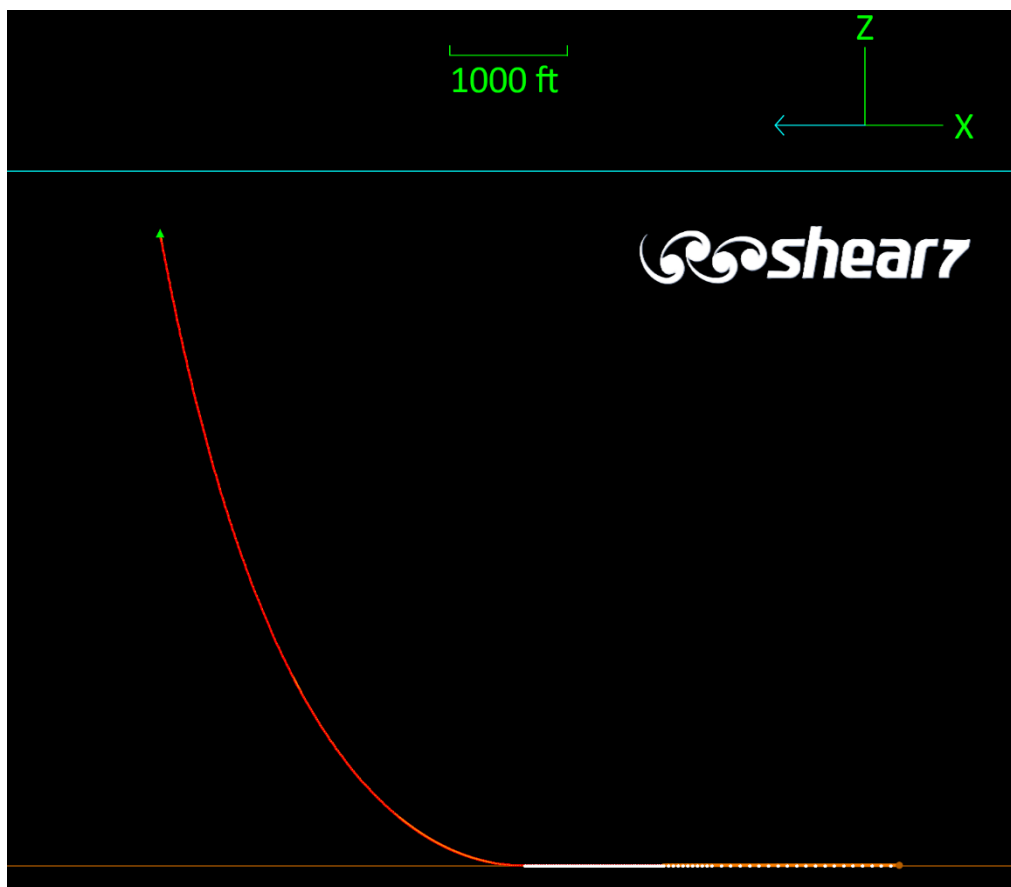


# A06 SHEAR7 interface

## Introduction

OrcaFlex offers a variety of modelling options for vortex induced vibration (VIV) analysis of lines. For this example, we demonstrate how the OrcaFlex interface to SHEAR7 can be used to perform a simple VIV analysis on a steel catenary riser (SCR).

The example demonstrates how to access the interface, what input data are required and how to access the available results.



## The OrcaFlex - SHEAR7 interface

SHEAR7 is a third-party program, distributed by AMOG, which performs frequency domain VIV calculations generally for the purpose of estimating fatigue and/or drag amplification due to VIV. OrcaFlex offers an interface to SHEAR7, which allows it to be called as part of a standard OrcaFlex static calculation.

Note that a separate SHEAR7 licence is required to make use of the interface. The example model includes the results of the SHEAR7 calculations, which can be reviewed as part of a standard OrcaFlex static simulation file. However, the analysis cannot be re-run without independent access to the SHEAR7 software.

In simple terms, OrcaFlex will prepare the necessary SHEAR7 input files, using the existing model information as far as possible. SHEAR7 is then called, and its results are passed back into OrcaFlex.

In more detail, SHEAR7 requires three input files:-

- **A data file (.s7dat):** which defines the line properties, current profile and calculation options.
- **A modal analysis file (.s7mds):** which describes the system modal frequencies and shapes.
- **A lift coefficient file (.common.s7cl):** which contains lift coefficient data.

