heights for calculation of transfer functions using linearisation with respect to wave height (see the SEAFRQ command).

PARAMETERS:

H1 Wave height for wave frequency no. 1.
H2 Wave height for wave frequency no. 2.
HN Wave height for wave frequency no. N.

NOTES:

See also the FRQ command.

RESTRICTIONS:

These commands must be preceded by the FRQ command.

The number of wave heights must correspond to the number of waves specified by the FRQ command.

API — Dataset: HYDR

Load Calculation According to API RP2-WSD, 20th ed.

Field:	1	2	3	4	5	6
Column: 3	10	15	20	25	30	80
API		DOPP	WAKE	ALPH	CURW	

PURPOSE:

To specify load calculation according to the procedure described in API RP2-WSD, 20th edition.

PARAMETERS:

DOPP		Switch for Doppler effect. Available only when individual Doppler effect flag on SEAOPT card is set to 0 or left blank. For more information please refer to the description of SEAOPT card.
	$= 0.0$ or blank	The Doppler effect will be accounted for by using apparent wave (API 2.3.1b1).
	$= -1.0$	The Doppler effect will be neglected. Actual wave periods will be used.
WAKE	$= 0.0$ or blank	The dependency of wake encounter (Keulegan-Carpenter number) will be applied to all members within 15 degrees of the vertical (API 2.3.1b7) as specified by API.
	$= 1.0$	The dependency of wake encounter (Keulegan-Carpenter number) will be applied to all members within 15 degrees of the orbital plane of the wave kinematics.
	$= -1.0$	The effect of wake encounter will not be included for any members.
ALPH	$= 0.0$ or blank	The dependency of wake encounter (Keulegan-Carpenter number) will be applied to all members within 15 degrees of the vertical or orbital plane of the wave kinematics depending on the WAKE parameter.
	> 0.0	The dependency of wake encounter (Keulegan-Carpenter number) will be applied to all members within ALPH degrees of the vertical or orbital plane of the wave kinematics depending on the WAKE parameter.
CURW	$= 0.0$ or blank	The effect of wake encounter will be adjusted for current (API C2.3.1b7).
	$= -1.0$	The effect of wake encounter will not be adjusted for current.

NOTES:

In addition to the API command, the load conditions must be specified through SEA (variant 2) and SEAOPT commands and the water depth on the DPTH command.

In the evaluation of the Keulegan-Carpenter number given by $\mathrm{KC} = 2U_m T_2/D$, where U_m is the maximum fluid velocity, T_2 the duration of a half-wave cycle and D the effective diameter, the value of T_2 is depending on whether the load calculation point is below the crest or the trough. The value of T_2 is proportional to the distance between the free surface points at the mean water level for the crest and the trough respectively.

RESTRICTIONS:

Only one API command may be given.

The command is only applicable for deterministic wave analysis.

BUOA — Dataset: HYDR

Overriding non-flooded and/or flooded buoyancy areas

Field:	1	2	3	4
Column:	4 10	20	30	40
BUOA				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8		
Column:	45	50	60	70		
STYPE		INDEX	ANFLOO	AFLOO		

PURPOSE:

To override non-flooded and/or flooded buoyancy area for any member

PARAMETERS:

N1		Selected member (element number) or first member in a sequence.
NN		Last member in a sequence. Leave blank if only one member is defined on this command.
STEP		Step in element numbers.
SETNAM		A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE		Superelement type number to which this command applies.
INDEX		Superelement index to which this command applies.
ANFLOO	$= -1.0$	The buoyancy area used for calculating non-flooded buoyancy is based on data from the Input Interface File.
	≥ 0	The buoyancy area to be used for calculating non-flooded buoyancy of the specified members.
AFLOO	$= -1.0$	The cross section steel area used for calculating flooded buoyancy is based on data from the Input Interface File.
	≥ 0.0	The cross section steel area to be used for calculating flooded buoyancy of the specified members.

NOTES:

Note that buoyancy areas defined by this command have no effect on calculation of the dry weight (weight excluding buoyancy) of structure and weight of marine growth reported in LIS file.

Program will give an error message if non-flooded buoyancy area is smaller than the flooded buoyancy area.

The cross section area used for calculating flooded buoyancy will be set as zero if users have selected to avoid including steel area through OPT7 option on OPTI command.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

The total number of BUOA command cannot exceed 20000.

CDFN — Dataset: HYDR

Hydrodynamic Coefficients as Functions of Member Diameter for fouled and non-fouled members

Field:	1	2	3	4	5
Column: 4	8	16	24	32	40
CDFN		DIA	CDN fouled	CDL fouled	CMN fouled

Field:	6	7	8	9	10
Column:	48	56	64	72	80
CML fouled		CDN non-fouled	CDL non-fouled	CMN non-fouled	CML non-fouled

PURPOSE:

To specify the normal and longitudinal components of drag and inertia coefficients as functions of the member diameter for both fouled and non-fouled members. An array of member diameters (including marine growth, if specified) with corresponding hydrodynamic coefficients are set up. The coefficients corresponding to the actual member diameter at the load calculation point in question is calculated by linear interpolation between the values specified by these commands, see Figure 5.1.

PARAMETERS

DIA	Member diameter including marine growth if specified.
CDN fouled	Normal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA, if fouled.
CDL fouled	Longitudinal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA, if fouled.
CMN fouled	Normal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA, if fouled.
CML fouled	Longitudinal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA, if fouled.
CDN non-fouled	Normal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA, if non-fouled.
CDL non-fouled	Longitudinal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA, if non-fouled.
CMN non-fouled	Normal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA, if non-fouled.
CML non-fouled	Longitudinal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA, if non-fouled.

NOTES:

The user should specify the entire range of diameters in the given structure. If a member diameter is outside the specified range the value closest to the diameter under consideration will be used.

If either marine growth thickness or marine growth roughness height is larger than zero, a member is considered as fouled and the drag/inertial coefficients for fouled members will be applied for corresponding diameter. Otherwise, the member is non-fouled and the drag/inertia coefficients for non-fouled members will be applied for corresponding diameter.

For fouled members, the diameter used for drag forces in Morison equation will be equal to the original beam outer diameter D plus twice of marine growth thickness.

For fouled members, the diameter used for inertial forces in Morison equation will be equal to the original beam outer diameter D plus twice of marine growth thickness only if the option of using marine growth for inertia forces has been selected. Check OPT input in MGRW card for more details.

RESTRICTIONS:

A maximum of 12 CDFN commands, that is 12 diameters, may be specified.

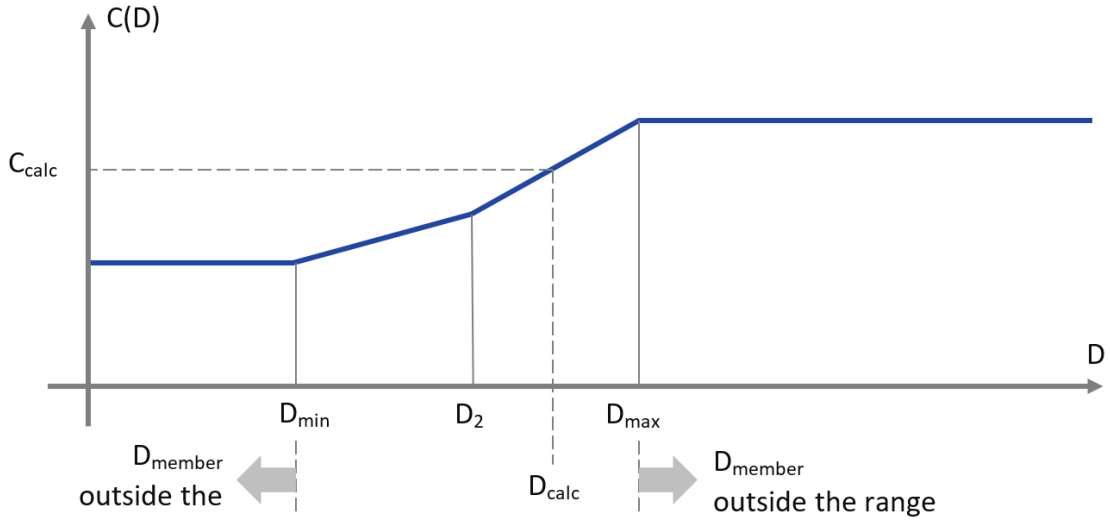


Figure 5.1: Hydrodynamic Coefficients as Function of Member Diameter

CDIA — Dataset: HYDR

Hydrodynamic Coefficients as Functions of Member Diameter

Field:	1	2	3	4
Column: 4	10	20	30	40
CDIA		DIA1	CDN1	CMN1

Field: 5	6	7	8
Column: 50	60	70	80
DIA2	CDN2	CMN2	

PURPOSE:

To specify the normal components of drag and inertia coefficients as functions of the member diameter. An array of member diameters (including marine growth, if specified) with corresponding hydrodynamic coefficients are set up. The coefficients corresponding to the actual member diameter at the load calculation point in question is calculated by linear interpolation between the values specified by these commands, see Figure 5.1.

PARAMETERS:

DIA1 Member diameter including specified marine growth.

CDN1 Normal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA1

CMN1 Normal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA1

DIA2 Member diameter including specified marine growth.

CDN2 Normal component of hydrodynamic drag coefficient at load calculation points with member diameters = DIA2

CMN2 Normal component of hydrodynamic inertia coefficient at load calculation points with member diameters = DIA2

NOTES:

The user should specify the entire range of diameters in the given structure. If a member diameter is outside the specified range the value closest to the diameter under consideration will be used.

RESTRICTIONS:

A maximum of 6 CDIA commands, that is 12 diameters, may be specified.

CDIR — Dataset: HYDR

Directional Hydrodynamic Coefficients

Field:		1	2	3	4	5	6	7
Column:	4 5	10	15	20	25	30	35	40
CDIR					STYPE	INDEX	CD1	CD2
	var.1	N1	NN	STEP				
	var.2	SETNAM						

Field:	8	9	10	11	12
Column:	45	50	55	60	80
	CD3	CM1	CM2	CM3	

PURPOSE:

To specify hydrodynamic drag and inertia coefficients with different components in the local member coordinate system, see Figure 5.2. This is necessary if the effect of non-circular cross sections is to be accounted for.

PARAMETERS:

N1	First member (external element number) for which the coefficients in this command apply.	
NN	Last member for which the coefficients apply.	
STEP	Step in element numbers	
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).	
STYPE	Superelement type number to which the data applies	
INDEX	Actual superelement index of superelement type STYPE to which the data applies	
CD1	≥ 0	Drag coefficient along local x-axis (transverse)
	$= -1$	Retain value specified by another command type.
CD2	≥ 0	Drag coefficient along local y-axis (longitudinal)
	$= -1$	Retain value specified by another command type.
CD3	≥ 0	Drag coefficient along local z-axis (transverse)
	$= -1$	Retain value specified by another command type.
CM1	≥ 0	Inertia coefficient along local x-axis (transverse)
	$= -1$	Retain value specified by another command type.
CM2	≥ 0	Inertia coefficient along local y-axis (longitudinal)
	$= -1$	Retain value specified by another command type.
CM3	≥ 0	Inertia coefficient along local z-axis (transverse)
	$= -1$	Retain value specified by another command type.

NOTES: As opposed to the definition in the SESAM preprocessors, the local cartesian coordinate system in Wajac is defined by letting the local y-axis be along the member in the direction from node no. 1 to node no. 2 (depending on the order of definition in the preprocessor). The relation between the local coordinate system in Wajac and the local coordinate system in the SESAM preprocessors is then:

Wajac	Preprocessor
x	$-y$
y	x
z	z

See also Section 2.2.7 for a more detailed description of the local coordinate system.

All coefficients specified by this command will supersede values defined by any other command unless the value -1.0 is specified.

Note that the longitudinal coefficients CD2 and CM2 will only be used when calculating total structural loads, i.e. no longitudinal force components will be written on the Loads Interface Files.

The members may either be referred to by the element numbers (var. 1) or through named a set of members defined on the Input Interface File (var. 2).

If the referred element numbers have more than 5 digits the CDIX command must be used instead of CDIR.

RESTRICTIONS:

A maximum of 20000 CDIR commands may be specified.

The total number of CDIR and CDIX commands cannot exceed 20000.

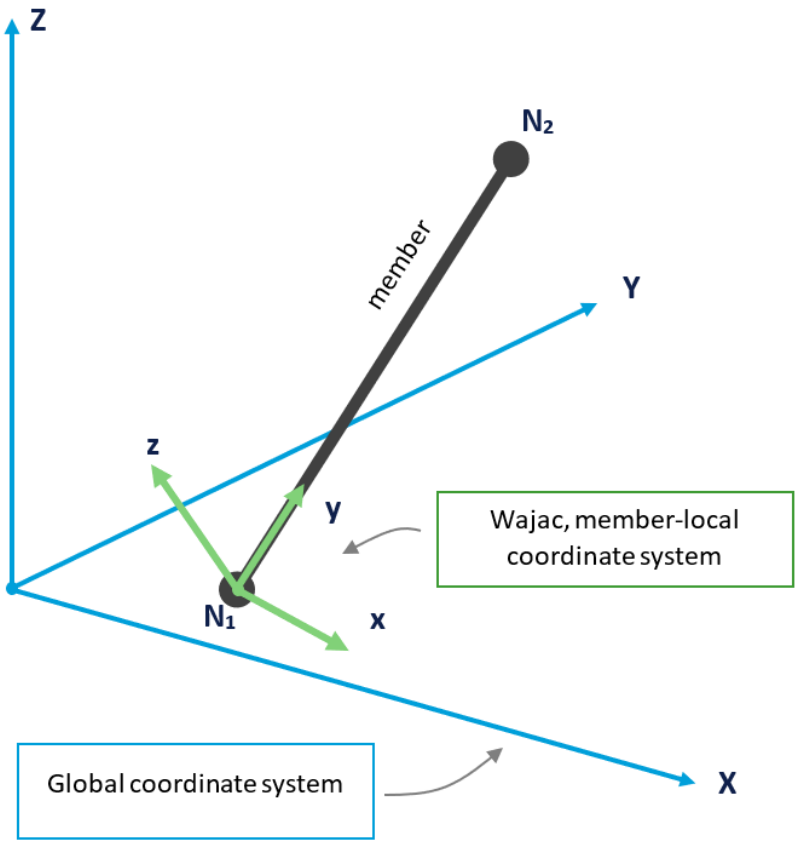


Figure 5.2: Local coordinate system

CDIX — Dataset: HYDR

CDIR Command for up to 10 Digit Element Numbers

Field:	1	2	3	4
Column:	4 10	20	30	40
CDIX				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8	9	10	11	12
Column:	45	50	55	60	65	70	75	80
STYPE	INDEX	CD1	CD2	CD3	CM1	CM2	CM3	

PURPOSE:

Replace the CDIR command for element numbers with more than 5 digits.

PARAMETERS:

The parameters are the same as for the CDIR command.

RESTRICTIONS:

The total number of CDIR and CDIX commands cannot exceed 20000.

CDRG — Dataset: HYDR

Drag Coefficients as Functions of Roughness and Rn or KC Number

Field:		1	2	3	4
Column: 4	5	10	20	30	40
CDRG		OPT	ROUGH	NU1	CDN1

Field: 5	6	7	8
Column: 50	60	70	80
NU2	CDN2	NU3	CDN3

PURPOSE:

To specify the transverse global drag coefficients as functions of the roughness number and either the Reynolds number (Rn) or the Keulegan-Carpenter number (KC) at the individual load calculation points. See Section 2.2.7 for the definition of the Rn and KC numbers. The coefficients corresponding to the actual load calculation point in question is calculated by linear interpolation between the values specified by these commands, see Figure 5.3.

