

SESAM EXAMPLE

Flare Boom Wind Fatigue Analysis





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## **1** Introduction

In this example, a workflow is established in Sesam Manager for wind induced fatigue analysis of the flare boom shown in **Figure 1-1** below. Programs and versions used are GeniE 8.3, Wajac 7.8, Sestra 10.15, Prepost 8.4 and Framework 4.3. Wajac and Sestra are run from GeniE. Prepost and Framework are controlled by Sesam Manager, see the workflow in **Figure 1-2**. Inputs files are provided for GeniE and Framework. Sesam Manager creates the input for Prepost.

The wind fatigue damage to the flare boom has two contributing factors, wind buffeting (variable wind acting on the whole structure) and vortex shedding (due to constant wind acting on individual members).

Such a wind fatigue analysis in Sesam requires two analyses in Sestra:

- 1. Eigenvalue analysis including computation of modal load factors
- 2. Static analysis of constant wind loads computed by Wajac

The two results files from Sestra are merged in Prepost. Opening the merged results file, Framework computes fatigue damages due to wind gusts (buffeting) and vortex shedding.

On the following pages the task is described step by step.



Figure 1-2 Sesam Manager workflow shown as 'Tree View'



## 2 The Sesam Manager Workflow

Start Sesam Manager, create a new job and import the ZIP file Flare\_Boom\_Wind\_Fatigue.zip.

The workflow shown in Figure 1-2 appears.

The GeniE activity GeniEModelllingAndAnalyses creates the model and runs two analyses:

- Eigenvalue analysis computing the free vibration modes and periods.
  - The analysis also computes 'modal load factors' (also termed 'modal mass factors' and 'mass participation factors'). This is achieved by checking the *Modal Mass Factors* option highlighted below when editing the eigenvalue analysis within the GeniE activity monitor:

Activity Monitor			×	
*		Sta	rt Cancel	
Journal activity executions			Linear Analysis	
Activity	Duration	Status		
I - Eigenvalue - Analysis	2s	Succes	<b>EE</b>	
🗹 🤁 1.1 - Meshing (Conditional Regenerate)	1s	Succes	I Datacheck Only I Automatic gene	eration of input files
1.1.1 - Delete loads	Os	Succes	Analysis type	Eigenvalues
1.1.2 - Update loads	Os	Succes		Solver eqMultifrontLanczos
1.1.3 - Delete mesh	Os	Not St	Static Analysis	Contra Co
1.1.4 - Update mesh	1s	Succes	Eigenvalue Analysis	Number of Modes 10
✓ <sup>Kr</sup> <sub>=R</sub> 1.2 - Linear Structural Analysis, Eigenvalu	- 15	Succes	C Dynamic Response	chift 0
R 1.3 - Load Results	ar Sestra Anal	ysis		Shire
sestra.im			Modal Superposition	Modal Mass Factors

Figure 2-1 Compute modal mass factors in the eigenvalue analysis

- o ('Modal load factors' are also computed as part of an earthquake analysis.)
- Static analysis of constant wind loads. A single wind speed from six directions (0°, 30°, 60°, 90°, 120°, 150°) are analysed. When editing the 'wave load' activity, actually 'wind load activity' in this case, within the GeniE activity monitor check the *Single step* and *Prepare for gust wind induced fatigue* options as shown below. This involves that three wind load cases are created for each single wind speed, namely wind load in the wind direction and wind loads in the two perpendicular directions.



Figure 2-2 Prepare for gust wind induced fatigue in the static analysis

The Prepost activity PrepostMergeAnalyses merges the static results file into the eigenvalue results file thus combining both results in a single file.

The Framework activity FrameworkWindFatigue performs the wind fatigue analysis.



# 3 Run the Job

The required input files are assigned to the various activities, so the job is ready to be run.

After running the GeniE activity with its eigenvalue and static analyses make sure the results files EigenvalueR1.SIN and StaticR1.SIN reside in the repository.

The Prepost activity has *AnalysisType* set to *MergeResultFiles*, *InputFilePrefix* set to Eigenvalue and *MrgeInputFilePrefix* set to Static. This involves that Sesam Manager establishes the proper Prepost input for merging the static results file into the eigenvalue results file. After running Prepost make sure the results file MERGED\_EigenvalueR1.SIN resides in the repository and that this file is bigger than the two other results files.