Both the data and modal analysis files can be prepared by OrcaFlex. OrcaFlex does not prepare the lift coefficient file, as this is already supplied with SHEAR7.

OrcaFlex will first perform a standard static calculation, before it prepares the SHEAR7 data file. The user can also, optionally, select that OrcaFlex will prepare the modal analysis file. The input files are then passed to SHEAR7 for analysis.

The OrcaFlex help contains a full description of how both input files are prepared – please see the pages [VIV analysis | Frequency domain models | SHEAR7 | SHEAR7 data file](#) and [VIV analysis | Frequency domain models | SHEAR7 | SHEAR7 modes file](#).

When the first SHEAR7 calculation is complete, the results are passed back to OrcaFlex – including details of any drag amplification associated with the VIV.

OrcaFlex will then adjust the line type drag coefficients to take account of this amplification and repeat the static calculation. A new data file (and, optionally, a new modes file) is prepared using the revised static solution and passed to SHEAR7.

This process repeats until the static position of the line has converged.

The SHEAR7 results can then be accessed within the OrcaFlex GUI. The calculated drag amplification can also be imported into other OrcaFlex model files for inclusion in subsequent analysis work.

Full details of the interface workflow can be found in the OrcaFlex help page [VIV analysis | Frequency domain models | SHEAR7](#).

## Description of example model

Open the example model [A06 SHEAR7 interface.sim](#). This example uses the catenary line from the [A05 Catenary with spar](#) example. For simplicity only the line object has been retained. In addition, the VIV suppression strakes included in the original model have been removed, leaving the line bare along its entire length.

The original analysis considers a non-zero offset and trim for the spar, due to the extreme weather conditions under consideration. For simplicity, this example considers the riser top end position and declination associated with zero offset and trim angle.

SHEAR7 performs a frequency domain analysis based on the relative flow velocity experienced by the line. Thus, it is not possible to input wave loading, or pass the results of a dynamic analysis to SHEAR7; only steady current is applied.

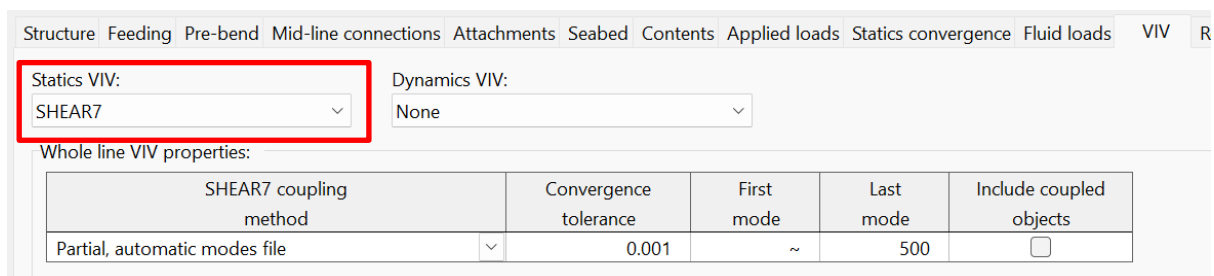
The current profile used in the example model is idealised, creating a simple slab profile over the length of the riser. This has been done to allow easier understanding of the SHEAR7 input data

and results output. The current is applied in the riser's in-plane direction (the negative OrcaFlex global X-axis) – we would therefore expect the transverse VIV response to be in the out-of-plane (global Y-axis) direction.

For simplicity, we have used the same segmentation as in the original A05 model, however, this may not be optimal for a VIV analysis. SHEAR7 will compare the chosen segment length against the wavelengths of the excited modes and issues a warning if finer segmentation is required.

## Accessing the SHEAR7 interface

To enable the interface, "SHEAR7" should be selected for the *statics VIV* option on the *VIV* page of the line data form, as highlighted here:-