PARAMETERS:

OPT	Member diameter including specified marine growth.
	$= 1.0$ Reynolds number functional dependency
	$= 2.0$ Keulegan-Carpenter number functional dependency
ROUGH	Roughness number defined by roughness height, as defined by the MGRW command, divided by the member diameter (including marine growth).
NU1	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CDN1	Transverse drag coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU1 and roughness number ROUGH.
NU2	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CDN2	Transverse drag coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU2 and roughness number ROUGH.
NU3	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CDN3	Transverse drag coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU3 and roughness number ROUGH.

NOTES:

The OPT and the ROUGH parameters need not be repeated on consecutive commands.

Records with data for equal roughness numbers (ROUGH) must be in sequence.

This command is not applicable for seastate simulations, nor for calculation of transfer functions using equivalent linearisation, and the command is allowed to be used together with the API command. See Section 2.2.7. If this command is used together with API including doppler effect, it should be noted that Reynolds- and/or Keulegan-Carpenter numbers defined in Equation (2.9) and Equation (2.10) are calculated by use of apparent wave period. It should also be noted that coefficients calculated by CDRG will by default override coefficients calculated by API for all members.

The user should specify the entire range of Reynolds- and/or Keulegan-Carpenter numbers that will apply to the analysis. If the value at a load calculation point is outside the specified range the coefficient specified for the closest number will be used.

NU_i or CDN_i being either blank or 0.0 is understood as the particular point $_i$ has NOT been defined. A zero value must therefore be specified as a small value, i.e. 1.0E-10.

See the CMAS command for specification of inertia coefficients.

RESTRICTIONS:

A maximum of 9 different coefficients may be specified for each roughness number.

A maximum of 5 roughness numbers may be specified.

A maximum of 15 CDRG commands may be given.

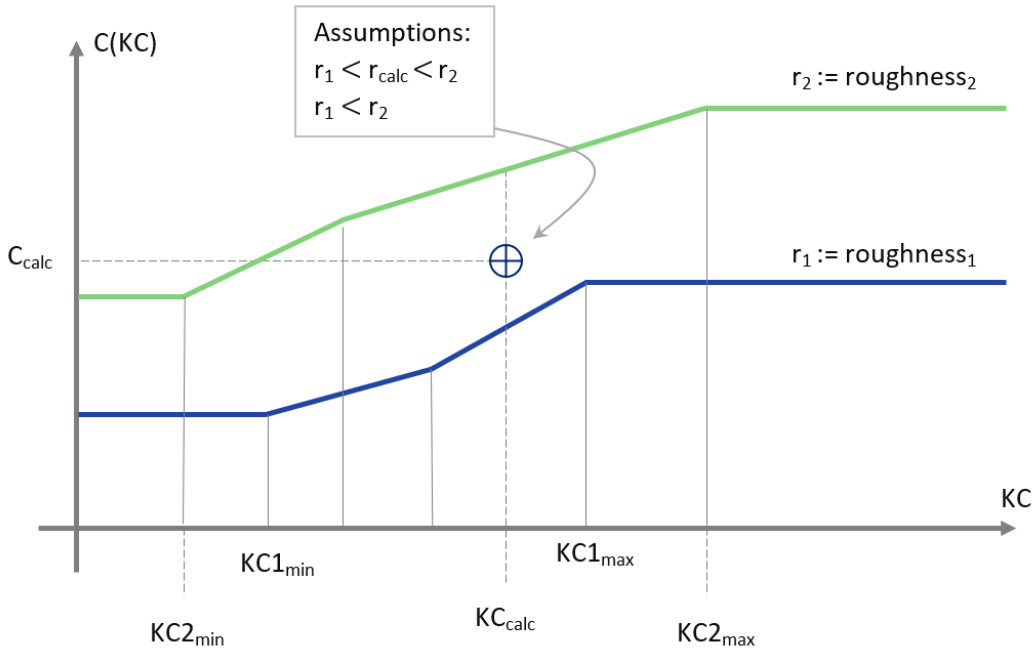


Figure 5.3: Hydrodynamic Coefficients as Function of Rn or KC

CDWN — Dataset: HYDR

Air Drag Coefficients for Specified Members

Field:	1	2	3	4
Column:	4 10	20	30	40
CDWN				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8	9	10
Column:	45	50	55	60	65	80
STYPE	INDEX	CDX	VOID	CDZ		

PURPOSE:

To specify air drag coefficients for specified members in the local coordinate system.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.	
NN	Last member in a sequence. Leave blank if only one member is defined by this command.	
STEP	Step in element numbers.	
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).	
STYPE	Superelement type number to which this command applies.	
INDEX	Superelement index to which this command applies.	
CDX	≥ 0.0	Drag coefficient along local x-axis.
	$= -1.0$	Retain default value or specification by CDWR
CDZ	≥ 0.0	Drag coefficient along local z-axis.
	$= -1.0$	Retain default value or specification by CDWR

NOTES:

Values specified by this command will supersede values defined by CDWR unless the value -1 is specified.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

A maximum of 20000 CDWN commands may be specified.

If WIMET=1.0 on the SEAOPT command then CDX must be equal to CDZ.

CDWR — Dataset: HYDR

Air Drag Coefficients as Functions of Reynolds Number

Field:	1	2	3	4	5	6
Column: 4	10	20	25	30	35	45
CDWR		RN1	CDX1	VOID	CDZ1	RN2

Field:	7	8	9	10
Column:	50	55	60	80
CDX2		VOID	CDZ2	

PURPOSE:

To specify air drag coefficients as functions of the Reynolds number in the local element coordinate system. The coefficients at the actual load calculating points are obtained by linear interpolation between coefficients specified by this command.

PARAMETERS:

RN1	Reynolds number.
CDX1	Drag coefficient along local x-axis (transverse).
CDZ1	Drag coefficient along local z-axis (transverse).
RN2	Reynolds number.
CDX2	Drag coefficient along local x-axis (transverse).
CDZ2	Drag coefficient along local z-axis (transverse).

NOTES:

The user should specify the entire range of Reynolds numbers that will apply to the analysis. If the value at a load calculation point is outside the specified range the coefficient specified for the closest number will be used.

RESTRICTIONS:

A maximum of 20 CDWR commands may be specified.

If WIMET=1.0 on the SEAOPT command then CDX* must be equal to CDZ*.

CGWD — Dataset: HYDR

Global Wave Direction/Seastate dependent Hydrodynamic Coefficients

Field:		1	2	3	4	5	6	7
Column: 4	5	10	15	20	25	30	35	40
CGWD		IGWD	CD1	CD2	CD3	CM1	CM2	CM3

Field:	8	9
Column:	50	55
DIR		ISEA

PURPOSE:

To specify global wave direction or seastate dependent hydrodynamic drag and inertia coefficients with different components in the local member coordinate system. This command is only relevant for deterministic analyses and can be referred to in SPEC/SPEX command.

PARAMETERS:

IGWD	The index number for command referring to additional data specified in SPEC/SPEX command.
CD1	Drag coefficient along local x-axis (transverse).
CD2	Drag coefficient along local y-axis (longitudinal).
CD3	Drag coefficient along local z-axis (transverse).
CM1	Inertia coefficient along local x-axis (transverse).
CM2	Inertia coefficient along local y-axis (longitudinal).
CM3	Inertia coefficient along local z-axis (transverse).
DIR	Global wave direction defined in existing seastates, see command SEAOPT. In degrees. An empty (blank) DIR will be treated as zero.
ISEA	Seastate index defined in existing seastates, see ISEA in command SEA and SEAOPT.

NOTES:

As opposed to the definition in the Sesam preprocessors, the local cartesian coordinate system in Wajac is defined by letting the local y-axis be along the member in the direction from node no. 1 to node no. 2 (depending on the order of definition in the preprocessor). The relation between the local coordinate system in Wajac and the local coordinate system in the Sesam preprocessors is then:

Wajac	Preprocessor
x	$-y$
y	x
z	z

See also Section 2.2.7 for a more detailed description of the local coordinate system.

During calculation, Wajac will use CD/CM values for the corresponding wave directions defined through DIR or seastate index ISEA. If both DIR and ISEA have been given at the same line, the direction defined in DIR has to be the same as the direction defined in seastate ISEA. DIR value can be specified without ISEA parameter. For this situation, we will use CD/CM values for all ISEA with the same directions as defined in DIR.

The IGWD index should be unique for each command. If no IGWD has been specified, program will understand it as a continuation of the previous command. Repeated IGWD indices are not allowed. Repeated ISEA number is not allowed within the same command. Values of DIR can be repeated within the same command only if a

different seastate index ISEA is specified at the same time. If ISEA specified in a command does not relate to any existing seastate, the program will report an error.

RESTRICTIONS:

A maximum of 20000 commands may be specified.

A maximum direction number for each card is 36.

CHCK — Dataset: WAJAC

Data Check Option

Field:		1	
Column:	4		80
CHCK			

PURPOSE:

To specify a datacheck of all input data including input model and Analysis Control Data. Wajac will give a list of the Analysis Control Data and print a summary of the run specifications. No calculations will take place. This command must be removed to perform a full analysis.

CMAS — Dataset: HYDR

Inertia Coefficients as Functions of Roughness and Rn or KC Number

Field:		1	2	3	4
Column: 4	5	10	20	30	40
CMAS		OPT	ROUGH	NU1	CMN1

Field:	5	6	7	8
Column:	50	60	70	80
NU2		CMN2	NU3	CMN3

PURPOSE:

To specify the transverse inertia coefficients as functions of the roughness number and either the Reynolds number (Rn) or the Keulegan-Carpenter number (KC) at the individual load calculation points. See Section 2.2.7 for the definition of the Rn and KC numbers. The coefficients corresponding to the actual load calculation point in question is calculated by linear interpolation between the values specified by these commands, see Section 5.3.

PARAMETERS:

OPT	Member diameter including specified marine growth. $= 1.0$ Reynolds number functional dependency $= 2.0$ Keulegan-Carpenter number functional dependency
ROUGH	Roughness number defined by roughness height, as defined by the MGRW command, divided by the member diameter (including marine growth).
NU1	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CMN1	Transverse inertia coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU1 and roughness number ROUGH.
NU2	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CMN2	Transverse inertia coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU2 and roughness number ROUGH.
NU3	Reynolds- or Keulegan-Carpenter number, depending on the OPT parameter.
CMN3	Transverse inertia coefficients to be applied at load calculation points with Reynolds- or Keulegan-Carpenter number NU3 and roughness number ROUGH.

NOTES:

The OPT and the ROUGH parameters need not be repeated on consecutive commands.

Record with data for equal roughness numbers (ROUGH) must be in sequence.

This command is not applicable for seastate simulations, nor for calculation of transfer functions using equivalent linearisation, and the command is not allowed to be used together with the API command. See Section 2.2.7. If this command is used together with API including doppler effect, it should be noted that Reynolds- and/or Keulegan-Carpenter numbers defined in Equation (2.9) and Equation (2.10) are calculated by use of apparent wave period. It should also be noted that coefficients calculated by CMAS will by default override coefficients calculated by API for all members.

The user should specify the entire range of Reynolds- and/or Keulegan-Carpenter numbers that will apply to the analysis. If the value at a load calculation point is outside the specified range the coefficient specified for the closest number will be used.

NU_i or CMN_i being either blank or 0.0 is understood as the particular point $_i$ has NOT been defined. A zero value must therefore be specified as a small value, i.e. 1.0E-10.

See the CDRG command for specification of drag coefficients.

RESTRICTIONS:

A maximum of 9 different coefficients may be specified for each roughness number.

A maximum of 5 roughness numbers may be specified.

A maximum of 15 CMAS commands may be given.

COEF — Dataset: HYDR

Hydrodynamic Coefficients as Functions of Vertical Position

Field:	1	2	3	4
Column: 4	10	20	30	40
COEF		Z1	Z2	CDN

Field:	5	6	7	8
Column:	50	60	70	80
CDL		CMN		

PURPOSE:

To specify the value of the transverse and longitudinal drag coefficients as well as the transverse inertia coefficient as functions of the vertical position, see Figure 5.4.

Z1	Lower limit of the region for which the coefficients are specified given relative to the mudline.
Z2	Upper limit of the region for which the coefficients are specified given relative to the mudline.
CDN	Transverse drag coefficient to be used at all load calculation points within the specified range, that is with vertical position above mudline, Z, satisfying Z1$\leq Z <$ Z2.
CDL	Longitudinal drag coefficient to be used within the specified range.
CMN	Transverse inertia coefficient to be used within the specified range.

NOTES:

The user should specify values for all vertical regions including the wave crest.

Note that the longitudinal drag coefficient CDL will only be used when calculating total structural loads, i.e. no longitudinal drag force components will be written on the Loads Interface File.

RESTRICTIONS:

A maximum of 10 regions may be specified.

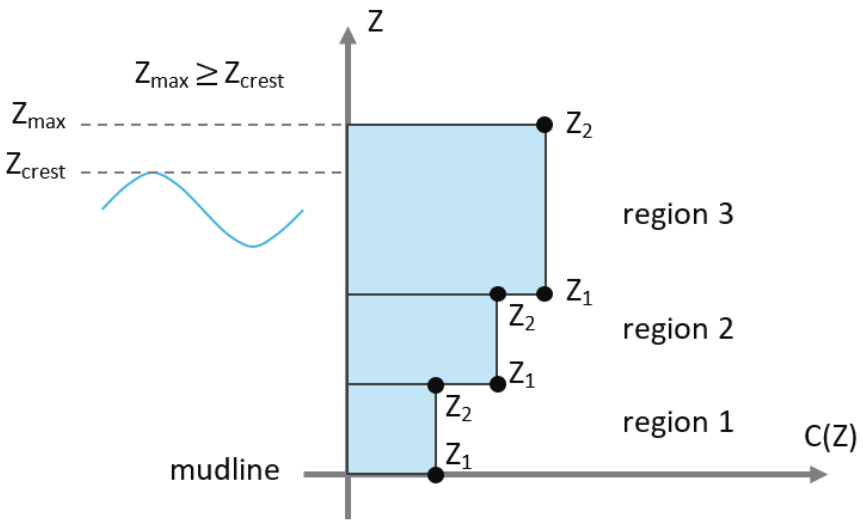


Figure 5.4: Hydrodynamic coefficients

CONDCT — Dataset: GEOM

Shielding Effects for Conductor Arrays

Field:	1	2	3	4
Column:	6 20	30	40	45
CONDCT				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8	9
Column:	50	55	60	70	80
STYPE	INDEX		DX	DY	

PURPOSE:

To specify conductor shielding for groups of members.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined by this command.
STEP	Step in element numbers.
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.
DX	Centre to centre distance between conductors in global X-direction to be used when calculating the shielding factor.
DY	Centre to centre distance between conductors in global Y-direction to be used when calculating the shielding factor.

NOTES:

This command will have effect on specified or calculated drag and inertia coefficients of all referenced members independent of which option has been used to specify the coefficients.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

A maximum of 20000 CONDCT commands may be given.

CONS — Dataset: WAJAC

Units and Constants Definition

Field:	1	2	3	4
Column: 4	10	20	30	40
CONS		OPT	GRAVITY	RO

Field:	5	6	7	8
Column: 50		60	70	80
VISC	ROAIR	VISCAIR		

PURPOSE:

To specify a different unit system than the SI system used as the default units in Wajac. The default values are given below for each parameter.