The Framework activity input contains:

- Opening the merged results file and transferring results into the Framework database
- Definition of various wind parameters
- Definition of wind directions
- Definition of wind speeds
- Definition of wind probabilities
- Definition of wind drag correction factors (the computation of these is not discussed here)
- Definition of member fixities for the vortex shedding
- Definition of various vortex parameters
- Creation of analysis planes
- · Assignment of wind type as buffeting or vortex shedding or both, in this case both
- Selection of joints and members (within the analysis planes) to consider
- Assignment of SCFs
- Assignment of run case parameters for the fatigue analysis
- The RUN command executing the fatigue analysis

The Framework wind fatigue output is discussed in the next chapter.



## 4 The Wind Fatigue Results

There is no graphic presentation of wind fatigue results, rather the results are found in tables in the file <prefix>FrameworkWind.lis where <prefix> is a string given in the RUN command in Framework. In this case the file with the tabulated results is named FATIGUEFrameworkWind.lis.

Subsequent to an outline of the analysis by interpretation of the input, the buffeting damages are tabulated followed by the vortex induced damages and concluded by the total, buffeting plus vortex induced, damages.

### 4.1 Buffeting Damages

The buffeting damage tables include the following tables.

BUFFETING	DAMAGE	ΤZ	BLE	FOR WIND DIRECT	EON 1,	0.0 DE	G. (PRI	INT OF	DAMAG	E > 1.0	00E-1	5)								
		===																		
N	N	Ρ	ΡS																	
0	0	L	0 1							<==REL	ATIVE	DAMAGES	AROU	ND THE	WELD	====>				
D	D	А	SI	)	<-	-	Side 1:	Chord	side	points		>	<	Si	de 2:	Brace	side j	points		>
E	E	Ν	NE																	
1	2	Е		DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	54	1	4 1	9.3015E-07	7 31.3	53.8	89.9	100.0	70.1	40.4	28.0	25.4	31.3	53.8	89.9	100.0	70.1	40.4	28.0	25.4
1	55	1	8 1	2.1955E-0	67.7	38.0	27.2	27.4	35.9	58.5	92.5	100.0	67.7	38.0	27.2	27.4	35.9	58.5	92.5	100.0
4	8	1	1 1	5.0050E-04	100.0	61.7	20.0	12.4	14.6	12.5	14.9	47.8	50.1	27.5	6.8	4.1	5.6	4.4	4.7	19.8
8	11	1	4 1	4.7394E-0	0.5	0.3	20.6	100.0	61.1	4.3	2.0	5.0	0.0	0.1	4.4	9.2	2.3	0.1	1.3	1.4
10	8	1	2 1	2.8094E-04	4 86.2	100.0	67.5	61.9	47.2	15.5	7.1	23.1	45.9	47.3	25.2	27.0	23.7	5.1	1.4	7.8
mmin	ويستريم المسار	~~	man	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	1	with man	-azm	-saa-	~~~ 5	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	$\sim$	mm	naa		man	R4-	mana		~~ <u>~</u> ~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~



BUFFETING	DAMAGE TAB	LE FOR	ALL WIND DIRE	CTIONS	(PRIN	T OF E	AMAGE	> 1.0	00E-15)										
========																			
N	NPP	S																	
0	OLO	I							<==REL	ATIVE	DAMAGE	S AROU	ND THE	WELD	====>				
D	DAS	D		<	S	ide 1:	Chord	side	points		>	<	Si	de 2:	Brace	side p	oints		>
E	ENN	E																	
1	2 E		DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	54 1 4	1	1.3742E-06	35.2	58.2	92.1	100.0	72.0	43.8	31.2	28.6	35.2	58.2	92.1	100.0	72.0	43.8	31.2	28.6
1	55 1 8	1	3.4530E-07	79.0	46.9	29.6	28.8	39.9	65.9	92.8	100.0	79.0	46.9	29.6	28.8	39.9	65.9	92.8	100.0
4	8 1 1	1	1.3351E-03	100.0	52.1	12.6	7.5	9.2	8.1	12.1	50.4	54.0	23.9	4.1	2.5	3.6	2.8	3.9	22.9
8	11 1 4	1	1.2155E-06	0.6	0.3	26.8	100.0	44.4	2.2	1.4	4.8	0.0	0.2	6.8	11.3	1.7	0.0	1.2	1.6
10	8 1 2	1	4.4499E-04	85.6	100.0	76.2	90.5	81.7	25.6	8.9	24.1	45.1	46.4	27.9	41.1	43.2	8.9	1.7	8.1
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Figure 4-2 Buffeting damage for members for all wind directions, highest for all directions