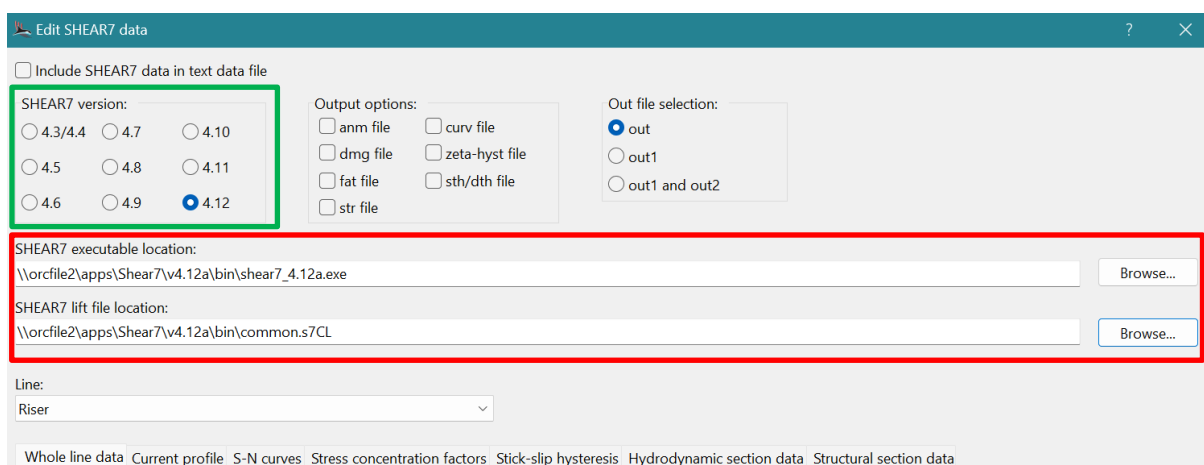


SHEAR7 coupling method	Convergence tolerance	First mode	Last mode	Include coupled objects
Partial, automatic modes file	0.001	~	500	<input type="checkbox"/>

To allow SHEAR7 to be called by OrcaFlex, it is also necessary to specify the SHEAR7 version being used and the path locations for the SHEAR7 executable (.exe) & lift (.s7cl) files. OrcaFlex requires information on both version and path location for the executable because the format of the input data file (.s7dat) varies for different SHEAR7 versions and OrcaFlex needs to know which version to target. The lift file specifies the lift coefficients required for the SHEAR7 analysis – typically, the standard .s7cl file supplied with SHEAR7 will be used.

These path locations are defined on the SHEAR7 data form, which can be opened directly from the *model browser* or from the *SHEAR7 data...* button at the bottom of the line data form.

As an example, the following screenshots highlight where the version number (green box) and file locations (red box) are defined:-



Although OrcaFlex will use as much of the model data as possible when creating the SHEAR7 input files, there are many SHEAR7-specific data items that cannot be determined from a standard OrcaFlex model. These data items are defined in the various pages of the SHEAR7 data form.

As is typical, OrcaFlex includes default values for these data items, but these *always* need to be reviewed to ensure that they are appropriate for the system under consideration. Full guidance on all these data items can be found in the SHEAR7 documentation. The example model simply uses the OrcaFlex default data – these will allow SHEAR7 to successfully run, but may not necessarily be most appropriate for this type of analysis.

The user can also control whether the SHEAR7 analysis considers the inline (i.e. in line with the relative flow) or transverse (perpendicular to the relative flow) direction when performing the VIV analysis. This choice is made through the *response* data item on the *whole line data* page of the SHEAR7 data form, as highlighted in red here:-

Whole line data | Current profile | S-N curves | Stress concentration factors | Stick-slip hysteresis | Hydrodynamic section data

Whole line data:

Bending stress curvature load factor (kpf/ft <sup>2</sup> /(rad/ft))	Structural damping ratio	Power ratio cutoff level	Primary zone amplitude limit	Non-orthogonal damping	Beta c nurr
~	0.003	0.05	0.3	<input checked="" type="checkbox"/>	

Output summary locations:

Arc length range (ft)		Increment
Start	End	step-size (ft)
~	~	32.8084

Include gravity for tilt contamination estimation

Power ratio exponent:

Equal probabilities  
 Ratio

Fatigue calculation method:

Default  
 Zero crossing

Response:  Transverse  
 Inline

In addition to the SHEAR7 data form, it may also be necessary to adjust the data on the *VIV* page of the line data form – these settings control the iterative aspects of the coupled SHEAR7 calculation.

First, the user can select the type of coupling iteration required, through the *SHEAR7 coupling method*. Three main calculation options are available, which are detailed below. For more information on the fourth option “User specified drag amplification” please see the ‘Results’ section of this document. The coupling interface options are:-

- **Partial, automatic modes file:** where OrcaFlex will prepare the modes file based on the results of the first static calculation, but will then use the same modes file for all subsequent iterations. This is the default option.
- **Partial, user modes file:** where the user can supply their own modes file, which will be used in all iterations.
- **Full:** where OrcaFlex will prepare a new modes file for each iteration, based on the latest static solution.