PARAMETERS:

OPT	Option for selection of units and constants	
	$= 0.0$	The units will be metres, kg, sec. and angles in degrees (default units)
	$= 1.0$	The units are user defined by the specification of gravity and water density (or specific mass)
GRAVITY	Acceleration of gravity. Default value is $9.81 \quad m/s^2$.	
RO	Water density (specific mass). Default value is $1025.0 \quad kg/m^3$.	
VISC	Fluid kinematic viscosity. The default value used by Wajac is: $1.19 \cdot 10^{-6} m^2/s$. The kinematic viscosity is only used when calculating the Reynolds number. See the CDRG/CMAS command.	
ROAIR	Density of air. Default value: $1.226 \quad kg/m^3$	
VISCAIR	Kinematic viscosity of air. Default value: $1.462 \cdot 10^{-5} \quad m^2/s$	

NOTES:

This command may be omitted if the default values listed above are to be used.

RESTRICTIONS:

Only one CONS command may be given.

CPRI — Dataset: HYDR

Change Priority of Specified Hydrodynamic Coefficients

Field:	1	2	3	4
Column: 4	10	20	30	40
CPRI		TYPE		

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To change priority of hydrodynamic coefficients specified either on the Input Interface File or by the Analysis Control Data. The default priority hierarchy is given in Section 2.2.7.

PARAMETERS:

TYPE	Type of specification	
	=FEM	Coefficients specified on Input Interface File.
	=API	Coefficients specified according to API.
	=COEF	Coefficients specified by COEF.
	=FUNC	Coefficients specified either by CDIA, or by CDFN or by CDRG and CMAS.
	=SPEC	Coefficients specified by SPEC/SPEX.
	=CDIR	Coefficients specified by CDIR/CDIX.

NOTES:

One or more commands may be specified. The TYPE on the last command specified will get priority 1, i.e. highest priority. The TYPE on the last but one command will get priority 2, and so on.

RESTRICTIONS:

A maximum of 6 CPRI commands may be given.

CRNT — Dataset: LOAD

Definition of Current Profiles

Field:		1	2	3	4
Column: 4	5	10	20	30	40
CRNT		CTNO			
		var.1	VX	VY	VZ
		var.2			
		var.3			

Field:	5	6	7	8
Column:	50	60	70	80
	Z			
	Z	V	THETA	
	Z	V		OPT

PURPOSE:

To define stationary current profiles which may be referred to by commands specifying the seastates to be analysed. The current profiles are assumed to vary linearly between the specified levels. One command is given for each level of each current profile.

PARAMETERS:

CTNO	Current profile index. This index is used as reference when the current is included in the analysis.	
VX,VY,VZ	Current velocity components in the global coordinate system at the vertical position in question.	
Z	Vertical position relative to the mudline.	
V	Total horizontal current velocity at the vertical position in question	
THETA	Direction of the current at the vertical position in question relative to the global X-axis given in degrees.	
OPT	$= 0.0$ or blank	The direction of the current is specified by the THETA parameter.
	$= 1.0$	The current is to be applied in the direction of the wave to which is added. This parameter must be specified in the first command for the current profile to which it applies.

NOTES:

The current profiles must be described from the mudline and include the wave crests. Values of Z must be given in increasing order.

Each of the of the points defining current profile are becoming load calculation points when located under water. This way results reflect contribution of current profile accurately.

RESTRICTIONS:

A maximum of 3000 current profiles may be defined.

A maximum of 30 levels may be specified for each current profile.

DENS — Dataset: LOAD

Energy Density Values in a NEWWAVE Wave Spectrum

Field:	1	2	3	4
Column: 4	10	20	30	40
DENS		SPNO	NDENS	

Field:	5	6	7	8
Column:	50	60	70	80

Field:	1	2	3	4
Column: 4	10	20	30	40
		$DENS_1$	$DENS_2$	...

Field:	5	6	7	8
Column:	50	60	70	80
...		...	$DENS_{NDENS}$	

PURPOSE:

To specify the sequence of energy density values in a user defined wave spectrum.

SPNO	$= 3.0$ identifies the user defined spectrum. This corresponds to SPECTR$= 3.0$ on the NEWWAVE command.
NDENS	Number of energy density values in the user defined wave spectrum. NDENS must be equal to NOMEG on the OMEG command.
$DENS_i$	Energy density value number i corresponding to $OMEG_i$ on the OMEG command with the same SPNO number.

NOTES:

See also the OMEG command.

RESTRICTIONS:

The energy density values $DENS_i$ must correspond to $OMEG_i$. The number of frequency values NDENS must not exceed 60.

DPTH — Dataset: LOAD

Water Depth

Field:	1	2	3	4	5
Column: 4	10	20	25	30	40
DPTH		DEPTH	IDPT		

Field: 6	7	8	9
Column: 50	60	70	80

PURPOSE:

To specify water depths which are defined as the distance between the mudline and the still water line, see Figure 2.1.

PARAMETERS:

DEPTH	Water depth between the mudline and the still water level.
IDPT	Water depth index.
	$= 0.0$ or blank
	> 0

NOTES:

More than one depth may be specified in deterministic load calculations (see Section 2.1.1) and frequency domain load calculations (see Section 2.1.2). One DEPTH parameter is specified on each DPTH command. A non-negative index number can be given for each DPTH command through column of IDPT. If blank, this index number is taken as 0. If more than one water depth is defined, mixing zero and non-zero IDPT number is not allowed. If one of IDPT number is 0 or blank, all the other IDPT numbers should be set as 0 too.Wajac does not allow a repeated non-zero IDPT number.

For frequency domain calculations, IDPT column is not relevant and will be ignored. For each depth specified, loads will be calculated for all given seastates. Load case numbering in such multiple depths analysis is shown in Figure 3.1.

For deterministic load calculations, for each depth specified, loads will be calculated for all given seastates if water depth index numbers (IDPT) are all blank or zero. Load case numbering in such multiple depths analysis is shown in Figure 3.1. If water depth index numbers (IDPT) are non-zero, for each depth specified, only those seastates defined under this water depth will be calculated correspondingly, see IDPT column under SEAOPT command. If a water depth is never used by any seastate through SEAOPT command, the load calculation for this water depth will be skipped. Load case numbering in such multiple depths analysis is shown in Figure 3.2.

When loads are calculated in an irregular sea (see Section 5.5) only specification of one single depth is possible.

RESTRICTIONS:

Maximum 20 DPTH commands may be specified.

ELIM — Dataset: GEOM

Member Elimination

Field:	1	2	3	4
Column: 4	10	20	30	40
ELIM				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8
Column:	50	60	70	80
STYPE		INDEX		

PURPOSE:

To eliminate members from the load calculation. These members will receive neither hydrodynamic nor buoyancy forces.

PARAMETERS:

N1	Member to be eliminated (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined on this command.
STEP	Step in element numbers.
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.

NOTES:

The members may either be referred to by the external element numbers (var. 1) or through a named set of members defined on the Input Interface File (var.2).

RESTRICTIONS:

A maximum number of 20000 ELIM commands may be given.

The limit of maximum number of elements within one superelement includes any elements which have been eliminated from the load calculation by the ELIM command.

END

Last Command in Input Stream

Field:		1	
Column:	3		80
END			

PURPOSE:

To identify the end of the Analysis Control Data. This command must be the last encountered in the input stream.

EQVL — Dataset: WAJAC

Command and Format Redefinition

Field:		1	2	3	4
Column: 4	5	9	13	17	57
EQVL		DSET	OLD	NEW	FORMAT

PURPOSE:

To enable the user to redefine commands.

PARAMETERS:

DSET	Dataset in which a command is to be redefined
OLD	Command to be redefined, maximum four characters.
NEW	New command keyword of maximum four characters. The new keyword must be different from the old one.
FORMAT	New format of the form (5X,nFm.d), (5X,nEm.d), (5X,nFm.d,nEm.d,...,...) etc. where
	n is the number of fields in the command
	m is length of each field
	d is the number of decimal points
	The keyword is not included in the format.

NOTES:

All original commands are uniquely specified by the four first characters of the keyword and the dataset to which it belongs.

The maximum number of columns on the redefined commands are 80.

RESTRICTIONS:

No command belonging to the execution directives dataset (WAJAC) can be redefined.

A maximum of 10 commands may be redefined.

ERG — Dataset: LOAD

Fraction of Energy for Wave Directions

Field:	1	2	3	4
Column:	4 10	20	30	40
ERG		EPART1	EPART2	EPART3

Field:	5	6	7	8
Column:	50	60	70	80
EPART4		EPART5		

PURPOSE:

To specify the fraction of energy to be associated with each wave direction in a short crested seastate used in a seastate simulation analysis.

PARAMETERS:

EPARTi — The fraction of the energy (a value between 0. and 1.) associated with component wave direction no. i, i = 1,...,5.

NOTES:

The number of component wave directions for short crested seastates is fixed to 5. These are the main wave direction, two directions 45 and 90 degrees to the left of the main wave direction, and two directions 45 and 90 degrees to the right of the main wave direction of the simulated seastate. The wave directions are numbered from left to right when seen in the direction of wave propagation.

The sum of the fractions of the energy should be 1 (i.e $\sum_i(\text{EPART}_i) = 1$)

See also the LOASIM and the SEASIM commands.

RESTRICTIONS:

Maximum one ERG command may be given.

FCOMP — Dataset: WAJAC

Prefix for output file storing wave components used when performing time simulation analysis.

Field:		1
Column: 5	10	50
FCOMP		PREFIX

PURPOSE:

To specify prefix for name of output file storing individual wave components.

PARAMETERS:

PREFIX — First part of the file name. The resulting file name will be <PREFIX>COMP.lis. If no prefix is specified default name is used, that is COMP.lis. If no FCOMP card is present then no output file will be generated.

NOTES: There are six columns in the output file, see description below for details. Each row except the first one corresponds to individual wave components. First component always relates to frequency equal 0.

COLUMN	UNIT	DESCRIPTION
ID	-	Row id
AMPLITUDE	L	Amplitude
OMEGA	$rad \cdot s^{-1}$	Angular frequency
PHASE	rad	Phase angle
WAVE_NUM	$rad \cdot s^{-1}$	Wave number
SPEC_DENS	$L^2 \cdot s \cdot rad^{-1}$	Spectral density function

RESTRICTIONS:

Only one FCOMP command may be given.

FLOO — Dataset: GEOM

Definition of Flooded Members

Field:	1	2	3	4
Column:	4 10	20	30	40
FLOO				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8
Column:	50	60	70	80
STYPE		INDEX		

PURPOSE:

To specify selected members as flooded. That is only the steel cross section area contributes to the buoyancy of these members.

PARAMETERS:

N1	Member to be defined as flooded (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined by this command.
STEP	Step in element numbers.
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.

NOTES:

See Section 2.2.4 and Figure 2.17 for a more detailed description of flooded and non-flooded members.

The members may either be referred to by the external element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

A maximum of 20000 FLOO commands may be given.

FMOD — Dataset: WAJAC

Prefix for Input Interface File

Field:	1	2
Column: 4	10	50
FMOD		PREFIX

PURPOSE:

To specify prefix for name of Input Interface File and Loads Interface File.

PARAMETERS:

PREFIX — First part of the names of the Input Interface File and generated Loads Interface Files (preceding the default T- or L-). See Table 4.1.

NOTES:

A different prefix may be specified for the Loads Interface File by the FWAVE command.

RESTRICTIONS:

Only one FMOD command may be given.

The prefix should not exceed 40 characters.

FRQ — Dataset: LOAD

Wave Periods for Calculation of Transfer Functions

Field:	1	2	3	4
Column: 3	10	20	30	40
FRQ		NPER	TMIN	TMAX

Field:	5	6	7	8
Column:	50	60	70	80

second and following commands if TMIN = TMAX = 0.0 or blank:

Field:	1	2	3	4
Column: 3	10	20	30	40
FRQ		T1	T2	...

Field:	5	6	7	8
Column:	50	60	70	80
				TN

PURPOSE:

To specify the wave periods for which hydrodynamic transfer functions are to be calculated.

PARAMETERS:

NPER	Number of wave periods
TMIN	Shortest wave period in a sequence. The other wave periods are defined between TMIN and TMAX with constant time increment.
TMAX	Longest wave period.
T1	First wave period if waves are specified explicitly, that is if TMIN=TMAX=0.0 or blank.
T2	Second wave period.
TN	Last wave period.

NOTES:

This command may contain one or more records. When the wave periods are defined explicitly only NPER is given on the first record. The actual periods are given on the following records.

RESTRICTIONS:

The maximum number of wave periods to be specified is 196.

FWAVE — Dataset: WAJAC

Prefix for Loads Interface Files

Field:	1	2	3
Column: 5	10	50	61
FWAVE		PREFIX	FORM

PURPOSE:

To specify prefix for file name of the Loads Interface Files different from that of the Input Interface File containing the model. If this command is omitted the prefix given by the FMOD command is used.

PARAMETERS:

PREFIX	First part of the names of the Loads Interface Files (preceding the default L-)
FORM	Format of the Loads Interface File. The text FORMATTED written (fully out, from position 51), gives an ASCII formatted file, otherwise the file will be unformatted.

NOTES:

The auxiliary program Waloco may be used to reformat the Loads Interface File between ASCII formatted and unformatted.

If the Loads Interface File is formatted this information must be given to Sestra (LNAM command).

RESTRICTIONS:

The prefix should not exceed 40 characters.

GEOM — Dataset: GEOM

Dataset Identification: Geometry Definition

Field:		1	
Column:	4		80
GEOM			

PURPOSE:

To identify GEOM dataset

NOTES:

This command must precede all commands in the geometry dataset.

GRID — Dataset: LOAD

Horizontal Extremity of Simulation Grid

Field:	1	2	3	4
Column: 4	10	20	30	40
GRID		RADMAX	HDIST	

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To define the horizontal extremity of the volume in which Wajac will generate a grid for pre-calculation of fluid kinematics used in a seastate simulation analysis

PARAMETERS:

RADMAX — Radius of a horizontal circle with centre at the z-axis of the global coordinate system in which the horizontal projection of the structure will be completely contained.

HDIST — Horizontal spacing between grid cells at sea surface. If this parameter is omitted or put equal to zero, the default value calculated by the program will be half of the wave length corresponding to the parameter TCUT given on the SEASIM command.

NOTES:

At the sea surface the vertical spacing between the grid cells will be the same as the horizontal one. When going deeper the spacing may increase.

Wajac allows a maximum of 15 times 15 grid points for each grid level and a maximum of 10 grid levels.

For a given RADMAX value the minimum horizontal distance between the grid points will be

$$\text{HDIST}_{\text{MIN}} = \frac{1}{7} \cdot \text{RADMAX}$$

However, the actual horizontal distance between the grid points is automatically computed by the program based on the desired TCUT value. The relationship between this value and the TCUT value is

$$\text{HDIST} = \frac{g}{4\pi} \cdot \text{TCUT}^2$$

Combining the two equations above gives the minimum TCUT value for a given RADMAX without using the HDIST option as

$$\text{TCUT}_{\text{MIN}} = \sqrt{\frac{4\pi \cdot \text{RADMAX}}{7g}}$$

RESTRICTIONS:

Only one GRID command may be given.

HYDR — Dataset: HYDR

Dataset Identification: Hydrodynamic Properties

Field:	1	
Column: 4		80
HYDR		

PURPOSE:

To identify the HYDR dataset.

NOTES:

The command must precede all commands in the hydrodynamic properties dataset.