20	WORST	BUFFETING DAMAGE	S - ALL WIND D	IRECTIO	NS (P	RINT OF	DAMAG	2 > 1	.000E-1	5)									
==		NDDC								==									
	0	OLOI							<==REL	ATIVE	DAMAGE	S AROU	ND THE	WELD	====>				
	D	DASD		<		Side 1:	Chord	side	points		>	<	Si	de 2:	Brace	side p	oints		>
	E	ENNE																	
	1	2 E	DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	17	11 1 1 1	8.6966E-03	100.0	21.1	0.0	0.0	0.2	0.0	0.9	39.1	10.5	1.4	0.0	0.0	0.0	0.0	0.0	3.1
	16	21 1 1 1	6.1310E-03	100.0	39.7	0.4	1.5	12.9	2.2	0.3	29.0	44.3	18.1	0.2	0.5	4.6	0.8	0.1	11.7
	17	20 1 1 1	5.2808E-03	100.0	38.3	4.7	9.8	20.5	5.3	2.0	27.6	28.0	10.6	1.1	2.2	3.8	0.7	0.3	5.9
	4	8 1 1 1	1.3351E-03	100.0	52.1	12.6	7.5	9.2	8.1	12.1	50.4	54.0	23.9	4.1	2.5	3.6	2.8	3.9	22.9
L	16	22 1 1 1	1.0996E-03	100.0	35.2	0.4	4.3	29.1	5.4	0.1	22.3	39.7	15.7	0.5	1.7	10.6	2.2	0.1	





### 4.2 Vortex Induced Damages

The buffeting damage tables include the following tables.

VORTEX	INDUCED	M	EMBI	ER	END	DAI	MAGE TABI	LE FO	R WIN	D DIRE	CTION	1, 0.0	DEG.	(PRINT	OF DA	AMAGE >	1.000	)E-15)						
	N	N	PI	P S	F	F																		
	0	0	Г	L C	1	1								<==RET	ATIVE	DAMAGES	AROU	JND THE	WELD	====>				
	D	D	A	s D	X	X			<	5	ide I:	Chord	side	points	;	>	<	Si	de 2:	Brace	side p	oints		>
	E	E	NI	NE	1	2							-						-		-		-	
	1	2	E		*8	*	DAMA	ΞE	1	2	3	4	5	6	1	8	1	2	3	4	5	6	1	8
	4	8	1 :	2 1	80	20	1.1866E-	-04	5.7	100.0	0.0	1.6	5.7	100.0	0.0	1.6	6.4	89.0	0.0	1.0	6.4	89.0	0.0	1.0
	8	11	1 2	21	80	80	6.0058E-	-04	0.6	100.0	0.0	10.4	0.6	100.0	0.0	10.4	0.4	9.2	0.0	0.2	0.4	9.2	0.0	0.2
	.0	8	1 4	4 1	80	20	1.8221E-	-04	4.5	2.1	0.0	100.0	4.5	2.1	0.0	100.0	4.8	1.4	0.0	87.3	4.8	1.4	0.0	87.3
	1	8	1 4	1 1	80	80	1.3526E-	-05	9.2	0.8	0.0	100.0	9.2	0.8	0.0	100.0	9.2	0.3	0.0	71.2	9.2	0.3	0.0	71.2
	.3	20	1 4	4 1	80	80	1.6173E-	-04	0.6	11.3	0.0	100.0	0.6	11.3	0.0	100.0	0.9	3.2	0.0	57.4	0.9	3.2	0.0	57.4
m	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	<u></u>	-1	2. 1	~~~	-09	~ <u>~</u>	- am	man	200-Ar	ma	سمحم		100~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	man	_a~~	-60-7-		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	ma	-60-07-	~~ <u>~</u> ~~~	~~~~~
VORTEX	INDUCED	M	EMBI	ER	CEN	<b>F</b> RE	DAMAGE 1	FABLE	FOR	WIND D	IRECTI	ON 1, (	0.0 DI	EG. (PR	INT OF	F DAMAGE	> 1.	000E-1	5)					
					===:														==					
	N	Ν	ΡI	P S	F	F																		
	0	0	L (	ΙC	I	I								<==REL	ATIVE	DAMAGES	AROU	JND THE	WELD	====>				
	D	D	A S	5 D	Х	Х																		
	E	E	N 1	ΙE	1	2																		
	1	2	Е		8	8	DAMAG	ΞE		1		2		3		4		5		6		7		8
	4	8	1 1	1 1	35	65	1.4125E-	-03		100.0		17.7		0.0		17.7		100.0		17.7		0.0		17.7
	8	11	1 1	11	80	80	2.0465E-	-04		100.0		17.7		0.0		17.7		100.0		17.7		0.0		17.7
	.0	8	1 1	ι 1	20	80	1.6441E-	-03		100.0		17.7		0.0		17.7		100.0		17.7		0.0		17.7
	1	8	1 1	1 1	80	80	2.0465E-	-04		100.0		17.7		0.0		17.7		100.0		17.7		0.0		17.7
	3	20	1 1	1 1	80	80	1.2181E-	-04		100.0		17.7		0.0		17.7		100.0		17.7		0.0		17.7
	ver man			× 1	0.0	- 00	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	asn		100.00	m	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	maria				10000		~17-7	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	ma 0 .	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	man an