Although the “full” option is perhaps the most accurate approach, recalculating the modes at each iteration can significantly increase the static calculation time. In many practical cases, there is little

change in the modal responses between iterations, and so a single modes file can often be used throughout. The example file simply uses the default “partial, automatic modes file” option.

It is also possible to set the coupling *convergence tolerance* on the *VIV* page of the line data form – this can typically be left at its default value (as we have here).

The *first mode* and *last mode* options control which mode numbers are included in the modes file. These options are generally used to avoid infringing SHEAR7’s mode number range limit. In the example model, the first mode is left at its default setting of “~”, which means the lowest numbered transverse mode. For the purposes of the example, the last mode has been arbitrarily set to 500, but this could potentially be reduced. Reducing the overall mode number range can improve calculation time, but this needs to be done carefully to avoid excluding any important modal contributions.

The *include coupled objects* data item affects the calculation of the modes and can be useful in cases where other objects are connected onto the line, or if other objects contact it during statics.

In more detail, when OrcaFlex prepares the modes file, it considers the modes only of the line of interest (and not the whole system). However, it may be possible for other model objects to interact with the line of interest, e.g. through direct connection or contact.

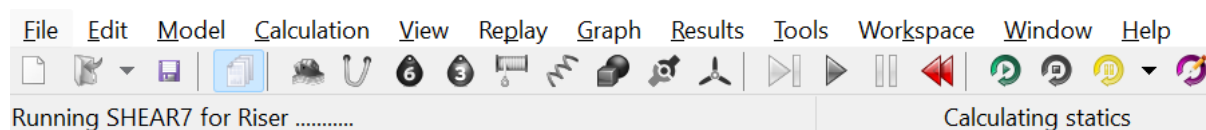
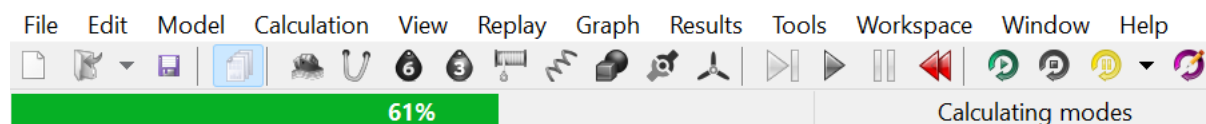
If the *include coupled objects* option is checked, OrcaFlex will determine whether any other objects are coupled to the line, by examining the system mass and stiffness matrices – any such couplings will then be included in the line modal results output to the SHEAR7 modes file. This option is not required in the example file, as it contains only a single line in isolation (i.e. with no parent or child objects, and no other objects coming into contact).

The SHEAR7 input data file also requires information about the relative velocity in the direction normal to the line axis. OrcaFlex determines this from the static solution based on the defined current profile and the static orientation of the line. The current data output can be most easily reviewed within the input data echo from the *.s7out* file (see the section ‘Results’ for more details).