KPRT — Dataset: LOAD

Fluid Kinematics Printout

Field:	1	2	3	4
Column: 4	10	20	30	40
KPRT		X	Y	Z

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To specify print of wave, current and wind kinematics in specific points.

PARAMETERS:

X, Y, Z — Coordinates of the point for which fluid kinematics are printed. The point is specified relative to the origin of the global coordinate system except for the Z coordinate which is relative to the mudline.

NOTES:

The X-,Y- and Z-components of the velocity and acceleration components are printed. The wave and current contributions to the velocities are given individually and combined.

If the specified point is above the instantaneous surface elevation then the point is interpreted as the point projected down onto the instantaneous surface elevation.

If the SEAOPT command is used to select only the phase of maximum base shear/overturning moment then the fluid kinematics are printed only for these two phases of each seastate.

Wind kinematics is printed at each time step for the specified point which is not below SWL and simultaneously above the instantaneous surface elevation,

RESTRICTIONS:

The command is only applicable for deterministic wave load calculation.

Maximum 100 points may be specified.

KSCA — Dataset: HYDR

Wave Kinematics Adjustment Factor

Field:		1	2	3
Column:	4	10	15	80
KSCA			KINSCA	

PURPOSE:

Adjust for wave spreading and irregularities of nonlinear waves. The specified scaling factor will also have effect on linear waves.

PARAMETERS:

KINSCA Wave kinematics scaling factor by which the horizontal components of the velocity and acceleration are multiplied.

NOTES:

Wave kinematics of all seastates will be multiplied by the ’global’ scaling factor KINSCA in addition to the wave spreading factor WKFAC specified for each seastate on the SEAOPT command. The total scaling factor will then be WKFAC*KINSCA.

RESTRICTIONS:

The command is only applicable for deterministic wave analysis.

LEG — Dataset: GEOM

Soil Permeability Factors for Leg

Field:	1	2	3	4
Column: 5	10	20	30	40
LEG	BAWMG	CPERM	NODBOT	NODTOP

Field:	5	6	7	8
Column:	50	60	70	80
STYPE		INDEX		

PURPOSE:

To define the soil permeability factor for a leg consisting of pipe members. See Section 2.2.5.

PARAMETERS:

BAWMG — Parameter controlling reduction of marine growth weight and buoyancy attached to a leg.
- blank: full buoyancy and weight assumed,
- 0.0-1.0: value specified relates to fraction of actual weight and buoyancy,
- 2.0: marine growth buoyancy excluded,
- 3.0: marine growth weight excluded.

CPERM — Soil permeability factor given in the range from 0. to 1.
- 0.0: no buoyancy of the leg,
- 1.0: full buoyancy.

NODBOT — Lower most node (node number) for the leg under consideration.

NODTOP — Upper most node for the leg under consideration.

STYPE — Superelement type number to which this command applies.

INDEX — Superelement index to which this command applies.

NOTES:

The most vertical members between NODBOT and NODTOP are interpreted as the leg. See Figure 2.18.

RESTRICTIONS:

A maximum of 50 LEG commands may be given. Parameter BAWMG is only available for Deterministic analysis.

LOAD – Dataset: LOAD

Dataset Identification: Loading Conditions

Field:		1	
Column:	4		80
LOAD			

PURPOSE:

To identify the LOAD dataset.

NOTES:

The command must precede all commands in the load dataset.

LOASIM — Dataset: LOAD

Time Simulation of Wave Loads in a Seastate

Field:	1	2	3	4
Column: 6	10	20	30	40
LOASIM		T0	TIM	DELT

Field:	5	6	7	8
Column:	50	60	70	80
CTNO		BETA	LOACON	MEMCON

Field:	9
Column:	90
WHEELSTR	

PURPOSE:

To specify time simulation of wave loads in a given short term seastate including options controlling the storing of results from the analysis.

PARAMETERS:

T0 — Starting time for the wave load calculation given relative to the time history of the generated irregular sea.

TIM — Length of the time series of wave loads to be calculated in seconds.

DELT — Time increment in the wave load calculation. If specified 0.0 or blank, DELT=TCUT/2 will be used when TIMESTEP is zero. If TIMESTEP>0, then DELT=TIMESTEP will be applied. TCUT and TIMESTEP are given by the SEASIM command.

CTNO — Parameter identifying current

- $= 0.0$ No current is added.
- > 0.0 Current profile index referring to current profiles specified through the CRNT command. The current velocities will be added to the velocities in the irregular sea before calculating the loads.

BETA — Main direction of propagation of the pre-generated irregular sea in degrees relative to the global X-axis.

LOACON — Parameter controlling the storing on file of time series for total loads and the sea surface elevation at origin of the global coordinate system. See the notes below for a description of the Simulation Result Files.

- $= 0.0$ No data is stored.
- $= 2.0$ Time series for the sea surface elevation at origin of the global coordinate system are stored on a Simulation Result File. No loads are calculated.
- $= 3.0$ Time series for the sea surface elevation and total loads are stored on Simulation Result Files.

MEMCON — Parameter controlling the storing on file of time series for member loads. See notes below for description of the Simulation Result Files.

- $= 0.0$ No data is stored.
- $= 1.0$ Time series of force intensities for all members are stored on Loads Interface Files. The generation of Loads Interface File must also be specified by the MODE command.
- $= 3.0$ Time series of force intensities for selected members are stored on Simulation Result Files. The members in question must be selected by the MPRT command.

WHEELSTR Parameter controlling whether Wheeler stretching should be enabled.

$= 0.0$	Disabled. All kinematics above still water line will be determined at still-water level.
$= 1.0$	Enabled. All kinematics determined for updated z-coordinate, according to Eq. (2.3).

NOTES:

Simulation Result Files

When storing of data on Simulation Result Files is specified the data are stored on files with names on the following format:

S<nnnn>.SER

where <nnnn> is a at least four-digit number starting at 1030. The numbers are assigned as follows:

1030	Sea surface elevation at origin.
1031,1032,1033	Total forces (FX, FY, FZ).
1034,1035,1036	Total moments (MX, MY, MZ).

and further for individual member loads:

1037, 1038, 1039	Force intensities (FX, FY, FZ) for 1st member.
1040, 1041, 1042	Force intensities (FX, FY, FZ) for 2nd member etc.

until nnnn $= 1036 +$ N*3 for the Z component of the force intensities of the Nth member.

First line in SER-files includes following information:

Symbolic	a	b	c	d	e	f
Example, total loads, FY	1032	0	2	0	0	0
Example, member loads, FX	1037	1	1	2	1	1
Example, surface elevation at origin	1030	0	0	0	0	0

Where: a - file identification number; b - member id in the group of members selected through MPRT command; c - id of force component {1:FX, 2:FY, 3:FZ}; d - external basic element id; e - superelement type; f - index of superelement type; **NOTE:** Parameters b,d,e and f are not relevant to printing of total loads and will always be equal 0. In case of sruface elevation, only parameter a will have non-zero value.

Other notes

See the MOMT command for the definition of the moment reference point used for calculation of the total moments.

For statistical postprocessing of the results stored on Simulation Results Files the user is referred to Ref. [3].

See also the SEASIM command for specification of the seastate and pre-calculation of fluid kinematics.

Wave particle velocity and acceleration in the wave crest are set equal to their values at the still water level.

RESTRICTIONS:

The time interval to be analysed must not exceed the duration of the pre-generated irregular sea as defined by the TIMLEN parameter in the SEASIM command.

Maximum one LOASIM command may be given.

LONO — Dataset: WAJAC

Loadcase Numbering

Field:	1	2	3	4
Column: 4	10	20	30	40
LONO		LN		

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To specify an initial loadcase number which will be used as the lowest loadcase number for loads written to the Loads Interface File for all first level superelement types.

PARAMETERS:

LN The first loadcase number used for loads written to the Loads Interface Files. This number applies to all superelement types.

NOTES:

If no LONO command is given the loadcase numbers for loads written to each Loads Interface File will automatically be consecutive to any existing loads already defined on the Input Interface File containing the corresponding superelement type. The loadcase numbers for one load (one wave) may in this case be different for the different superelement types. See Figure 3.1 for the generation of loadcase numbers.

Use of LONO will involve that an S-file will be produced even when there are loads on the Input Interface File (normally, an S-file is created only when no loads have been created by the preprocessor). Unless you are performing a Sestra analysis followed by a fatigue analysis in Framework you should delete this S-file prior to running Sestra.

RESTRICTIONS:

Only one LONO command may be given.

MASS — Dataset: HYDR

Added Mass to the Load Interface File

Field:	1	2	3	4
Column: 4	10	20	30	40
MASS		ADMAS	DAMP	IMET

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To store constant added mass and damping on the Loads Interface Files for transfer to subsequent dynamic structural analysis.

PARAMETERS:

ADMAS Added mass control parameter.

- $= 0.0$ Hydrodynamic added mass and the mass of marine growth and internal water in flooded members are not written to the Loads Interface File.
- $= 1.0$ Hydrodynamic added mass and the mass of marine growth, normal components, are written to the Loads Interface File independently of the analysis type. The mass of internal water in flooded members is not included.
- $= 2.0$ Hydrodynamic added mass and the mass of marine growth and internal water in flooded members, normal components, are written to the Loads Interface File.
- $= 3.0$ Hydrodynamic added mass and the mass of marine growth and internal water in flooded members, in all directions, are written to the Loads Interface File.
- $= 4.0$ Hydrodynamic added mass, only normal components, is written to the Load Interface File. The mass of marine growth and internal water in flooded members, in all directions, is written to the Load Interface File.

DAMP Damping mass control parameter

- $= 0.0$ No damping or drag data is written to the Loads Interface Files
- $= 1.0$ Drag or damping, normal components, is written to the Loads Interface Files.
- $= 2.0$ Drag or damping, in all directions, is written to the Loads Interface Files.

IMET Added mass calculation approach.

- $= 0.0$ New, more accurate method is used. Weight of marine growth over still water level is included. This method is a default one for pure added mass analysis and deterministic analysis.
- $= 1.0$ Old method. Added mass calculated based on load calculation points evenly distributed along member. Weight of marine growth over still water level not included. This method is a default one for time simulation analysis and frequency domain analysis.

NOTES:

Only one set of added mass for each member is calculated for each superelement type since only one mass matrix for each superelement type may be used in the structural analysis. If two occurrences of one superelement type shall have different added mass they must be duplicated and given different superelement type numbers.

In a multiple depths analysis, only added mass and/or damping from the first depth specified through DPTH command will be written to the Loads Interface File.

The added mass and damping data are stored as BEMASS1 and BEDRAG1 records respectively on the Loads Interface Files.

The mass of marine growth is calculated only up to still water level in frequency domain analysis and seastate simulation. In deterministic analysis, the mass of marine growth over still water level is also included.

For all three types of analysis, damping is calculated only up to the still water level.

If frequency dependent inertia or drag coefficients are specified at a load calculation point (either by Mac-Camy-Fuchs, KC/Rn number dependency or by API) 2.0 and 0.7 will be used for the inertia coefficient C_m and drag coefficient C_d respectively.

See Section 2.4.5 and Section 2.4.6 for descriptions of the calculation of added mass and damping.

RESTRICTIONS:

Only one MASS command may be given.

IMET parameter is only available for pure added mass analysis and when added mass calculation is performed alongside with deterministic analysis.

MEMGRW — Dataset: HYDR

Member Specification of Marine Growth Data

Field:	1	2	3	4
Column:	6 10	20	30	40
MEMGRW				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8
Column:	45	50	55	80
STYPE	INDEX	IMEM		

PURPOSE:

To specify marine growth data for selected members and/or to specify multiple marine growth profiles.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined by this command.
STEP	Step in element numbers.
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.
IMEM	Index number ($\geq$0.0) referring to the MGRW command.

NOTES:

For each member (element) the program will check whether it has a reference to MGRW commands through IMEM. If it has, the marine growth data are taken from MGRW commands with the same IMEM number. If the load calculation point is outside the interval specified by Z1 and Z2 on MGRW, marine growth data are taken from MGRW commands with IMEM=0.0.

For members without any reference to MGRW marine growth data are taken from MGRW commands with IMEM=0.0.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

A maximum of 20000 MEMGRW commands may be given.

MEMSEG — Dataset: LOAD

Member Specification of Segmentation Coefficient

Field:	1	2	3	4
Column: 6	10	20	30	40
MEMSEG				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field: 5	6	7	8
Column: 45	50	55	80
STYPE	INDEX	IMEM	

PURPOSE:

To specify member segmentation coefficient for selected members.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined by this command.
STEP	Step in element numbers.
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.
IMEM	Index number (≥ 0.0) referring to the SEGM command.

NOTES:

For each member (element) the program will check whether it has a reference to SEGM commands through IMEM. If it has, the segmentation data are taken from SEGM commands with the same IMEM number. If the load calculation point is outside the interval specified by Z1 and Z2 on SEGM, segmentation data are taken from SEGM commands with IMEM=0.0.

For members without any reference to SEGM segmentation data are taken from SEGM commands with IMEM=0.0.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

A maximum of 20000 MEMSEG commands may be given.

MFPR — Dataset: HYDR

MacCamy-Fuchs parameters

Field:	1	2	3	4	5
Column: 4	10	20	25	30	40
MFPR		DIAMMF			

Field: 6	7	8	9
Column: 50	60	70	80

PURPOSE:

To specify additional parameters for MacCamy-Fuchs modification (see section 2.4.4).

PARAMETERS:

DIAMMF Minimum diameter for which MacCamy-Fuchs modification will be applied. Default value equals 0., meaning that no member is going to be excluded.

NOTES:

It is worth noting that only members with vertical inclination up to 10 degrees will be affected by MacCamy-Fuchs modification, those members can then be additionally excluded by using MFPR command.

RESTRICTIONS:

Maximum one MFPR command can be specified. This command is not available for frequency domain analysis.

MGRW — Dataset: HYDR

Marine Growth and Roughness Definition

Field:	1	2	3	4
Column: 4	10	20	30	40
MGRW		Z1	Z2	HMGRW

Field:	5	6	7	8	9
Column:	50	60	65	75	80
HROUGH		OPT	IMEM	GRWFAC	

PURPOSE:

To specify marine growth thickness and its roughness height, see Section 2.2.6 and Figure 5.5.

PARAMETERS:

Z1	≥ 0.0	Lower most vertical position relative to the mudline from which the specified data applies
	<0.0	This indicates linearly varying marine growth and roughness between levels given by Z2 in subsequent MGRW commands. The value of Z1 has no other meaning.
Z2	If Z1≥ 0.0	Upper most vertical position relative to the mudline to which the specified data applies. The Marine growth and roughness height are assumed to be constant between the levels given by Z1 and Z2.
	If Z1< 0.0	Vertical position relative to the mudline for the specified data.
HMGRW	Marine growth thickness specified as an additional thickness. This marine growth times two will be added to the member diameter (equivalent diameter for non-pipe members) before calculating the drag and, optionally, the inertia forces (see the OPT parameter below) at load calculation points within the specified range.	
HROUGH	Roughness height. The roughness height is used as a reference to hydrodynamic coefficients specified as a function of the roughness number, either according to API, or by the CDRG and CMAS commands. HROUGH > 0.0 will give rough A/D dependent force coefficients if ADDEP=1.0 on the NEWWAVE command. HROUGH=0.0 will give smooth A/D force coefficients.	
OPT	Parameter specifying the use of marine growth when calculating inertia force.	
	$= 0.0$	The marine growth is not added.
	$= 1.0$	The specified marine growth will also be taken into account when calculating the inertia component of the wave force.
IMEM	Reference to MEMGRW commands for specification of members.	
	$= 0.0$ or blank	No reference
	> 0.0	Index number referring to member specification on the MEMGRW command.
GRWFAC	Marine growth density factor. Density of marine growth = density of water * (1+GRWFAC).	