#### Figure 4-4 Vortex induced damage for members for wind directions 1, 2, 3 ..., member ends and centres

VODEEV	TNDUCET	ME	MDT	ED 1	END	DBA	ADCE MADIE	FOD ALL	MIND	DIDECT	TONG	DDTNE	OF DAM	DCE >	1 000	P-1E)							
VORTEA	INDUCEL	J ME	PIDI	5R .	END	DAP	AGE TABLE	FOR ALL	- WIND	DIRECI		(PRINI	OF DAP	IAGE >	1.000	E-15)							
	N	N	PI		F	F																	
	0	0	T. C		Ť	Ť							<==RFI	ATTVE	DAMAG	ES ARO	UND THE	WELD	====>				
	D	D		s n	x	x		1 <		Side 1	Chore	d side	noints		>	<	Si	de 2.	Brace	side	noints		> 1
	F	F	NN	a F	1	2				Dide i	OHOL	a brac	porner	, 			01	ac z.	Druce	Dide	porneo		
	1	2	E I		\$	2	DAMAGE	1	2	3	4	5	6	7	8	1	2	з	4	5	6	7	8
	1	-	-			0	DHINGE	-	2	5	-	5	0		0	-	2	5	-	5	0		0
	4	8	1 1	2	80	20	1.9767E-04	89.3	95.9	0.0	5.6	89.3	95.9	0.0	5.6	100.0	88.0	0.0	5.1	100.0	88.0	0.0	5.1
	8	11	1 2	2 1	80	80	7 8541E-04	11 2	100 0	0.0	41 2	11 2	100 0	0.0	41 2	6 7	9.5	0.0	3 1	6.7	9.5	0.0	3 1
	10	8	1 4	1 1	80	35	2.6796E-04	75.3	7.3	0.0	100.0	75.3	7.3	0.0	100.0	79.9	6.4	0.0	89.3	79.9	6.4	0.0	89.3
	11	8	1 1	îĩ	80	80	2 8340E-05	100 0	21.6	0.0	67 6	100 0	21.6	0.0	67 6	100 0	16.0	0.0	49.9	100.0	16.0	0.0	49 9
	13	20	1 4	1 1	80	80	2.2937E-04	13.1	34.2	0.0	100.0	13.1	34.2	0.0	100.0	21.8	17.3	0.0	59.7	21.8	17.3	0.0	59.7
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VORTEX	INDUCED	) ME	MBE ===	ER (	CEN	TRE	DAMAGE TAB	LE FOR	ALL W	IND DIF	RECTIO	NS (PR	INT OF	DAMAG	E > 1.	000E-1	5) ==						
VORTEX	INDUCED	) ME ===== N	MBE === P E	ER S S	CEN ==== F	FRE F	DAMAGE TAB	LE FOR	ALL W	IND DIF	RECTION	NS (PR	INT OF 	DAMAGI	E > 1.	000E-1 ======	5)						
VORTEX	INDUCED N O	0 ME N 0	MBE === P E L C	ER  P S D I	CEN ==== F I	F F I	DAMAGE TAB	LE FOR	ALL W	IND DIF	RECTION	NS (PR =====	INT OF ======= <==REI	DAMAG ======	E > 1. ====== DAMAG	000E-1 ====== ES ARO	5) == UND THE	WELD	====>				
VORTEX	INDUCED N O D	0 ME N 0 D	MBE PE LC AS	ER 9 S 0 I 5 D	CEN F I X	F F I X	DAMAGE TAB	LE FOR	ALL W	IND DIF	RECTION	NS (PR =====	INT OF ======= <==REI	DAMAGI	E > 1. ====== DAMAG	000E-1 ===== ES ARO	5) == UND THE	WELD	====>				
VORTEX	INDUCED N O D E	0 ME N O D E	MBE PE LC AS NN	ER PS DI DI DI E	CEN F I X 1	F F I X 2	DAMAGE TAB	LE FOR	ALL W	IND DIF	RECTION	NS (PR =====	INT OF ======= <==REI	DAMAGI	E > 1. ====== DAMAG	000E-1 ====== ES ARO	5) == UND THE	WELD	====>				
VORTEX	INDUCED N O D E 1	0 ME N O D E 2	MBE P E L C A S N N E	ER PS DI DI DI E	CEN F I X 1 %	F F I X 2 %	DAMAGE TAB	LE FOR	ALL W	IND DIF	ECTION	NS (PR =====	INT OF ======= <==REI 3	DAMAGI	E > 1. DAMAG	000E-1 ====== ES ARO	5) == UND THE 5	WELD	====>		7		8