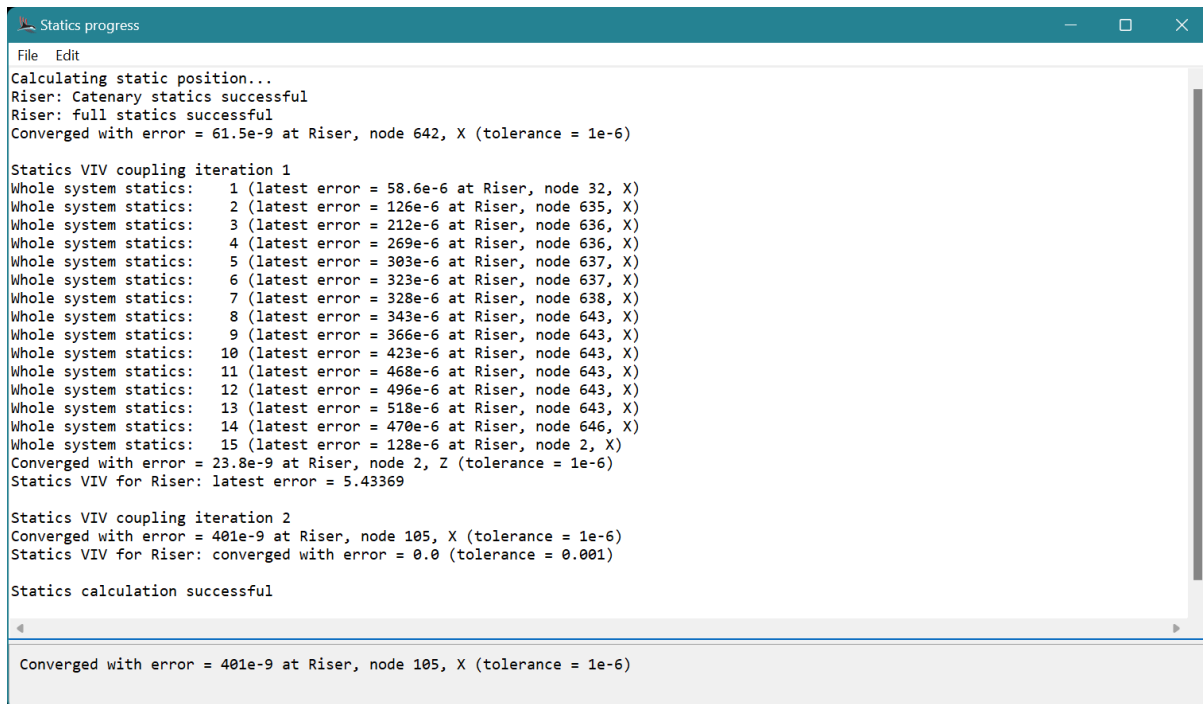
## Performing the calculations

Once the input data has been prepared, SHEAR7 can be called simply by performing a standard OrcaFlex statics calculation. OrcaFlex will prepare the necessary input files, call SHEAR7 and extract its results, all within the static solve.

While statics is solving, the calculation progress can be viewed through the OrcaFlex *status bar*. For example, as shown in the following screenshots:-



Alternatively, progress can be viewed through the [statics progress window](#), as shown here, either during the static calculation or after statics has completed:-



```

Statics progress
File Edit
Calculating static position...
Riser: Catenary statics successful
Riser: full statics successful
Converged with error = 61.5e-9 at Riser, node 642, X (tolerance = 1e-6)

Statics VIV coupling iteration 1
Whole system statics: 1 (latest error = 58.6e-6 at Riser, node 32, X)
Whole system statics: 2 (latest error = 126e-6 at Riser, node 635, X)
Whole system statics: 3 (latest error = 212e-6 at Riser, node 636, X)
Whole system statics: 4 (latest error = 269e-6 at Riser, node 636, X)
Whole system statics: 5 (latest error = 303e-6 at Riser, node 637, X)
Whole system statics: 6 (latest error = 323e-6 at Riser, node 637, X)
Whole system statics: 7 (latest error = 328e-6 at Riser, node 638, X)
Whole system statics: 8 (latest error = 343e-6 at Riser, node 643, X)
Whole system statics: 9 (latest error = 366e-6 at Riser, node 643, X)
Whole system statics: 10 (latest error = 423e-6 at Riser, node 643, X)
Whole system statics: 11 (latest error = 468e-6 at Riser, node 643, X)
Whole system statics: 12 (latest error = 496e-6 at Riser, node 643, X)
Whole system statics: 13 (latest error = 518e-6 at Riser, node 643, X)
Whole system statics: 14 (latest error = 470e-6 at Riser, node 646, X)
Whole system statics: 15 (latest error = 128e-6 at Riser, node 2, X)
Converged with error = 23.8e-9 at Riser, node 2, Z (tolerance = 1e-6)
Statics VIV for Riser: latest error = 5.43369

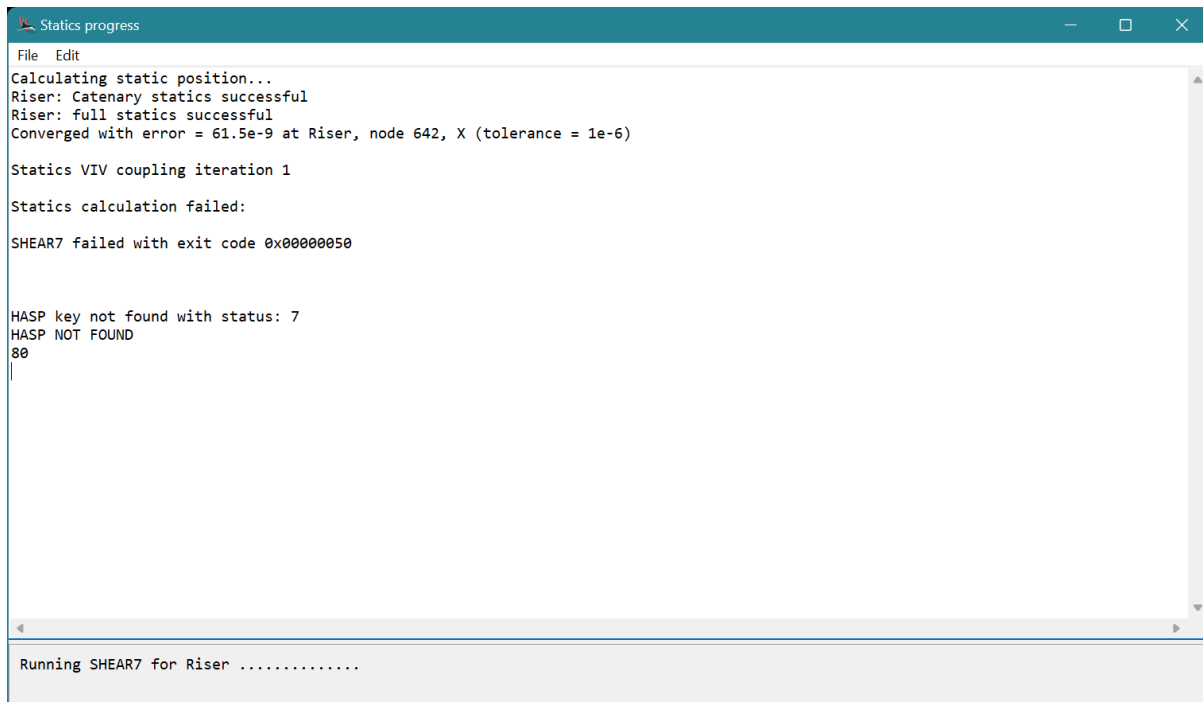
Statics VIV coupling iteration 2
Converged with error = 401e-9 at Riser, node 105, X (tolerance = 1e-6)
Statics VIV for Riser: converged with error = 0.0 (tolerance = 0.001)

Statics calculation successful

Converged with error = 401e-9 at Riser, node 105, X (tolerance = 1e-6)