NOTES:

Outside the ranges specified by the MGRW commands zero marine growth, zero roughness and smooth A/D will be assumed.

RESTRICTIONS:

The sign of Z1 must be equal on all cards. A maximum of 100 MGRW commands may be given.

If marine growth is specified using constant intervals ($Z1 \geq 0$), then it is required that these intervals do not overlap.

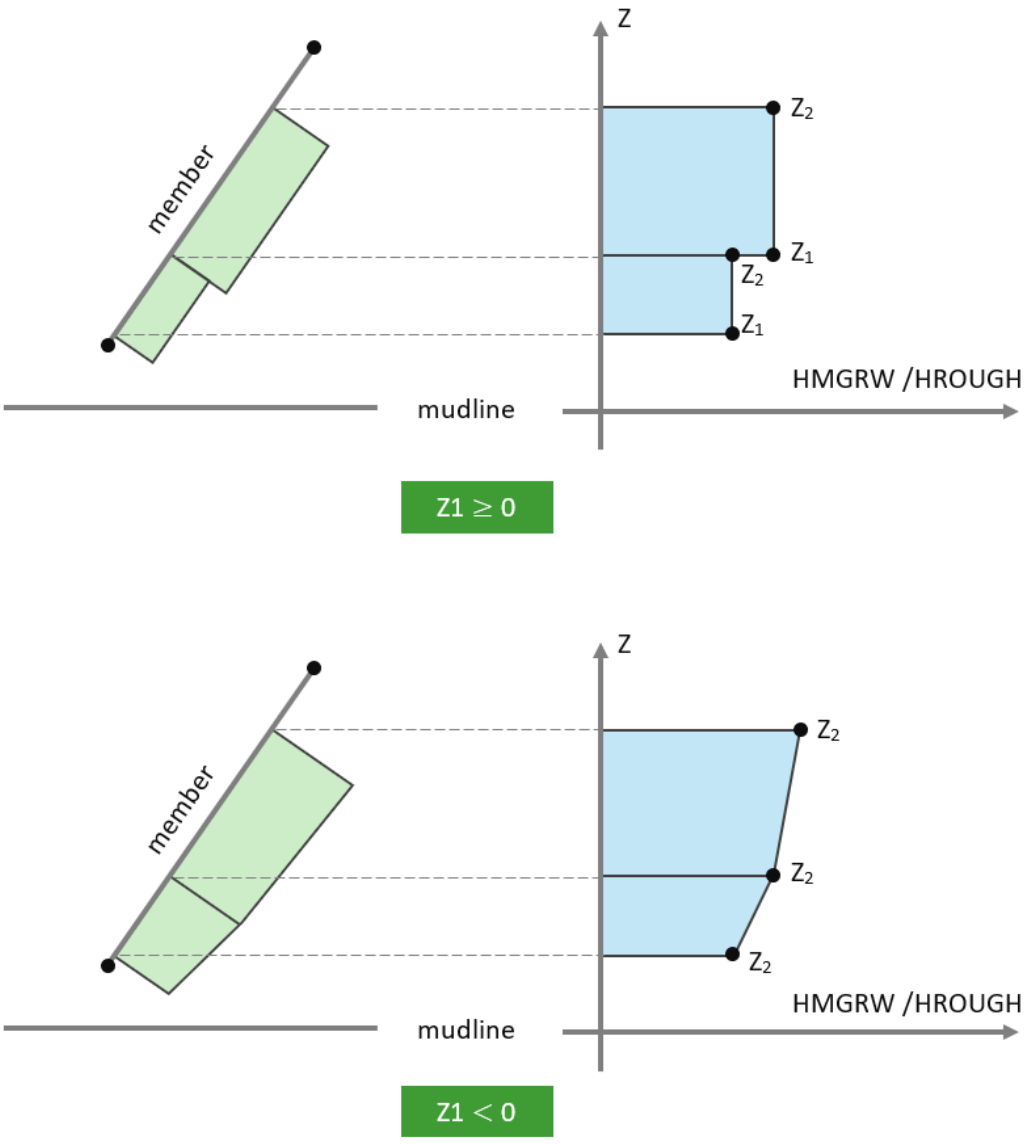


Figure 5.5: Specification of marine growth

MODE — Dataset: WAJAC

Model Identification and Loads Interface File Generation

Field:	1	2	3	4
Column: 4	10	20	30	40
MODE			ILFSAV	ISETOP

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To identify the model for which loads will be calculated and to specify the generation of Loads Interface Files.

PARAMETERS:

ILFSAV — Parameter controlling the generation of Loads Interface Files. This parameter will also affect the generation of output files from a seastate simulation analysis, see the LOASIM command.

- $= 0.0$ — No Loads Interface Files is generated.
- $= 1.0$ — Loads Interface Files are generated for all first level superelement types which is not excluded from the calculations by the SELI command.

ISETOP — Superelement type number of top level superelement type identifying the input geometry to Wajac.

RESTRICTIONS:

Only one MODE command may be given.

MOMT — Dataset: LOAD

Moment Reference Point Definition

Field:	1	2	3	4
Column: 4	10	20	30	40
MOMT		X	Y	Z

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To specify the moment reference point. The integrated moments printed in the Print File and on the Simulation Result Files from the seastate simulation analysis are calculated with respect to this point. If no MOMT command is given the origin of the global coordinate system is used as moment reference point.

PARAMETERS:

X, Y, Z Coordinates of the moment reference point specified in the global coordinate system.

RESTRICTIONS:

Maximum one MOMT command may be given.

MPRT — Dataset: LOAD

Member Force Printout Specification

Field:	1	2	3	4
Column:	4 10	20	30	40
MPRT				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8
Column:	50	60	70	80
STYPE		INDEX	ISEA	ISTEP

PURPOSE:

This command has different meaning depending of the analysis type:

If deterministic load calculation or calculation of transfer functions is specified the purpose of the MPRT command is to specify print of total force components for selected load cases and selected members.

If seastate simulation of wave loads is specified, this command identifies members for which timeseries are stored on file, see the MEMCON parameter on LOASIM command. In this case the ISEA parameter must be set =1.0, while the ISTEP parameter is neglected.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.
NN	Last member in a sequence. Leave blank if only one member is defined on this command.
STEP	Step in element numbers
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).
STYPE	Superelement type number to which this command applies.
INDEX	Superelement index to which this command applies.
ISEA	Index identifying result case (wave frequency, wave direction, current) for which print is wanted. ISEA must be =1.0 if seastate simulation is performed. The index is defined by the sequence in which the waves are specified by the SEA (deterministic load calculation) or the SEAFRQ (calculation of transfer functions) commands. Giving ISEA = 0 implies all seastates.
ISTEP	Index identifying the time step or wave frequency (depending on the analysis type) for which print is wanted (not applicable for a seastate simulation). Giving ISTEP = 0 implies all steps.

NOTES:

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

RESTRICTIONS:

Maximum 20000 MPRT commands may be given.

MSEG — Dataset: LOAD

Member Segmentation Definition

Field:	1	2	3	4
Column: 4	10	20	30	40
MSEG		SEG	ASEG	MAXSEG

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To specify a member segmentation coefficient controlling the segmentation of the members. Allows to request auto-segmentation, i.e. to allow Wajac to decide the segmentation and ensure accuracy of load calculation to within 1%. See Section 2.2.3 and the notes below.

PARAMETERS:

SEG	Member segmentation coefficient. Value of SEG is used to determine number of segments based on formula presented below unless auto-segmentation is switched on, in such case value of SEG is ignored.
ASEG	Auto-segmentation switch.
	$= 0$ or blank — Auto-segmentation is turned off.
	$= 1$ — Auto-segmentation is turned on.
MAXSEG	Maximum number of segments used in auto-segmentation. Note that Wajac will not use more than 20 segments per member.

NOTES:

Different procedure will be applied depending whether auto-segmentation is enabled or not.

1. Auto-segmentation is disabled.

   The following formula is used for controlling the number of segments in each member.

$$\text{Number of segments} = \frac{\text{SEG} \cdot \text{Member length}}{\text{Wave length}}$$

   The default value for SEG is 1.0. Irrespective of the result given by the above formula, the number of segments will be minimum 2 and maximum 20. The default value of SEG involves that only members longer than three times the wave length will be split in three or more segments.

   To avoid too refined segmentation close to the mudline the SEGM command should preferably be used in stead of the MSEG command. The segmentation coefficients specified by this command may be overruled by the SEGM command.

2. Auto-segmentation is enabled.

   If auto-segmentation feature is turned on the above formula is not used, instead Wajac finds optimal segmentation, i.e. segmentation that will ensure predefined accuracy and will minimize number of segments. Note that auto-segmentation procedure is performed per member, not per entire structure.

RESTRICTIONS:

Only one MSEG command may be given.

MUDP — Dataset: GEOM

Mudline Elevation

Field:		1	2	3	4
Column:	4	10	20	30	40
MUDP			Z		

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To define the mudline with respect to the origin of the global coordinate system, see Figure 2.1.

PARAMETERS:

Z Vertical coordinate of the mudline given in the global coordinate system.

NOTES:

Loads are not calculated for members or parts of members below the mudline.

If this command is omitted the origin of the global coordinate system will be used as the position of the mudline.

Maximum one MUDP command may be given.

MWIA — Dataset: WAJAC

Parameters controlling member-wave intersection algorithm for time simulation analysis.

Field:	1	2	3	4
Column:	10	20	30	40
MWIA	TASOL	NUMIT	TASRI	

Field:	5	6	7	8
Column:	50	60	70	80
ATYPE				

PURPOSE:

To specify parameters related to algorithm responsible for determining member-wave intersection in time simulation analysis.

PARAMETERS:

TASOL	Absolute tolerance applied on solution. Iteration will stop and accept solution if difference between member z coordinate and corresponding wave elevation is less than value specified through TASOL (default = 2.e-4).	
NUMIT	Maximum number of iterations. Wajac will terminate if solution is not found during NUMIT number of iterations (default = 45).	
TASRI	Absolute tolerance applied on search-interval. Wajac will stop and accept solution if search interval length is less than TASRI (default = 5.e-4).	
ATYPE	Algorithm type.	
	$= 0$ or blank	Regula-Falsi method + Anderson & Björk modification (default).
	$= 1$	Regula-Falsi method + Illinois modification
	$= 2$	Bisection method

NOTES:

It is advised to use this command only in case WAJAC failed at determining member-wave intersection point.

RESTRICTIONS:

A maximum of one MWIA commands may be given.

NEWWAVE — Dataset: LOAD

NEWWAVE Theory Parameters

Field:	1	2	3	4
Column: 7	10	20	30	40
NEWWAVE		SPECTR	FREEZ	GAMMA

Field:	5	6	7	8
Column:	50	60	70	80
DS/A		DELTA	SALPHA	US

Field:	1	2	3	4
Column:	10	20	30	40
		THETA	ADDEP	ADPRI

Field:	5	6	7	8
Column:	50	60	70	80
OFFSET				

PURPOSE:

To specify parameters for the NEWWAVE theory.

Parameters:

SPECTR — Spectrum type.
- $= 1.0$ Pierson Moskowitz.
- $= 2.0$ JONSWAP spectrum.
- $= 3.0$ User defined spectrum. The spectrum is defined by the OMEG and DENS commands.

FREEZ — Frozen/Evolving surface profile
- $= 0.0$ Frozen profile (default).
- $= 1.0$ Evolving profile.

GAMMA — Enhancement factor for Pierson Moskowitz and JONSWAP spectra.

$= 0.0$ Frozen profile (default)

$1.0 <$ GAMMA < 10.0 if JONSWAP spectrum (recommended$= 3.3$).

Irrelevant for user defined wave spectrum.

DS/A — Stretching relative depth (recommended$= 0.54$).

DELTA — Delta stretching parameter (recommended$= 0.3$)

SALPHA — Standard deviation of wave spreading (degrees).

US — Surface current velocity (used for Doppler shift).
- $= 0.0$ No current and hence no Doppler shift (default).
- > 0.0 The actual value of the current velocity on the surface which shall be used for Doppler shift calculation.

Note: If current is specified on the CRNT card and US$= 0.0$ then the Doppler shift effect will be suppressed. However, the current contribution to the total fluid force will be included.

THETA Common phase shift applied to all component waves (degrees).

$= 0.0$	All the wave frequency components are in phase yielding maximum wave crest at $x = t = 0.0$ (default).
> 0.0	All the wave frequency components are phase-shifted through a common angle THETA relative to $x = t = 0.0$ (default).

ADDEPP A/D dependency flag.

$= 0.0$	A/D dependency calculation OFF. Fixed force coefficients will be user specified.
$= 1.0$	A/D dependency calculation ON. rough/smooth A/D dependent force coefficients will be computed according to the specifications on the MGRW command.

ADDPRI Print option for print of A/D dependent force coefficients at the segment evaluation points within a member. That is, position no.1 is close or at end 1 (first node of member) and the last position is close to or at end 2.

$= 0.0$	No print.
$= 1.0$	Print force coefficients at all segment evaluation points.

OFFSET Offset for the evolving wave in the direction of the wave propagation. An offset greater than zero defines the position along the positive X-axis where wave crests are in phase.

NOTES:

Note that the MGRW command must be used to specify vertical zones where rough/smooth A/D dependent force coefficients shall be applied.

RESTRICTIONS:

Only one NEWWAVE command may be used in each Wajac run.

OMEG — Dataset: LOAD

Frequency Values in a NEWWAVE Wave Spectrum

Field:	1	2	3	4
Column: 7	10	20	30	40
OMEG		SPNO	NOMEG	

Field:	5	6	7	8
Column:	50	60	70	80

Field:	1	2	3	4
Column:	10	20	30	40
		OMEG_1	OMEG_2	...

Field:	5	6	7	8
Column:	50	60	70	80
...		...	$\text{OMEG}_{\text{NOMEG}}$	

PURPOSE:

To specify the sequence of angular frequencies in a user defined wave spectrum.

PARAMETERS:

SPNO	$= 3.0$ identifies the user defined spectrum. This corresponds to SPECTR=3.0 on the NEWWAVE command.
NOMEG	Number of frequencies in the user defined wave spectrum.
OMEG_i	Angular frequency value number i (radians/sec).

NOTES:

See also the DENS command.

RESTRICTIONS:

The frequency values must be specified in ascending order. The number of frequency values NOMEG must not exceed 60.

OPTI — Dataset: WAJAC

Special Options

Field:	1	2	3	4
Column: 4	10	20	30	40
OPTI		OPT1	OPT2	OPT3

Field:	5	6	7	8
Column:	50	60	70	80
OPT4		OPT5	OPT6	OPT7

Field:	1	2	3	4
Column:	10	20	30	40
		OPT8	OPT9	OPT10

Field:	5	6	7	8
Column:	50	60	70	80
OPT11		OPT12	OPT13	OPT14

Field:	1	2	3	4
Column:	10	20	30	40
		OPT15	OPT16	OPT17

PURPOSE:

To invoke special options, mainly intended for comparative studies. The default value for all parameters in this command is zero. Notice that notes for this command are included in the text for each parameter.

