SESAM EXAMPLE

Flare Boom Wind Fatigue Analysis

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Flare Boom Wind Fatigue Analysis

Date: March 2022

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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.

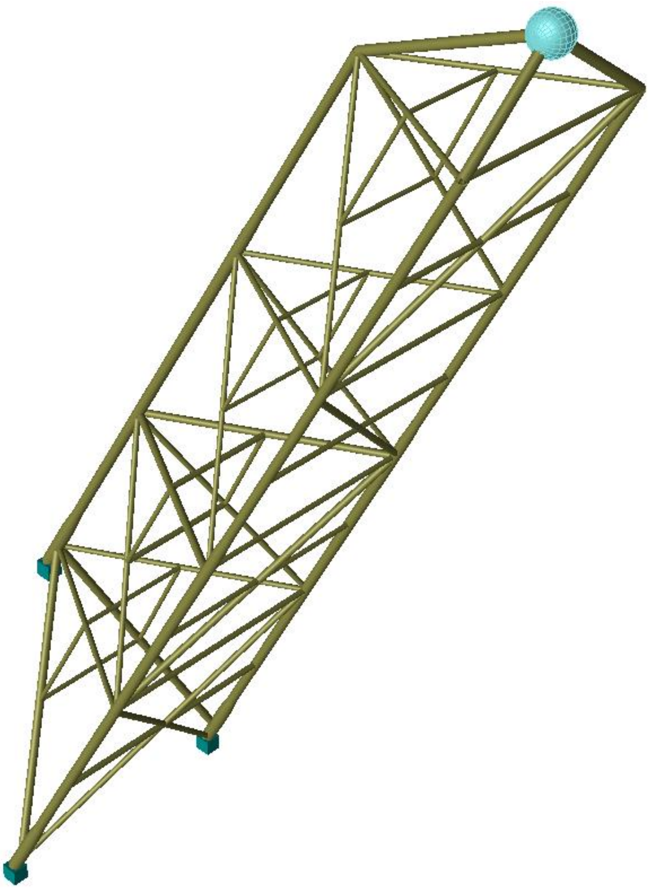

Figure 1-1 Flare boom model

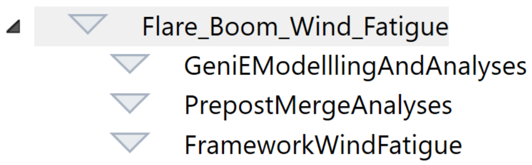

Figure 1-2 Sesam Manager workflow shown as ‘Tree View’

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:

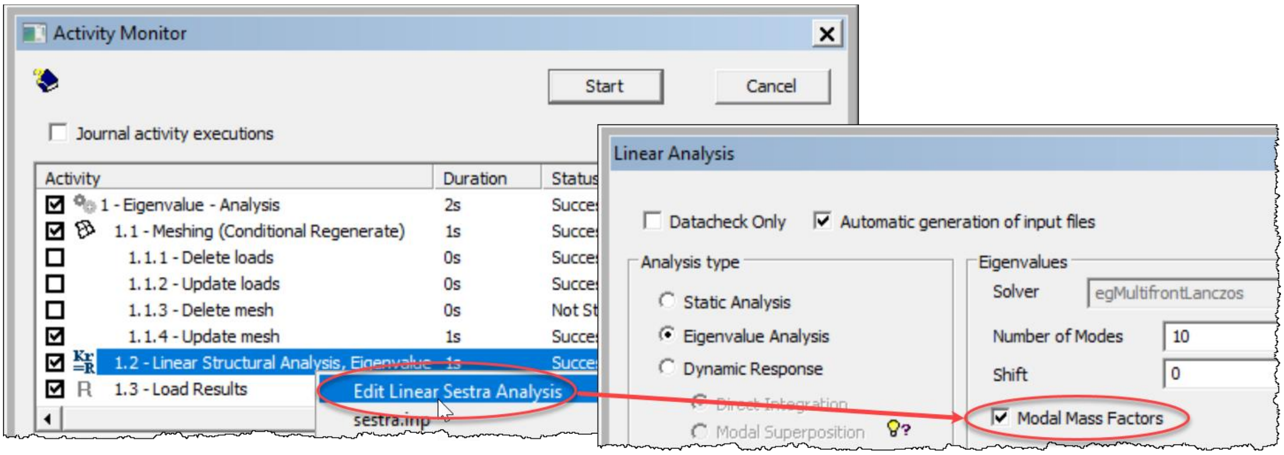

Figure 2-1 Compute modal mass factors in the eigenvalue analysis

- ('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.