```

If the calculation aborts for any reason, error messages received from SHEAR7 will be echoed into the statics progress window. For example, the following screenshot of the statics progress window shows the error seen when a SHEAR7 licence is not available to the process:-



```

Statics progress
File Edit
Calculating static position...
Riser: Catenary statics successful
Riser: full statics successful
Converged with error = 61.5e-9 at Riser, node 642, X (tolerance = 1e-6)

Statics VIV coupling iteration 1

Statics calculation failed:
SHEAR7 failed with exit code 0x00000050

HASP key not found with status: 7
HASP NOT FOUND
80
|

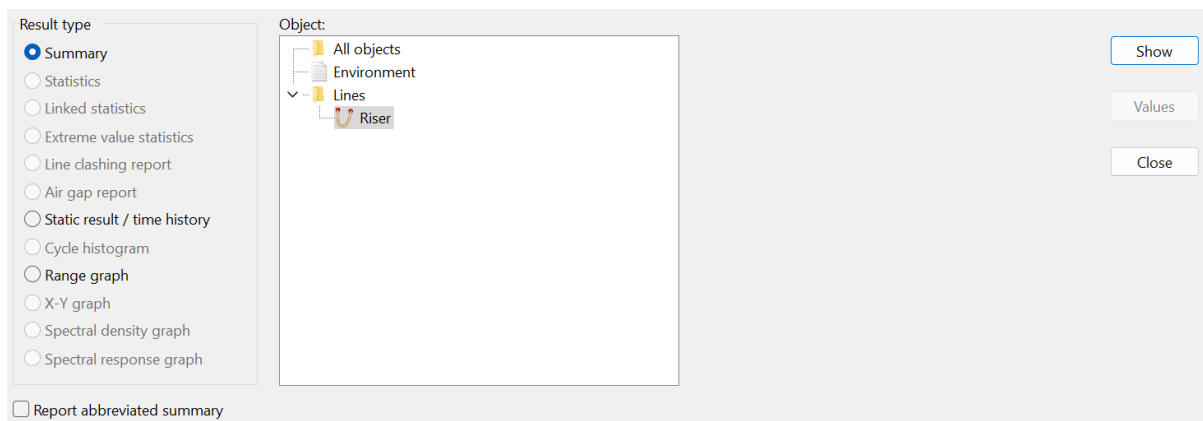
Running SHEAR7 for Riser .....