PARAMETERS:

OPT1 — Parameter controlling the velocity decomposition used when calculating the normal components of the drag forces:

- =0.0 The absolute value of the velocity component normal to the member is multiplied with the velocity component normal to the member (as in Equation (2.23)).
- =1.0 The absolute value of the velocity component normal to the member in Equation (2.23) is replaced by the absolute value of the total velocity.

OPT2 — Parameter controlling added mass transferred to the Loads Interface File.

- =0.0 Use inertia coefficients Cm defined in input commands when generating added mass (i.e. added mass coefficient $= C_m - 1.0$)
- =1.0 Use $C_m = 2.0$ (added mass coefficient = 1.0) for all elements irrespective of the C_m values used in the force calculation.

Note: See the MASS command for storing of added mass on the Loads Interface File.

OPT3 — Generation of Hydrodynamic Results Interface File

- =0.0 Do not write a Hydrodynamic Results Interface File.
- =1.0 Write total forces to the old Global Response Interface File G1.FEM.
- =2.0 Write total forces to the Hydrodynamic Results Interface File G1.SIF.

Note: A Hydrodynamic Results Interface File may only be generated when calculating transfer functions.

OPT4 Parameter specifying the use of MacCamy-Fuchs' solution

>0.0 MacCamy-Fuchs' solution (see Section 2.4.4) is used. In frequency domain analysis it is only applied to members with $C_m = 0.0$.

=0.0 If the inertia coefficient, C_m, at a load calculation point is zero no inertia forces are calculated.

=1.0 The inertia forces from MacCamy-Fuchs' solution are applied using a phase lag compared to the wave as given by potential solution. This option is only available in frequency domain analysis.

=2.0 The inertia forces are applied in phase with the horizontal wave particle acceleration at the point in question. This option is available in all analyses types.

Note: MacCamy-Fuchs solution is available in deterministic analysis, frequency domain analysis and irregular sea analysis (also including constrained wave) but there are some minor differences between frequency domain analysis and other analyses types. For frequency domain analysis all members must have an inclination of less than 30 degrees, for other analyses types maximum inclination equals 10 degrees. For deterministic and irregular sea analyses user may specify MFPR card and provide minimum diameter for which MacCamy-Fuchs modification will be applied. In frequency-domain analysis explicit selection of members is done by specifying $C_m = 0.$ for selected members.

OPT5 Parameter controlling the writing of fluid kinematics to the Loads Interface File.

=0.0 Only member loads are written to the Loads Interface File.

=1.0 Only fluid kinematics at member ends are written to the Loads Interface Files (see note below).

=2.0 Both fluid kinematics at the member ends and member loads are written to the Loads Interface File.

Note: Fluid kinematics may only be written to the Loads Interface File in time domain, that is for deterministic load calculation and seastate simulation analysis. The generation of Loads Interface File must in addition be specified through the MODE command. The fluid kinematics are stored on BEWAKIN command. This command will not be accepted by other Sesam modules.

OPT6 Parameter controlling the calculation of buoyancy forces with non-horizontal water-plane.

=0.0 Buoyancy is calculated assuming a horizontal surface above each member. A wave causes the surface elevation vertically above the member ends to differ (unless the member is vertical). This is dealt with by using the higher of the surface elevations above the two ends.

=1.0 Buoyancy forces are calculated using the actual, i.e. a non-horizontal waterplane, which gives small buoyancy components in the horizontal plane, see Section 2.4.8.

Note: The OPT6 parameter is only relevant in time domain analysis.

OPT7 Parameter for turning off the buoyancy due to the steel area for flooded members.

=0.0 The buoyancy due to the steel area is included.

=1.0 The buoyancy due to the steel area is not included in the loads. This implies that buoyancy is only included for non-flooded members and members with marine growth.

OPT8 Parameter controlling whether the effect of eccentricities is to be included or not, see Section 2.2.1. This option is specified by a second OPTI command.

=0.0 or blank	Take eccentricities into account (Default).
=1.0	Do not take eccentricities into account.

OPT9

Print of local data from member loads generation for validating purpose. This option is specified by a second OPTI command. Note, that Wajac will write up to 1e6 number of data rows for each of the files generated. Also note, that it is recommended to use OPT9=2 over OPT=1.

=0.0 or blank	No print of local data from member loads generation (Default).
=1.0	Print local data from member loads generation. File names are of following form: *fort.*number, e.g. *fort.46*.
=2.0	Print local data from member loads generation. Six different files will be created. File names are of following form: <*prefix*>LocalData_<*file index*>.lis. Where: <*prefix*> is determined based on FWAVE *prefix* parameter; <*file index*> is a natural number between 1 and 6, unique for each of the files generated.

OPT10

Relax wave breaking limits, see comments under HEIGHT in card SEA. This option is specified by a second OPTI command.

=0.0 or blank	Program is terminated if waves are beyond the breaking limits (Default).
=1.0	Program will continue, however, with warning messages printed out if the given wave(s) are beyond the breaking limits.

OPT11

Parameter controlling whether buoyancy forces at member ends are ignored or not in the Input Interface File, see comments under Section 2.4.8. This option is specified by a second OPTI command.

=0.0 or blank	Rational method. The components of the buoyancy force normal to the member are applied as constant force intensities along the member. The longitudinal components, are applied as nodal forces at both member nodes pointing into the member. This will induce compression forces in the member. (Default)
=1.0	Marine method. Include buoyancy in global vertical direction (+z), i.e. the weight of displaced fluid, as constant vertical force intensities along the member. There will be no nodal forces at both member nodes.
=2.0	Mixed method. This method uses the rational method for non-flooded members (non-flooded space and steel). For flooded members the marine method is used (steel). Buoyancy of marine growth is calculated using the marine method whether the member is flooded or not. This option is only available for deterministic analysis.

OPT12

Parameter controlling whether buoyancy forces as well as added mass and damping of horizontal beams at mudline are ignored, see comments under Section 2.4.8. When the global Z coordinates of two ends of a beam are located between a range of [seabed-tol, seabed+1.0e-6], such a beam is considered located at mudline. The tolerance for the lower limit (tol) is set as 10mm while the upper limit is always set as an absolute value of 1.0e-6 for backward compatibility. This option is specified by second OPTI command and applies to deterministic analysis only.

=0.0 or blank	The buoyancy of beams at mudline is not included. (Default)
=1.0	Include buoyancy, added mass and damping of beams at mudline. If a marine growth property is assigned on such beams, the weight and buoyancy contributed from marine growth is also included in the calculation.

OPT13 Parameter controlling whether some of the warning messages should be displayed in the Wajac print file or not. Possible values of the parameter and their meaning are described below.

=0.0 or blank	All relevant messages described here are displayed (default).
=1.0	None of the relevant messages will be displayed.
=2.0	Do not display following message: HYDRODYNAMIC COEFFICIENTS WERE NOT SPECIFIED FOR MEMBER NO. XXXX, DEFAULT VALUES WERE USED
=3.0	Do not display following message: MEMBER NO XXXX RECEIVES NO LOADS MEMBER NO XXXX RECEIVES NO ADDED MASS

OPT14 Parameter controlling which of the two methods available for calculation of Inverse Fast Fourier Transform should be used.

=0.0 or blank	New, more robust method is used (default).
=1.0	Previous method is used.

OPT15 Parameter controlling whether Wajac should produce a single Loads Interface File (for each superelement) or multiple Loads Interface Files, containing different types of loads as described below or in section Loads Interface File. If more than one file is to be generated then file names will differ, as described below.

Name of Loads Interface File is of the following form: *<prefix><Ls>n*.FEM. Where:

<prefix>	optional string provided through FMOD or FWAVE command.
<Ls>	string equal to *L* for OPT15=0 and equal to *WL*, *BL* or *GL* for other values of OPT15. Please see table below for values of this string referring to different pairs of OPT15 value and load/quantity type.
n	Superelement type number.

Note that with OPT15>0 Wajac will produce more than one S-file as described in section Analysis Control Data for Sestra, each corresponding to different load file type.

	OPT15		
	0. or blank	1.	2.
Quantity	*Value of <Ls>* L-file id		
Wave and current loads	L	WL	WL
Wind loads	L	WL	WL
Member buoyancy	L	BL	BL
Marine growth buoyancy	L	BL	BL
Marine growth weight	L	BL	GL
Added mass and damping	L	BL	BL
Wave kinematics, as requested through OPT5	L	WL	WL

OPT16 Parameter controlling choice of pseudo-random phase generator used within irregular sea analysis. See SEASIM command for description of input seed parameter and maximum value of seed for each of the OPT16 values available.

=0.0 or blank	Wajac will generate unique random phase sequence for each of the input seeds specified, i.e. two separate Wajac runs with different initial seeds will always generate different phase sequences. For most input seeds, this option will generate the same phase sequences as OPT16=1. Please see description of OPT16=1 for differences.
=1.0	This option should be used for backward-compatibility check, to compare results with those obtained with versions prior to Wajac 7.6-00. For most input seeds Wajac will generate the same sequences as OPT16=0, however for pairs listed below, two runs of Wajac will produce identical results, despite the fact that the two input seeds do differ. a) (k-1, k), where k is an odd natural number greater than 127. Example: (138, 139). b) (j, j*128+3), where j is a natural number less than 128. Example: (2, 259). Please note that Wajac may also generate identical results for some values of seed specified with more than 7 digits, this is a result of limited precision. There is no specific rule here, therefore it is advised not to use values of seeds with number of digits higher than 7.

OPT17 Parameter controlling decimal accuracy of some of the values printed in the Print File.

=0. or blank	Wajac will use default decimal accuracy equal 4.
=4. to 6.	Wajac will use decimal accuracy equal to 4.,5. or 6., correspondingly.
other	Wajac will use default decimal accuracy equal 4. A WARNING message will be printed to Wajac.lis file.

NOTES:
For valid input values equal 4., 5. or 6. additional, log information will be printed to the Print File

NOTES:

User may specify up to three OPTI commands. Each of the three OPTI commands relate to individual set of options as specified below.

	Relevant options
OPTI command no. 1 :	options 1-7
OPTI command no. 2 :	options 8-14
OPTI command no. 3 :	option 15-17

RESTRICTIONS:

No more than three OPTI commands may be specified.

SEA — Dataset: LOAD

Deterministic Load Calculation

Field:		1	2	3	4	5
Column: 3	5	10	15	20	30	40
SEA						
	var.1	THEO	CTNO	HEIGHT	PERIOD	PHI0
	var.2	0.0	ISEA	THEO	HEIGHT	PERIOD

Field:	6	7	8	9
Column:	50	60	70	80
T0		STEP	NSTEP	BETA
PHI0		T0	STEP	NSTEP

PURPOSE: To specify deterministic load calculation including waves and wave theory to be applied.

PARAMETERS:

THEO — Parameter identifying the wave theory to be used and the type of loads to be included in the calculation. The THEO parameter is of the form XY.NN where 'X' controls the type of loads included - only for var.1, see LOAD parameter on SEAOPT command for var.2 of SEA command specification. Description of LOAD parameter presents all available options for load-type selection. See the examples in the notes below. The 'Y.NN' identifies the wave theory through the following values:

- =1.1 Linear (Airy) wave theory with constant wave particle velocity and acceleration in the wave crest, equal to their values at the still water level (SWL).
- =1.2 Linear wave theory with exponential extrapolation of the wave particle velocity and acceleration above the SWL.
- =1.3 Linear wave theory with Wheeler stretching of the fluid kinematics. Any current specified is also stretched. For non-linear waves see the CSTR option on the SEAOPT command.
- =5.0 Stokes' 5th order wave theory
- =6.NN Dean's Stream Function wave theory of order NN, e.g.:
  THEO = 6.03 specifies wave theory order of 3
  THEO = 6.14 specifies wave theory order of 14
  THEO = 6.0 gives default value for NN which is 8
  Maximum value for NN is 24.
- =7.0 Cnoidal wave theory.
- =8.0 NEWWAVE wave theory. Additional data must be specified by the NEWWAVE command.
- =9.0 Calm sea condition. Only current, wind and buoyancy loads are calculated.

ISEA — Seastate index number referring to additional data specified on the SEAOPT command. If the ISEA parameter is blank or zero one SEAOPT command is required for each SEA command and must be specified in corresponding order.

CTNO — Parameter identifying current.

=0.0	No current is added.
> 0.0	Current profile index referring to current profiles specified through the CRNT command. The current velocities will be added to the velocities in the wave before calculating the loads.

HEIGHT	Wave height Shallow water breaking limit: HEIGHT/Depth=0.78 Deep water breaking limit: HEIGHT/Wave length =0.142. (Figure 3-4 in Ref. [2]) For each wave input, program will first roughly check whether the input wave is beyond the deep water and shallow water breaking limits. The wave length used for deep water breaking limit is based on deep water airy wave. Then the program will check again on deep water breaking limit, however with the wave length from the actual wave theory and actual water depth. To avoid terminating the program if the wave is beyond these limits, program can be continued however with warning messages printed out. Users need to set OPT10 as 1 in card OPTI in order to allow the program to make relaxation on these limits. If the NEWWAVE theory is specified then HEIGHT defines the maximum crest elevation measured from the still water level.
PERIOD	Wave period If the NEWWAVE theory is specified then PERIOD defines the peak period for the Pierson-Moskowitz or JONSWAP spectra. PERIOD is irrelevant for user defined wave spectrum but must be assigned a value different from zero.
PHI0	Initial phase angle of the wave in degrees defined through the position of the wave crest, see the notes below and Figure 2.2.
T0	Initial time. (The wave crest is at origin at $t = 0$.)
STEP	Phase or time step (phase step in degrees), see the NSTEP parameter.
NSTEP	Number of steps. If NSTEP is positive, STEP will indicate time steps. If NSTEP is negative, STEP is interpreted as phase steps.
BETA	Direction of wave propagation in degrees relative to the global X-axis. Positive angle is counter clockwise.

NOTES:

The interpretation of the THEO parameter may be clarified by the following examples. Note that load-type part of the THEO parameter has been underlined for clarity, the other part identifies wave theory and we will reference to it as wave-theory flag. The table 5.2 presented below, decodes types of loads relevant to specific value of load-flag. Please note that for variant 2 of SEA command load-type to be included can be selected through LOAD parameter on SEAOPT command, the description of which also includes the table mentioned. A description of each of these wave models or theories and guidelines for use of the different theories are given in Ref. [14].

Example	*Description*
THEO=1.1	Wave-theory flag = 1.1: Linear wave theory is applied. Load-type flag = blank: all type of loads are included.
THEO=16.10	Wave-theory flag = 6.10: wave is modeled using Dean's Stream Function wave theory of order 10. Load-type flag = 1: member buoyancy will be excluded from calculation - note that buoyancy and weight of marine growth, if present, will be included.
THEO=27.0	Wave-theory flag = 7.0: Cnoidal wave theory is used. Load-type flag = 2: only buoyancy loads and weight of marine growth will be calculated.

Table 5.2: Load types included in the analysis depending on the value of load-type flag

Load-type	Load-type selection flag						
	0. or blank	1.	2.	3.	4.	5.	6.
Wave	•	•			•	•	
Current	•	•			•	•	
Wind	•	•			•	•	
Member buoyancy	•		•		•		•
Marine growth buoyancy	•	•	•		•		•
Marine growth weight	•	•	•	•			

The phase angles of each step of the wave is defined relative to the zero phase defined in Figure 2.2, that is a wave with the crest at the origin of the global coordinate system. The phase angles (in radians) are given by

$$\text{PHI}_i = \text{PHI0} + 360 \cdot \frac{\text{T0}}{\text{PERIOD}} + \begin{cases} (i-1) \cdot 360 \cdot \dfrac{\text{STEP}}{\text{PERIOD}} & \text{if} \quad \text{NSTEP} > 0 \\ (i-1) \cdot \text{STEP} & \text{if} \quad \text{NSTEP} < 0 \end{cases}$$

Note that PERIOD in the above expression is set equal to T_Z if the NEWWAVE option is specified. T_Z is computed from the wave spectrum. For an evolving wave profile $\text{PHI}_i = 0.0$ corresponds to the phase angle where all the component waves are in phase. Since the NEWWAVE is non-harmonic with several frequency components the specified phase angle range should normally be in the range [-180,180] since the wave gradually dissolves.