VORTEX	INDUCED N O D E 1	0 ME N O D E 2	MBE PE LC AS NN	ER S S D I S D I E	CEN F I X 1 %	F I X 2 %	DAMAGE TAB	LE FOR ======	ALL W	IND DIF ======	RECTION	NS (PR	INT OF ======= <==REI 3	DAMAGI	E > 1. DAMAG	000E-1 ====== ES ARO	5) == UND THE 5	WELD	====>		7		8
VORTEX	INDUCED N O D E 1	0 ME N O D E 2 8	MBE P E L C A S N N E 1 1	ER PS DI DI E	CEN F I X 1 %	F F X 2 % 80	DAMAGE TAB DAMAGE 2.6101E-03	LE FOR	ALL W	IND DIF	2 17.7	NS (PR	INT OF ===REI 3 0.0	DAMAGI	E > 1. DAMAG 4 17.7	000E-1 ====== ES ARO	5) == UND THE 5 100.0	WELD	====> 6 17.7		7		8
VORTEX ======	INDUCED N O D E 1 4 8	0 ME N O D E 2 8 11	MBE P E L C A S N N E 1 1 1 1	ER ( S S S D N E L 1 L 1	CEN F I X 20 80	F F I X 2 % 80 80	DAMAGE TAB DAMAGE 2.6101E-03 3.2387E-04	LE FOR ======	ALL W 1 100.0 100.0	IND DIF	2 17.7 17.7	NS (PR	INT OF <==REI 3 0.0 0.0	DAMAGI	E > 1. DAMAG 4 17.7 17.7	000E-1 ====== ES ARO	5) == 5 100.0 100.0	: WELD	====> 6 17.7 17.7		7 0.0 0.0		8 17.7 17.7
VORTEX ======	INDUCED N O D E 1 4 8 10	0 ME N O D E 2 8 11 8	MBE P E L C A S N N E 1 1 1 1 1 1	ER ( S S S D I E I 1 I 1	CEN F I X 20 80 35	F F I X 2 % 80 80 80	DAMAGE TAB DAMAGE 2.6101E-03 3.2387E-04 2.9682E-03	LE FOR ======	1 100.0 100.0 100.0	IND DIF	2 17.7 17.7 17.7	NS (PR	INT OF <==REI 3 0.0 0.0 0.0	DAMAGI	E > 1. DAMAG 4 17.7 17.7 17.7	000E-1 ====== ES ARO	5) == 5 100.0 100.0 100.0	: WELD	====> 6 17.7 17.7 17.7		7 0.0 0.0 0.0		8 17.7 17.7 17.7
VORTEX ======	INDUCED N O D E 1 4 8 10 11	0 ME N O D E 2 8 11 8 8	MBE P E L C A S N N E 1 1 1 1 1 1	ER ( P S D I S D I E L 1 L 1 L 1 L 1	CEN F I X 20 80 35 80	F I X 2 % 80 80 80 80 80	DAMAGE TAB DAMAGE 2.6101E-03 3.2387E-04 2.9682E-03 3.2387E-04	LE FOR	1 100.0 100.0 100.0 100.0	IND DIF	2 17.7 17.7 17.7 17.7	NS (PR	INT OF <==REI 3 0.0 0.0 0.0 0.0	DAMAGI	E > 1. DAMAG 4 17.7 17.7 17.7 17.7	000E-1 ====== ES ARO	5) == 100.0 100.0 100.0 100.0 100.0	: WELD	====> 6 17.7 17.7 17.7 17.7		7 0.0 0.0 0.0 0.0		8 17.7 17.7 17.7 17.7
VORTEX	INDUCED N O D E 1 4 8 10 11 13	N O D E 2 8 11 8 20	MBE P E L C A S N N E 1 1 1 1 1 1 1 1 1 1	ER ( S D I S D I I 1 I 1 I 1 I 1	CEN F I X 20 80 35 80 80	F I X 2 % 80 80 80 80 80 80	DAMAGE TAB DAMAGE 2.6101E-03 3.2387E-04 2.9682E-03 3.2387E-04 2.3563E-04	LE FOR	ALL W 1 100.0 100.0 100.0 100.0 100.0	IND DIF	2 17.7 17.7 17.7 17.7 17.7 17.7	NS (PR	INT OF <==REI 3 0.0 0.0 0.0 0.0 0.0 0.0	DAMAGI	E > 1. DAMAG 4 17.7 17.7 17.7 17.7 17.7 17.7	000E-1 ====== ES ARO	5) == UND THE 5 100.0 100.0 100.0 100.0	: WELD	> 6 17.7 17.7 17.7 17.7 17.7		7 0.0 0.0 0.0 0.0 0.0		8 17.7 17.7 17.7 17.7 17.7