```

If a number of SHEAR7 calculations are to be performed, e.g. for a number of different current profile conditions, it can be more efficient to run the files through the OrcaFlex [batch processing](#) form. You can ensure that only the static calculation is performed for each file by unchecking the *dynamics enabled* box on the *analysis* page of the *general* data form within each individual model.

## Results

The SHEAR7 results can be accessed within the OrcaFlex GUI by looking at the *summary* results for the line object.



In addition to the standard set of OrcaFlex line results, the summary workbook will include pages containing the complete and summary SHEAR7 output files (*.s7out* and *.s7plt*, respectively), as highlighted in red below.

Summary results for Riser in static state

N11							
	A	B	C	D	E	F	G
1	<b>Riser SHEAR7 .plt</b>						
2	OrcaFlex 11.4c: A06 SHEAR7 interface.sim (modified 16:38 on 13/05/2024 by OrcaFlex 11.4c)						
3							
4	<b>Location</b>	<b>RMS displacement</b>	<b>RMS velocity</b>	<b>RMS acceleration</b>	<b>RMS stress</b>	<b>damage rate</b>	<b>Cf</b>
5	0.0	0.0	0.0	0.04832	0.94159	0.06739	1.0
6	100e-6	0.00155	0.00247	0.05491	0.85746	0.05089	1.03
7	200e-6	0.00317	0.00507	0.06148	0.78075	0.03841	1.048
8	310e-6	0.00486	0.00778	0.06803	0.7108	0.02898	1.064
9	410e-6	0.00662	0.0106	0.07455	0.64702	0.02185	1.078
10	510e-6	0.00844	0.0135	0.08106	0.58884	0.01647	1.091
11	610e-6	0.01031	0.0165	0.08756	0.53577	0.0124	1.104
12	710e-6	0.01223	0.01957	0.09404	0.48735	0.00933	1.116
13	820e-6	0.01419	0.02271	0.1005	0.44316	0.00702	1.128
14	920e-6	0.01619	0.02591	0.10696	0.40283	0.00527	1.134
15	0.00102	0.01823	0.02918	0.11339	0.36601	0.00395	1.145
16	0.00122	0.02241	0.03586	0.12625	0.30196	0.00222	1.166
17	0.00143	0.0267	0.04272	0.13906	0.24852	0.00123	1.186
18	0.00163	0.03107	0.04973	0.15184	0.20388	680e-6	1.205
19	0.00183	0.03533	0.05633	0.16458	0.16655	370e-6	1.224

Navigation bar: Riser SHEAR7 out Riser SHEAR7 .plt

These results can be viewed for the *A06 SHEAR7 interface.sim* file by opening the [workspace file A06 SHEAR7 results.wrk](#). Note that, even if you don't have access to SHEAR7 itself, you can still view these results within the simulation file.

It is also possible to export these results as text files – this is done from the *SHEAR7* data form in OrcaFlex using the [export output file...](#) button at the bottom of the data form.

In addition to the results of the VIV analysis, the *.s7out* file contains an echo of the input data defined in the *.s7dat* file. For example, this includes the flow velocity values being considered in the SHEAR7 calculation, as shown here:-

299	*** BLOCK 3. current data ***				
300	profile data pts: 300	probability: 1.000E+00	profile ID:	1	
301	location (x/L) and velocity (ft/s):	0.000	0.9749		
302	location (x/L) and velocity (ft/s):	0.003	0.9750		
303	location (x/L) and velocity (ft/s):	0.007	0.9749		
304	location (x/L) and velocity (ft/s):	0.010	0.9748		
305	location (x/L) and velocity (ft/s):	0.013	0.9747		
306	location (x/L) and velocity (ft/s):	0.017	0.9745		
307	location (x/L) and velocity (ft/s):	0.020	0.9744		
308	location (x/L) and velocity (ft/s):	0.023	0.9743		
309	location (x/L) and velocity (ft/s):	0.027	0.9741		
310	location (x/L) and velocity (ft/s):	0.030	0.9740		
311	location (x/L) and velocity (ft/s):	0.033	0.9738		
312	location (x/L) and velocity (ft/s):	0.037	0.9737		
313	location (x/L) and velocity (ft/s):	0.040	0.9735		
314	location (x/L) and velocity (ft/s):	0.043	0.9734		
315	location (x/L) and velocity (ft/s):	0.047	0.9732		
316	location (x/L) and velocity (ft/s):	0.050	0.9731		
317	location (x/L) and velocity (ft/s):	0.054	0.9729		
318	location (x/L) and velocity (ft/s):	0.057	0.9728		
319	location (x/L) and velocity (ft/s):	0.060	0.9726		

Note that the velocity values are not equal to the applied slab current velocity of 0.984ft/s. Instead, the velocity decreases from 0.965ft/s at End A (the top of the line) to zero at End B. SHEAR7 requires the relative velocity in the direction normal to the line axis – thus, OrcaFlex will determine the local component of current velocity in this direction and pass this to the SHEAR7 data file.