When loads are calculated according to API additional seastate information may be required through the SEAOPT command. In that case var. 2 of SEA must be used.

If wind loads are to be evaluated var. 2 of SEA and SEAOPT must be used.

RESTRICTIONS:

A maximum of 50 different combinations of wave period, wave height and/or wave model (theory) may be specified. If Doppler effects are included then waves with different current profiles will also be counted.

The total number of steps specified by all SEA commands cannot exceed 200000.

A maximum of 3000 SEA commands may be specified. Note that only one wave can be specified when the NEWWAVE theory is applied.

SEAFRQ — Dataset: LOAD

Calculation of Transfer Functions

Field:	1	2	3	4
Column: 6	10	20	30	40
SEAFRQ	OPT	CTNO	BETA	

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To specify calculation of load transfer functions including wave direction and current. Wajac is executed in frequency domain.

PARAMETERS:

OPT — Parameter controlling the linearisation method to be used for the drag force.

- $= 1.0$ — Equivalent linearisation with respect to a short term seastate as defined by its wave spectrum will be used. The wave spectrum is specified by the SPECTR command.
- $= 2.0$ — Linearisation with respect to wave heights. In this case the wave heights must be defined by the AMP command.

CTNO — Parameter identifying current.

- $= 0.0$ — No current is added.
- > 0.0 — Current profile index referring to current profiles specified through the CRNT command. The current will in this case only affect the loads through the linearisation process. The constant load due to the current is extracted and printed in the Print File.

BETA — Direction of wave propagation in degrees relative to the global X-axis.

NOTES:

The wave periods for which values of the transfer functions are calculated must be specified by the FRQ command.

When applying linearisation with respect to wave heights the inertia forces are highly overestimated for vertical members crossing the SWL. The maximum horizontal acceleration, and thus the maximum horizontal inertia loads, occurs at the still water level. With linear wave theory and linearisation with respect to wave heights the fluid kinematics are assumed constant above the still water level and all hydrodynamic loads are applied up to the specified linearisation wave height during the complete wave cycle. The user may therefore consider reducing the inertia force coefficient for vertical members above the SWL to reduce the total inertia force.

RESTRICTIONS:

Equivalent linearisation (OPT =1.0) requires that distributed loads are written to the Loads Interface File. See the MODE command.

The same linearisation method must be used for all transfer functions calculated in one execution of Wajac.

Number of SEAFRQ commands times number of frequencies defined by the FRQ command may not exceed 960.

A maximum of 30 SEAFRQ commands may be given.

SEAOPT — Dataset: LOAD

Additional Seastate Data for Deterministic Load Calculations

Field:	1	2	3	4	5	6	7
Column:	6 10	15	20	25	30	35	40
SEAOPT		ISEA	BETA	WKFAC	CTNO	CBFAC	CSTR

Field:	8	9	10	11	12	13	
Column:	45	50	55	60	65	70	80
LOAD	DLOAD	WID	WIMET	IDPT	IDOP		

PURPOSE:

To specify additional seastate data for each deterministic wave defined by variant 2 of the SEA command.

PARAMETERS:

ISEA — Seastate index referring to the relevant seastates defined by the SEA commands.

BETA — Direction of wave propagation in degrees relative to the global X-axis

WKFAC — Wave kinematics factor by which the horizontal components of the wave kinematics will be multiplied to account for wave spreading and wave irregularities. The wave kinematics will be multiplied by WKFAC in addition to the 'global' scaling factor KINSCA specified by the KSCA command, thus the total scaling factor will be WKFAC*KINSCA. (If 0.0 or blank the value 1.0 is assumed)

CTNO — Parameter identifying current.

- =0.0 — No current is added.
- $>$0.0 — Current profile index referring to current profiles specified through the CRNT command. The current velocities will be added to the velocities in the wave before calculating the loads.

CBFAC — Current blockage factor by which the specified current profile is multiplied before combined with the wave kinematics. (If 0.0 or blank the value 1.0 is assumed).

CSTR — Stretching method for current

- =0.0 — Linear stretching based on the current profile up to mean water level will be applied to the current profiles when combined with wave kinematics. Current specified above mean water level will be neglected. If linear waves are specified the current profile will be stretched in the same way as the kinematics of the specified Airy waves, i.e. the CSTR value is neglected.
- $= -1.0$ — No stretching will be applied to the current profiles and buoyancy.

LOAD — Parameter controlling calculated load components

	Load-type selection flag						
Load type	0./blank	1.	2.	3.	4.	5.	6.
Wave	•	•			•	•	
Current	•	•			•	•	
Wind	•	•			•	•	
Member buoyancy	•		•		•		•
Marine growth buoyancy	•	•	•		•		•
Marine growth weight	•	•	•	•			

DLOAD — Design load option

=0.0 or blank	All specified steps of the wave are calculated and reported as specified by other parameters.
=1.0	Specified loads are calculated for both maximum base shear and maximum overturning moment selected among the phase angles specified on the SEA command. Two loadcases written to loads interface file.
=2.0	Specified loads are calculated for maximum base shear selected among the phase angles specified on the SEA command. One loadcase written to loads interface file.
=3.0	Specified loads are calculated for maximum overturning moment selected among the phase angles specified on the SEA command. One loadcase written to loads interface file.
=4.0	Specified loads are calculated for minimum base shear selected among the phase angles specified on the SEA command. One loadcase written to loads interface file.
=5.0	Specified loads are calculated for minimum overturning moment selected among the phase angles specified on the SEA command. One loadcase written to loads interface file.
=6.0	Specified loads are calculated for both minimum base shear and minimum overturning moment selected among the phase angles specified on the SEA command. Two loadcases written to loads interface file.

WID — Parameter identifying wind.

=0.0 or blank	No wind loads are calculated.
> 0.0	Wind profile index referring to wind profile specified through the WIND or WINX command. Wind loads are calculated for part of the structure above the still water level and added to the wave loads.

WIMET — Wind load calculation method.

=0.0 or blank	Wind loads are calculated according to Equation (2.42).
=1.0	Wind loads are calculated according to Appendix 9 in the Framework Theory Manual – Wind Fatigue, i.e. prepare for gust wind induced fatigue in Framework. This option requires calm sea, no current and exclusion of buoyancy loads.

IDPT — Water depth index referring to the relevant depth defined by DPTH commands.

	=0.0 or blank	For each depth specified, loads will be calculated for all given seastates.
	> 0	For each depth specified, only those seastates defined with the same IDPT number under DPTH command will be calculated correspondingly.
IDOP	Flag allowing for including Doppler effect for each seastate individually.	
	=-1.0	Do not include Doppler effect regardless of API card input.
	= 0.0 or blank	Set Doppler effect flag based on value of IDOPP parameter specified on API card. If API card is not specified then Doppler effect will not be included.
	= 1.0	Include Doppler effect regardless of API card input.

NOTES:

The specified wave kinematics and current factors have no influence on the calculated apparent wave period which is based on the undisturbed wave and current.

If only wind loads are required buoyancy loads must be excluded (LOAD=1.0) and calm sea condition must be specified on the SEA command (THEO=9.0).

A negative base shear force/overturning moment will be opposite to the considered wave direction.

API card does not have to be present in Wajac input file in order to consider Doppler effect.

SEAIN — Dataset: LOAD

Input File for Time Simulation analysis KUPA

Field:		1	
Column:	10		50
SEAIN	FNAME		

Field:	2	3	4	
Column:	60	70	80	90
FTYPE	RSTART	REND		

Field:		1	2	3
Column:	10	20	30	40
	TIMEL	TSTEP	HEPS	

PURPOSE:

To specify input data for regeneration of the sea. User may regenerate sea state either by specifying time series of surface elevation or by introducing series of data corresponding to individual wave components.

PARAMETERS:

FNAME — File name containing input data

FTYPE — Parameter specifying what kind of data is stored on the input file.

- ≤ 10 — Data given as time series of surface elevation.
- $= 11$ — Data given as wave components. 3rd column in the input file corresponds to angular frequency.
- $= 12$ — Data given as wave components. 3rd column in the input file corresponds to period.
- $= 13$ — Data given as wave components. 3rd column in the input file corresponds to frequency.

RSTART — First row from input file to be considered in the simulation.

- $= 0.0$ or blank — Wajac will read starting from 1st row. This is only available if the input file does not contain any comments. In other case it needs to be specified as first row where valid data resides.

REND — Last row from input file to be considered in the simulation.

- $= 0.0$ or blank — Wajac will read until end of file.

TIMEL — Simulation time.

TSTEP — Minimum time step to be considered during simulation.

HEPS — Parameter that allows to reduce number of components involved based on resulting characteristic wave height. The meaning of HEPS parameter is as follows: we require that the resulting value of characteristic height should not differ more than $\varepsilon_H \cdot 100\% \cdot H_{S0}$, where H_{S0} corresponds to original value of characteristic wave height, and ε_H is the fraction of H_{S0} determined similarly for all the 3 options available and depends only on HEPS.

- in range $[0, 1)$ — Lower and higher frequencies will be eliminated. $\varepsilon_H =$ HEPS.
- in range $[1, 2)$ — Only lower frequencies will be eliminated. $\varepsilon_H =$ HEPS - 1.
- in range $[2, 3)$ — Only higher frequencies will be eliminated. $\varepsilon_H =$ HEPS - 2.

NOTES:

Value of parameter TSTEP correspond to minimum required time step resolution. Wajac will try to adjust this value (refine time resolution) in order to make it work for Fast Fourier Transform algorithms which require number of time steps to be equal to power of 2 and time step to be equal to inverse of maximum frequency considered.

When conducting wave reconstruction, wave kinematics is determined directly at load calculation points. This is equivalent to non-grid option on SEASIM card.

Data given by wave components

User should specify at least one wave component.

All components specified in the input file should be given with increasing frequency. Corresponding frequency step should be constant, i.e. components should be evenly sampled along frequency axis. In case period is used instead of frequency, values of period should decrease.

Data given by time series

It is possible to obtain more refined solution than the one resulting from the input file. That means that user may specify smaller time step on the SEAIN card than the one used inside the input data. The important part is that the resulting solution will not be a linear interpolation of the results but exact values resulting from use of wave components. User should specify the same value of time step on the LOASIM card to reflect it in the results, e.g. in values stored on *1030.SER file.

RESTRICTIONS:

Wajac will not assume any default value for FTYPE parameter thus user have to remember to specify it explicitly in the input file.

It is not yet possible to use SEAIN command alongside with WAVC command, i.e. when performing constrained wave analysis. User needs to use SEASIM command instead.

Seastate Simulation Directives

Field:	1	2	3	4
Column: 6	10	20	30	40
SEASIM		LISGEN	ISPECT	NELDIR

Field:	5	6	7	8
Column:	50	60	70	80
		SIMLEN	SEED	TCUT

Field: 9			
Column: 90			
TIMESTEP			

PURPOSE:

To specify directives for the generation of an irregular sea simulating a specified short term seastate. The generated data is used for the subsequent time simulation of wave loads.

PARAMETERS:

LISGEN Parameter controlling print from the wave kinematics generation

- $= 0.0$ No print from generation
- $= 1.0$ Moderate print from generation
- $= 2.0$ Detailed print from generation (Dump)

ISPECT Parameter identifying the wave energy spectrum type to be used. The wave spectrum is defined by the SPECTR command. Note that different spectra require different input parameters, thus definition of SPECTR command for different spectra will differ. For theoretical description of the individual spectra please refer to section 2.3.7 .

- $= 1.0$ Pierson-Moskowitz spectrum
- $= 2.0$ JONSWAP spectrum
- $= 4.0$ Six-parameter Ochi-Hubble
- $= 5.0$ Torsethaugen (full version)
- $= 6.0$ Torsethaugen (simplified version)

NELDIR Number of component wave directions in the simulated seastate

- $= 1.0$ Long crested seas.
- $= 5.0$ Short crested seas with wave spreading defined by the ERG command.

SIMLEN Desired simulation length of the irregular sea in seconds.

SEED Starting value for generation of random phases. Note, that there are two ways random-phases can be generated, this is controlled by 16th parameter of OPTI command.

- For OPT16=0 two otherwise identical runs using different values for SEED will produce two different realizations of the same seastate. The upper limit for input seed is set to 67099541.
- For OPT16=1 there are certain pairs of input seeds which will generate the same sequence of phases. This option should be used for backward-compatibility check to compare results with those obtained with versions prior to Wajac 7.6-00. Please refer to description of OPT16 for more information. The upper limit is set to 9999999.

TCUT — Smallest wave period which will be contained in the generated irregular sea. Required by Fast Fourier Transformation (FFT), the value of TCUT should be input as twice the value of TIMESTEP (when TIMESTEP >0). The value of TCUT will be reset internally by program as TCUT=2*TIMESTEP (when TIMESTEP>0), regardless of users' input.

TIMESTEP — Time step used for new option of irregular sea wave simulation. If TIMESTEP is specified as 0 or as blank, then the old option of calculating and storing wave kinematics in a 3D grid will be applied.

NOTES:

When generating an irregular sea simulating the specified short term seastate the directives given by this command are used in connection with information specified through the SPECTR, ERG and GRID commands.

As the fast Fourier transform algorithm used for generation of the irregular sea requires that the number of time steps is a power of two the simulation is carried out for a number of steps satisfying this requirements. The actual simulation length will therefore generally be longer than specified by the SEASIM command. The number of time steps (if TIMESTEP =0) is given by:

$$\text{NSTEP} = \frac{2 \cdot \text{actual simulation length}}{\text{TCUT}}$$

The number of time steps (if TIMESTEP >0) is given by:

$$\text{NSTEP} = \frac{\text{actual simulation length}}{\text{TIMESTEP}}$$

See the LOASIM command for specification of the actual time simulation of wave loads.

RESTRICTIONS:

A maximum of 8192 (if TIMESTEP=0) time steps may be generated

A maximum of 262144 (if TIMESTEP>0) time steps may be generated

Maximum one SEASIM commands may be given.

SEGM — Dataset: LOAD

Member Segmentation as a Function of Vertical Position

Field:	1	2	3	4
Column:	6 10	20	30	40
SEGM		Z1	Z2	SEG

Field:	5	6	7	8
Column:	50	60	65	80
SLMIN		SLMAX	IMEM	

PURPOSE:

To specify varying member segmentation as function of vertical position. See also Section 2.2.3 and the notes below.

PARAMETERS:

Z1	Lower most vertical position relative to the mudline from which the specified data applies.
Z2	Upper most vertical position relative to the mudline to which the specified data applies.
SEG	Segmentation coefficient to be used within the specified range, that is with vertical position above mudline Z, satisfying $Z1 \leq Z < Z2$.
SLMIN	The minimum segment length independent of the segmentation coefficient. 1/20 of the member length is the absolute minimum independent of this parameter.
SLMAX	The maximum segment length independent of the segmentation coefficient. 1/2 of the member length is the absolute maximum independent of this parameter.
IMEM	Reference to MEMSEG commands for specification of members.