#### Figure 4-5 Vortex induced damage for members for all wind directions, highest for all directions, member ends and centres

1	20 WORST	VORTEX	II	1DU	JCE	DM	EMBI	ER END DA	AMAGES	5 - A	VIT MIN	ND DI	RECTIO	NS (PR	INT OF	DAMAG	E > 1.0	000E-15	5)						
1																									
	N		N	P E	e s	F	F																		
	0		0	LC	) I	I	I								<==REI	LATIVE	DAMAGI	ES AROU	JND THE	WELD	====>				
	D		Di	A S	5 D	Х	Х			<		Side 1	: Chore	d side	points	3	>	<	Si	.de 2:	Brace	side	points		>
	E		Εl	N	ΙE	1	2																		
	1		2 1	2		8	8	DAMAG	GE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	33	2	2	14	1	80	80	1.0865E-	-02	6.4	36.9	0.0	100.0	6.4	36.9	0.0	100.0	2.6	3.3	0.0	11.0	2.6	3.3	0.0	11.0
	8	1	1	12	2 1	80	80	7.8541E-	-04 3	11.2	100.0	0.0	41.2	11.2	100.0	0.0	41.2	6.7	9.5	0.0	3.1	6.7	9.5	0.0	3.1
	21	2	0	1 4	1	80	80	6.6671E-	-04 2	24.5	30.8	0.0	100.0	24.5	30.8	0.0	100.0	24.5	8.7	0.0	31.0	24.5	5 8.7	0.0	31.0
	23	3	3	1 1	1	80	20	6.2278E-	-04 10	0.00	0.6	0.0	10.7	100.0	0.6	0.0	10.7	100.0	0.6	0.0	10.7	100.0	0.6	0.0	10.7
	23	5	8	1 1	. 1	80	20	2.7866E-	-04 10	0.00	14.2	0.0	17.9	100.0	14.2	0.0	17.9	100.0	14.2	0.0	17.9	100.0	14.2	0.0	17.9
L			~	اسها	-1	~~~~	~~~	mana	_o~mi	25		~~ <u>_</u> ~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	_76_~	mino			~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~	حروهر	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	mana	- mar	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
															(DD TRUE	0.0.0.0.0		1 0007	1.5.1						
1	20 WORST	VORTEX	II	1DU	ICE	DM	CMBE	CENTRE	E DAMA	AGES	- All	WIND	DIREC	TONS	(PRINT	OF DA	MAGE >	1.0008	5-15)						
-	20 WORST	VORTEX				D M.	SMBE F	CENTRE	E DAM	AGES	- ALL	WIND	DIREC.	TONS	(PRINT	OF DA	MAGE >	1.0008	=====						
=	20 WORST	VORTEX		5 b	S	F	EMBE F	CENTRE	E DAM#	AGES	- ALL	WIND	DIREC.		(PRINT	OF DA	DAMAGE >	1.000E	-15) 	WEID					
1	20 WORST  N O	VORTEX		5 P	S I	F I	EMBE F I	R CENTRE	E DAM#	AGES	- ALL	WIND	DIREC.		<==REI	LATIVE	MAGE > ====== DAMAGI	ES AROU	-15) 	WELD	>				
	20 WORST N O D	VORTEX		NDU PPP LO AS	D I D	F I X	F I X	R CENTRE	E DAM#	4GES 	- ALL	WIND	DIREC.		<==REI	LATIVE	MAGE > ====== DAMAGI	ES AROU	15) ===== JND THE	WELD	====>				
	20 WORST N O D E	VORTEX		NDU PPP CO AS	S I E	F I X 1	F I X 2	CENTRE	E DAM#	4GES 	- ALL	WIND	DIREC		(PRINT ======= <==REI	LATIVE	DAMAGE >	ES AROU		WELD	>		7		0