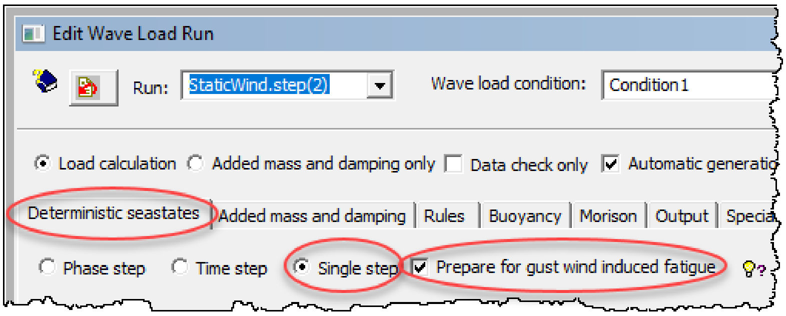

Figure 2-2 Prepare for gust wind induced fatigue in the static analysis

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 TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-15)
===================================================================================
       N       N P P S
       O       O L O I                                         <==RELATIVE DAMAGES AROUND THE WELD ====>
       D       D A S D                | <--     Side 1: Chord side points       --> | <--     Side 2: Brace side points       --> |
       E       E N N 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      9.3015E-07  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-07  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-07   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  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
```

Figure 4-1 Buffeting damage for members for wind directions 1, 2, 3 …

```
BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)
============================================================================
       N       N P P S
       O       O L O I                                         <==RELATIVE DAMAGES AROUND THE WELD ====>
       D       D A S D                | <--     Side 1: Chord side points       --> | <--     Side 2: Brace side points       --> |
       E       E N N 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
```

Figure 4-2 Buffeting damage for members for all wind directions, highest for all directions

```
20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)
==============================================================================
       N       N P P S
       O       O L O I                                         <==RELATIVE DAMAGES AROUND THE WELD ====>
       D       D A S D                | <--     Side 1: Chord side points       --> | <--     Side 2: Brace side points       --> |
       E       E N N E
       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
      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   8.1
```

Figure 4-3 20 worst buffeting damages for all wind directions

4.2 Vortex Induced Damages

The buffeting damage tables include the following tables.

VORTEX INDUCED MEMBER END DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	Side 1: Chord side points								Side 2: Brace side points							
								1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	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	1	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
10	8	1	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
11	8	1	4	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
13	20	1	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

VORTEX INDUCED MEMBER CENTRE DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	1	2	3	4	5	6	7	8
4	8	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	1	80	80	2.0465E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
10	8	1	1	1	20	80	1.6441E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
11	8	1	1	1	80	80	2.0465E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
13	20	1	1	1	80	80	1.2181E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7

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

VORTEX INDUCED MEMBER END DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	Side 1: Chord side points								Side 2: Brace side points							
								1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
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	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	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	1	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	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

VORTEX INDUCED MEMBER CENTRE DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	1	2	3	4	5	6	7	8
4	8	1	1	1	20	80	2.6101E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
8	11	1	1	1	80	80	3.2387E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
10	8	1	1	1	35	80	2.9682E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
11	8	1	1	1	80	80	3.2387E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
13	20	1	1	1	80	80	2.3563E-04	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7

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

20 WORST VORTEX INDUCED MEMBER END DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	Side 1: Chord side points								Side 2: Brace side points							
								1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
33	22	1	4	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	11	1	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
21	20	1	4	1	80	80	6.6671E-04	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	8.7	0.0	31.0
23	33	1	1	1	80	20	6.2278E-04	100.0	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	58	1	1	1	80	20	2.7866E-04	100.0	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

20 WORST VORTEX INDUCED MEMBER CENTRE DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

<==RELATIVE DAMAGES AROUND THE WELD ====>

NODE 1	NODE 2	PLAN	POSN	SIDE	FIX 1 %	FIX 2 %	DAMAGE	1	2	3	4	5	6	7	8
10	8	1	1	1	35	80	2.9682E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
23	58	1	1	1	35	50	2.6811E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
58	23	1	1	1	35	50	2.6811E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
4	8	1	1	1	20	80	2.6101E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7
33	22	1	1	1	80	80	1.6802E-03	100.0	17.7	0.0	17.7	100.0	17.7	0.0	17.7

Figure 4-6 20 worst vortex induced damages for all wind directions, member ends and centres

4.3 Total Damages

The total damage tables include the following tables.

TOTAL (VORTEX INDUCED AND BUFFETING) MEMBER END DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

NODE 1	NODE 2	PLAN	POSE	SIDE	FIX 1 %	FIX 2 %	DAMAGE	Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 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	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	100.0	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	86.8	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

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

20 WORST TOTAL (VORTEX INDUCED AND BUFFETING) MEMBER END DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-15)

NODE 1	NODE 2	PLAN	POSE	SIDE	FIX 1 %	FIX 2 %	DAMAGE	Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
33	22	1	4	1	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	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	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	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	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

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