NOTES:

The following formula is used for controlling the number of segments in each member:

$$\text{Numbers of segments} = \frac{\text{SEG} \cdot \text{Member length}}{\text{Wave length}}$$

Note that the length of the member must be more than three times the wavelength to be split in three or more segments with SEG = 1.0.

This command overrides information given by the MSEG command.

For vertical regions not covered by any SEGM commands the segmentation coefficient specified by the MSEG command or the default value 1.0 will be used.

RESTRICTIONS:

A maximum of 10 SEGM commands may be given.

If auto-segmentation is enabled for deterministic analysis through MSEG card this command will not be taken into account.

SELI — Dataset: GEOM

Superelement Type Elimination

Field:	1	2	3	4
Column: 6	10	20	30	40
SELI		STYPE		

Field:	5	6	7	8
Column:	50	60	70	80

PURPOSE:

To eliminate superelement types from the load calculation. That is no hydrodynamic loads, buoyancy loads, wind loads or added mass will be calculated for any superelement of the specified type.

PARAMETERS:

STYPE Superelement type number of the superelement type to be excluded from the load calculation.

RESTRICTIONS:

A maximum of 100 superelement types may be eliminated from the load calculation.

SPEC — Dataset: HYDR

Definitions for Special Members

Field:		1	2	3	4	5	6
Column:	4 5	10	15	20	25	30	40
SPEC					STYPE	INDEX	DIAM
	var.1	N1	NN	STEP			
	var.2	SETNAM					

Field:	7	8	9	10
Column:	50	60	70	80
CDN	CDL	CMN	CML	

Field:	
Column:	85
IGWD	

PURPOSE:

To specify hydrodynamic properties for members which require special attention.

PARAMETERS:

N1	Selected member (element number) or first member in a sequence.	
NN	Last member in a sequence. Leave blank if only one member is defined on this command.	
STEP	Step in element numbers.	
SETNAM	A case-sensitive set name defining the set of members (maximum 8 characters).	
STYPE	Superelement type number to which this command applies.	
INDEX	Superelement index to which this command applies.	
DIAM	$= -1.0$	Member diameter is based on data from the Input Interface File
	≥ 0.0	Member diameter to be used for the specified members.
CDN	$= -1.0$	Transverse drag coefficient as specified by other commands are used. See the priority list in Section 2.2.7.
	≥ 0.0	Transverse drag coefficient for the specified members.
CDL	$= -1.0$	Longitudinal drag coefficient as specified by other commands are used.
	≥ 0.0	Longitudinal drag coefficient for the specified members.
CMN	$= -1.0$	Transverse inertia coefficient as specified by other commands are used.
	≥ 0.0	Transverse inertia coefficient for the specified members.
CML	Longitudinal inertia coefficient for the specified members (this option is only available through the SPEC/SPEX and/or CDFN command).	
IGWD	$= 0.0$ or blank	The coefficients defined for the beam(s) or the set of beams will be applied for all wave directions and seastates.
	> 0.0	The coefficients dependent on either a specific global wave direction or a specific seastate index, will be applied to the beam(s) or the set of beams. For unspecifed wave directions or seastate indices, the coefficients CDN/CMN/CDL/CML defined in SPEC/SPEX command will be applied. Only relevant for deterministic analyses.

NOTES:

Values specified by this command will supersede all values specified by any other commands, except CDIR/CDIX, and/or specified on the Input Interface File unless given the value -1.

Note that diameters defined by this command have no effect on calculation of buoyancy, mass and weight of marine growth and mass of internal water.

The members may either be referred to by the element numbers (var. 1) or through a named set of members defined on the Input Interface File (var. 2).

If the referred element numbers have more than 5 digits, the SPEX command must be used instead of SPEC.

RESTRICTIONS:

The total number of SPEC and SPEX commands cannot exceed 20000.

SPECTR — Dataset: LOAD

Definition of Wave Energy Spectrum

Version 1: single-peak spectra (Modified Pierson-Moskowitz and JONSWAP). Available in irregular sea, constrained wave and frequency domain analysis.

Field:	1	2	3	4
Column: 6	10	20	30	40
SPECTR		HS	TZ	SIGMAA

Field:	5	6	7	8
Column:	50	60	70	80
SIGMAB			GAMMA	ISPECT

Version 2: double-peaked spectra (Ochi-Hubble, Torsethaugen). Available only for irregular sea and constrained wave analysis. Both Torsethaugen spectra make use of only two first parameters - see details below.

Field:	1	2	3	4
Column: 6	10	20	30	40
SPECTR		HS1	TP1	SH1

Field:	5	6	7	8
Column:	50	60	70	80
HS2		TP2	SH2	

PURPOSE:

To specify the wave energy spectrum defining the seastate used in time simulation of wave loads or equivalent linearisation of the drag force.

PARAMETERS - single-peaked spectra:

HS	Significant wave height
TZ	Average zero up-crossing period
SIGMAA	JONSWAP spectrum left width. A default value of 0.07 will be used if SIGMAA is specified as 0.0.
SIGMAB	JONSWAP spectrum right width. A default value of 0.09 will be used if SIGMAB is specified as 0.0.
GAMMA	JONSWAP peak enhancement factor. A default value of 3.3 will be used if GAMMA is specified as 0.0.
ISPECT	Parameter identifying the wave energy spectrum type to be used for the equivalent linearisation specified by the SEAFRQ command.
	$= 1.0$ Pierson-Moskowitz spectrum
	$= 2.0$ JONSWAP spectrum

PARAMETERS - double-peaked spectra:

In description of the command (Version 2) these parameters are specified with indices 1 and 2. The numbers relate to primary and secondary spectra respectively. Usually the primary spectra belongs to lower frequency range. In case of the Torsethaugen spectra, only the two first primary-spectra parameters are used, that is HS1 and TP1. In this case those relate to the entire spectrum.

HS	Significant wave height. This can be specified as 0., for example to suppress one part of the spectra.
TP	Period relevant to frequency of peak of the spectra. **This quantity cannot be specified as 0.**, both for Ochi-Hubble and Torsethaugen spectra.
SH	Spectral shape parameter. Used only for Ochi-Hubble spectrum. Default = 3.

NOTES:

For a seastate simulation analysis the type of wave energy spectrum to be used is specified by the ISPECT parameter on the SEASIM command and the last parameter on the SPECTR command is disregarded.

RESTRICTIONS:

Maximum one SPECTR command may be given.

SPEX — Dataset: HYDR

SPEC Command for up to 10 Digits Element Numbers.

Field:	1	2	3	4
Column:	4 10	20	30	40
SPEX				
	var.1	N1	NN	STEP
	var.2	SETNAM		

Field:	5	6	7	8	9	10	11
Column:	45	50	60	65	70	75	80
STYPE	INDEX	DIAM	CDN	CDL	CMN	CML	

Field:	5
Column:	85
IGWD	

PURPOSE:

Replace the SPEC command for element numbers with more than 5 digits.

PARAMETERS:

The parameters are the same as for the SPEC command.

RESTRICTIONS:

The total number of SPEC and SPEX commands cannot exceed 20000.

TANK — Dataset: LOAD

Cylindrical Tank in Vicinity of a Jacket Structure

Field:	1	2	3	4
Column: 6	10	20	30	40
TANK		X	Y	DIAM

Field:	5	6	7	8
Column:	50	60	70	80
PRSW		MAXQ	OPTWAV	OPTCUR

PURPOSE:

To specify location and dimension of a cylindrical tank in the vicinity of the jacket structure. The tank is assumed to have uniform diameter and to extend from the mudline and above the highest wave crest.

PARAMETERS:

X,Y — Coordinates of the centre of the cylinder, specified relative to the origin of the global coordinate system.

DIAM — Outer diameter of the tank.

PRSW — Print switch for intermediate results.

- $= 0.0$ — No additional output is produced (default)
- ≥ 6.0 — Overall results.
- ≥ 7.0 — Detailed results.
- ≥ 8.0 — All intermediate results.

Note that excessive amount of output may be produced.

MAXQ — Maximum number of terms in Bessel function expansion. Default value=20.0. Should be in range 10.0 to 50.0.

OPTWAV — Verification options for wave kinematics.

- $= 0.0$ — Modified wave kinematics are used (default).
- $= 1.0$ — Only diffracted kinematics are used (incoming wave omitted).
- $= 2.0$ — Only undisturbed wave kinematics are used.

OPTCUR — Verification options for current velocities.

- $= 0.0$ — Modified current is used (default).
- $= 1.0$ — Only modification of current is used.
- $= 2.0$ — Only undisturbed current is used.

RESTRICTIONS:

The command is only applicable for deterministic wave analysis. Maximum one cylindrical tank may be specified.

TITL — Dataset: WAJAC

Job Identification

Field:		1	
Column:	4		80
TITL	TEXT		

PURPOSE:

To enter user defined text strings which will be printed in the Print File and written to the Hydrodynamic Results Interface File. The text-strings may be used to identify the specific analysis which have been performed.

PARAMETERS:

TEXT Text describing the analysis.

RESTRICTIONS:

The text string may not contain more 76 characters.

Maximum 5 text strings may be specified.

TSKI — Dataset: LOAD

Filtering parameters for time simulation analysis

Field:		1	2	
Column: 4	10	20	30	40
TSKI		THRESHT	IFILT	

PURPOSE:

To specify threshold period allowed during time simulation analysis. Frequencies higher than $\frac{1}{\text{THREST}}$ will not be considered.

PARAMETERS:

THRESHT Minimum value of period allowed in the analysis. Note that this value cannot be smaller than two times of time step used for simulation. For example when SEASIM card is used, then it cannot be specified smaller that 2·TIMESTEP. Wajac will terminate with an ERROR message if this value is too low. The relevant message will contain information about minimum allowed value for THRESHT parameter.

IFILT Flag controlling whether filtering should be applied only to kinematics (IFILT = 0) or both kinematics and wave elevation calculation (IFILT > 0).

RESTRICTIONS:

Only one TSKI command may be specified. Period

WAJAC — Dataset: WAJAC

Dataset Identification: Execution Directives

Field:		1	
Column:	5		80
WAJAC			

PURPOSE:

To identify execution directives. This command must be the first command in the input.

RESTRICTIONS:

Maximum one WAJAC commands may be given.

WAVC — Dataset: LOAD

Definition of Constrained Wave

Field:		1	2	3	4
Column: 4	5	10	20	30	40
WAVC		CWOPT	TIME	HEIGHT	PERIOD

Field:	5	6	7	8
Column:	50	60	65	70
XG		YG	RBF1	RBFM

Field:	9	10		
Column:	75	80		
SFORDER		NWPROF		

PURPOSE:

To define parameters for a constrained wave embedded in an irregular sea. For more information please see the description in Sec. 2.1.4.

PARAMETERS:

CWOPT — Parameter controlling how Constrained Wave will be applied.
- $= 0$ — Constrained Wave will not be applied, standard time-simulation analysis will be executed. This is equivalent to omitting the WAVC command from the Wajac input file.
- $= 1$ — Analysis without constraining period. Only NewWave theory used.
- $= 2$ — Period constrained. NewWave and Stream Function theories used.
- $= 3$ — Period constrained. Only Stream Function theory used.

TIME — Time instant of occurance of Constrained Wave's crest.

HEIGHT — Constrained Wave height. Defined from trough to crest.

PERIOD — Constrained Wave period. Applicable only for CWOPT = 2,3

XG — X coordinate of occurance of Constrained Wave (default = 0.)

YG — Y coordinate of occurance of Constrained Wave (default = 0.)

RBF1 — Parameter controlling for how many peak periods of irregular sea the blending function for NewWave equals 1. Default equal 4.

RBFM — Parameter controlling for how many peak periods of irregular sea blending function for NewWave would gradually be decreasing from 1 to 0. This can be specified with 1-decimal precision. Default equal 1.

SFORDER — Stream Function order.

NWPROF — Parameter controlling which of the two available NewWave profiles will be applied.
- $= 1.0$ or blank — Evolving (default). Wave profile varies over space.
- $= 2.0$ — Frozen. Wave profile remains unchanged over space.

NOTES:

Following parameters are only applicable when NewWave theory is used: RBF1, RBFM, NWPROF.

Following parameters are only applicable when Stream Function theory is used: SFORDER.

RESTRICTIONS:

Maximum one WAVC command may be given.

WIND — Dataset: LOAD

Definition of Wind Profiles

Field:		1	2	3	4
Column: 4	5	10	20	30	40
WIND		WID	VEL	ANGLE	GUSTF

Field: 5	6	7	8	9	10
Column: 50	60	65	70	75	80
H0	HEXP	PRAT	IFORM	IAPP	

PURPOSE:

To define stationary wind profiles.

PARAMETERS:

WID	Wind profile index.	
VEL	Mean wind velocity at reference height: V defined in Section 2.4.9.	
ANGLE	Wind angle: θ defined in Section 2.4.9.	
GUSTF	Gust factor: f defined in Section 2.4.9.	
H0	Mean wind velocity reference level relative to SWL: H_0 defined in Section 2.4.9.	
HEXP	Height exponent: P defined in Section 2.4.9.	
PRAT	Mean period ratio: T_a/T_{a0} defined in Section 2.4.9.	
IFORM	Wind profile formula.	
	$= 0.0$ or blank	Equation (2.37).
	$= 1.0$	Equation (2.38).
	$= 2.0$	Equation (2.39).
	$= 3.0$	Equation (2.40)
	$= 4.0$	Equation (2.41)
IAPP	Approach used for wind calculation	
	$= 0.0$ or blank	Equation (2.42).
	$= 1.0$	Equation (2.43).

NOTES:

The wind profile may be printed to the Print File by using the KPRT command.

Whenever IFORM $= 2$ or IFORM $= 3$ is selected $H_0 = 10m$ is assumed regardless of user input.

If defined, marine growth thickness is added to member diameter.

RESTRICTIONS:

The total number of WIND and WINX cannot exceed 3000.

WINX — Dataset: LOAD

Definition of Wind Profiles allowing Mean Period Ratio with higher precision

Field:		1	2	3	4
Column: 4	5	10	20	30	40
WINX		WID	VEL	ANGLE	GUSTF

Field:	5	6	7	8	9
Column:	50	60	70	75	80
H0		HEXP	PRAT	IFORM	IAPP

PURPOSE:

To define stationary wind profiles.

PARAMETERS:

WID	Wind profile index.	
VEL	Mean wind velocity at reference height: V defined in Section 2.4.9.	
ANGLE	Wind angle: θ defined in Section 2.4.9.	
GUSTF	Gust factor: f defined in Section 2.4.9.	
H0	Mean wind velocity reference level relative to SWL: H_0 defined in Section 2.4.9.	
HEXP	Height exponent: P defined in Section 2.4.9.	
PRAT	Mean period ratio: T_a/T_{a0} defined in Section 2.4.9.	
IFORM	Wind profile formula.	
	$= 0.0$ or blank	Equation (2.37).
	$= 1.0$	Equation (2.38).
	$= 2.0$	Equation (2.39).
	$= 3.0$	Equation (2.40).
	$= 4.0$	Equation (2.41).
IAPP	Approach used for wind calculation	
	$= 0.0$ or blank	Equation (2.42).
	$= 1.0$	Equation (2.43).

NOTES:

The wind profile may be printed to the Print File by using the KPRT command.

Whenever IFORM $= 2$ or IFORM $= 3$ is selected $H_0 = 10m$ is assumed regardless of user input.

If defined, marine growth thickness is added to member diameter.

RESTRICTIONS:

The total number of WIND and WINX cannot exceed 3000.

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