=	20 WORST 	VORTEX	N 1 0 1 D 2 E 1 2 1	NDU PPP LO AS	S I E	F I X 1 %	F I X 2 %	DAMAG	E DAM2	AGES	- ALL 	WIND	2		(PRINT ======= <==REI 3	LATIVE	MAGE > ===== DAMAGI 4	ES AROU	5 (15)	WELD	====>		7		8
=	20 WORST N 0 D E 1 10	VORTEX	N 1 0 1 0 1 E 1 2 1	NDU PP CO AS NN E	S I E	D M F I X 1 %	EMBE F I X 2 % 80	CENTRE DAMAG	E DAM2 ====== GE -03	AGES	- ALL 1	WIND	2 17.7		(PRINT <==REI 3 0.0	LATIVE	MAGE > DAMAGI 4 17.7	1.0008	2-15) THE 5 100.0	: WELD	====> 6 17.7		7		8
=	20 WORST N O D E 1 10 23	VORTEX 	N 1 0 1 0 1 2 1 8 1 8 1	NDU P P C O A S N N C L 1 L 1	) I D I E 1	D M F I X 1 % 35	F I X 2 % 80 50	DAMAG 2.9682E- 2.6811E-	E DAM2  -03 -03	AGES	- ALL 1 100.0 100.0	WIND	2 17.7 17.7		<==REI 3 0.0 0.0	LATIVE	MAGE > DAMAGI 4 17.7 17.7	ES AROU	15) 	: WELD	====> 6 17.7 17.7		7 0.0 0.0		8 17.7 17.7
=	20 WORST N O D E 1 10 23 58	VORTEX 	N 1 0 1 D 2 E 1 2 1 8 3	NDU P P C O A S N N C 1 L 1 L 1	S D I E 1	F I X 35 35 35	F I X 80 50 50	DAMAG 2.9682E- 2.6811E- 2.6811E-	GE -03 -03 -03	AGES	- ALL 1 100.0 100.0 100.0	WIND	2 17.7 17.7 17.7		<==REI 3 0.0 0.0 0.0	LATIVE	MAGE > DAMAGI 4 17.7 17.7 17.7	ES AROU	5 100.0 100.0	: WELD	====> 6 17.7 17.7 17.7		7 0.0 0.0 0.0		8 17.7 17.7 17.7
=	20 WORST N O D E 1 10 23 58 4	VORTEX 	N 1 O 1 D 2 E 1 2 1 8 3 8 3	NDU 	CE S D I E I E 1 . 1	F I X 35 35 20	EMBE F I X 2 % 80 50 50 80	DAMAG 2.9682E- 2.6811E- 2.6911E- 2.6101E-	GE -03 -03 -03 -03 -03	AGES	- ALL 1 100.0 100.0 100.0 100.0	WIND	2 17.7 17.7 17.7 17.7		<==REI 3 0.0 0.0 0.0 0.0 0.0	LATIVE	MAGE > DAMAGI 4 17.7 17.7 17.7 17.7	ES AROU	JND THE 5 100.0 100.0 100.0 100.0	: WELD	====> 6 17.7 17.7 17.7 17.7		7 0.0 0.0 0.0 0.0		8 17.7 17.7 17.7 17.7
=	20 WORST N O D E 1 1 0 23 58 4 33	VORTEX 5 2 2	N 1 O 1 D 1 E 1 2 1 8 3 3	NDU P P P C O A S N N E L 1 L 1 L 1 L 1 L 1	) S ) I ; D ; E ; 1 ; 1 ; 1	F I X 35 35 35 20 80	EMBE F I 2 % 80 50 50 80 80	DAMAG 2.9682E- 2.6811E- 2.6811E- 2.6101E- 1.6802E-	GE -03 -03 -03 -03 -03 -03 -03 -03	AGES	- ALL 1 100.0 100.0 100.0 100.0 100.0	WIND	2 17.7 17.7 17.7 17.7 17.7		<==REI 3 0.0 0.0 0.0 0.0 0.0 0.0	LATIVE	DAMAGE > DAMAGI 4 17.7 17.7 17.7 17.7 17.7 17.7	ES AROU	JND THE 5 100.0 100.0 100.0 100.0 100.0 100.0	WELD	====> 6 17.7 17.7 17.7 17.7 17.7		7 0.0 0.0 0.0 0.0 0.0		8 17.7 17.7 17.7 17.7 17.7





### 4.3 Total Damages

The total damage tables include the following tables.

TOTAL	(VORTEX	IN	DUC	CED	A	ND	BUE	FFETING)	MEMBEF	END	DAMA	GE TAE	BLE FOR	ALL	WIND D	IRECTI	ONS (PR	INT OF	DAMAG	E > 1	.000E-1	15)			
	N		D	D	==: c		F			====															
	0	0	L	0	I	I	I								<==RE1	LATIVE	DAMAGE	S AROU	ND THE	WELD	====>				
	D	D	A	s	D	Х	Х		1	<	S	ide 1:	Chord	side	points	5	>	<	Si	de 2:	Brace	side	points		>
	E	E	Ν	Ν	Е	1	2																		
	1	2	Е			융	융	DAMAG	E	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	1	54	1	4	1	80	80	1.3742E-	06 35	2	58.2	92.1	100.0	72.0	43.8	31.2	28.6	35.2	58.2	92.1	100.0	72.0	43.8	31.2	28.6
	1	55	1	8	1	80	80	3.4530E-	07 79	.0	46.9	29.6	28.8	39.9	65.9	92.8	100.0	79.0	46.9	29.6	28.8	39.9	65.9	92.8	100.0
	4	8	1	1	1	80	20	1.5117E-	03 100	0.0	58.5	11.1	7.4	19.8	19.7	10.7	45.3	60.7	32.6	3.6	2.9	16.2	14.0	3.4	20.9
	8	11	1	6	1	80	80	7.8543E-	04 11	.2 1	0.00	0.0	41.4	11.2	100.0	0.0	41.2	6.7	9.5	0.0	3.2	6.7	9.5	0.0	3.1
	10	8	1	4	1	80	35	6.7078E-	04 86	5.8	69.3	50.5	100.0	84.3	19.9	5.9	55.9	61.8	33.4	18.5	62.9	60.6	8.5	1.1	41.0
L		-100-		~~~		~~	20-	Andra	onee	warmer warmer	nam	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	i	$\sim\sim\sim$		~~~~~~				~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

#### Figure 4-7 Total damages for members for all wind directions

20	WORST	TOTAL	()	OR:	FEX	IN	DUCE	ED AND BUFF	ETING)	MEMBER	R END E	AMAGES	- AL	L WIND	DIRECT	TIONS (1	PRINT	OF DAM	AGE >	1.000E	E-15)			
===			===																					
						-	-																	
	N		N	PI	PS	F.	F.																	
	0		0	L (	ΙC	I	I							<==REL	ATIVE	DAMAGES	S AROU	ND THE	WELD	====>				
	D		D	A	S D	Х	Х		<	- 5	Side 1:	Chord	side	points		>	<	Si	de 2:	Brace	side p	oints		>
	E		E	N 1	ΝE	1	2																	
	1		2	Е		୫	୫	DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	33		22	1 4	41	80	80	1.0887E-02	7.0	37.4	0.1	100.0	6.7	36.9	0.0	99.9	2.7	3.4	0.0	11.0	2.7	3.3	0.0	11.0
	17		11	1 1	1 1	80	80	8.6966E-03	100.0	21.1	0.0	0.0	0.2	0.0	0.9	39.1	10.5	1.4	0.0	0.0	0.0	0.0	0.0	3.1
	16		21	1 3	1 1	80	20	6.1651E-03	100.0	39.7	0.4	1.5	13.4	2.4	0.3	28.8	44.7	18.2	0.2	0.5	5.2	1.0	0.1	11.7
	17		20	1 3	1 1	80	80	5.3061E-03	100.0	39.4	4.7	10.2	20.9	6.6	2.0	27.9	28.8	11.4	1.1	2.5	4.7	1.6	0.3	6.2
-	4		8	1 3	1 1	80	20	1.5117E-03	100.0	58.5	11.1	7.4	19.8	19.7	10.7	45.3	60.7	32.6	3.6	2.9	16.2	14.0	3.4	20.9

Figure 4-8 20 worst total damages for all wind directions



### **About DNV**

We are the independent expert in risk management and quality assurance. Driven by our purpose, to safeguard life, property and the environment, we empower our customers and their stakeholders with facts and reliable insights so that critical decisions can be made with confidence. As a trusted voice for many of the world's most successful organizations, we use our knowledge to advance safety and performance, set industry benchmarks, and inspire and invent solutions to tackle global transformations.

### **Digital Solutions**

DNV is a world-leading provider of digital solutions and software applications with focus on the energy, maritime and healthcare markets. Our solutions are used worldwide to manage risk and performance for wind turbines, electric grids, pipelines, processing plants, offshore structures, ships, and more. Supported by our domain knowledge and Veracity assurance platform, we enable companies to digitize and manage business critical activities in a sustainable, cost-efficient, safe and secure way.