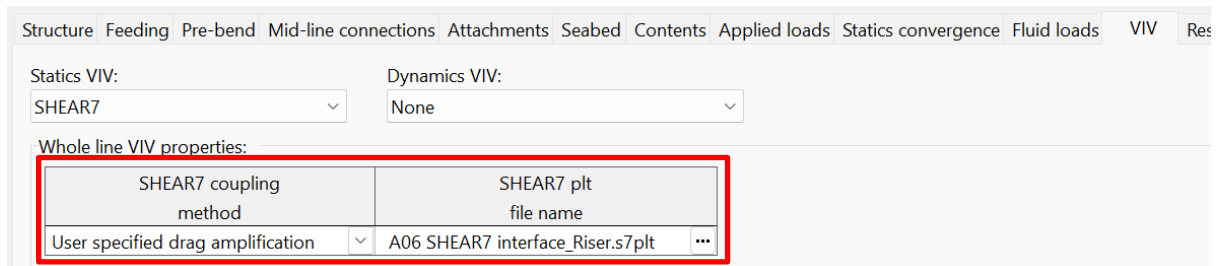
SHEAR7 offers a number of optional output files in addition to the standard *.s7out* and *.s7plt* files. For further details about these different files, please refer to the SHEAR7 documentation. You can nominate which of these optional files are of interest through the check boxes in the [output options](#) and [out file selection](#) areas of the OrcaFlex *SHEAR7* data form. All of the files selected will be automatically exported during batch processing (in addition to the *.s7out* and *.s7plt* files). However, only the various additional *.out* files included in the [out file selection](#) area will be available within the GUI line summary results.

If the OrcaFlex static calculations have been carried out in the [batch processing](#) form, then all the output files (including any optional output files nominated in the *SHEAR7* data form) will be automatically saved.

The amplified drag coefficients can be viewed by asking for a range graph of *x* or *y* [drag coefficient](#) for the line's static state. For example, when loading the workspace file *A06 SHEAR7 results.wrk*, a static state range graph of *x* drag coefficient is shown.

It is also possible to import the drag amplification factors from the *.s7plt* file into another OrcaFlex model. This is done by setting the [SHEAR7 coupling method](#) (on the *VIV* page of a line's data form) to "User specified drag amplification", as below:-





The imported drag amplification factors will then be combined with the normal drag coefficients defined in the line's line type properties to produce new, amplified, drag coefficients.

Being able to import the drag amplification factors avoids the need to re-run SHEAR7 every time the factors are required – instead, the VIV analysis can be run once, and the results re-used in multiple subsequent analyses.

The example file [A06 SHEAR7 import drag amplification.sim](#) demonstrates this import process. Note that a SHEAR7 licence is not required to import the drag coefficients – as the *.s7plt* file already exists.

The enhanced drag coefficients can be viewed by opening the [A06 Imported drag data.wrk](#) workspace file within this simulation. The example model simply considers a static simulation, using the same current profile as the SHEAR7 analysis. However, the amplified drag coefficients could also be used in a dynamic simulation, considering current and/or waves, as well as other lines (e.g. an interference analysis).

## Fatigue post-processing

The SHEAR7 results include details of the variation in fatigue damage rate with line arc length, e.g. see the results included in the *.s7plt* file.

This damage rate will be applicable for the specific load case (i.e. current profile) applied in the OrcaFlex model. However, when performing fatigue calculations, it is generally necessary to collate the damage from a number of different load cases to determine the overall damage.

The OrcaFlex [fatigue analysis](#) tool can be used to perform this collation. Note that no fatigue calculations are performed by OrcaFlex in this case - instead, the damage rate is extracted from the *.s7plt* file results for each load case. This damage rate is then combined with a defined *exposure time* to allow the damage per load case to be determined. Finally, the total damage is found by summing together the contributions from each individual load case.

The load cases files and exposure times can be defined on the [load cases](#) page of the OrcaFlex fatigue data form, as shown below. Note that the *damage calculation* must be set to "SHEAR7", as highlighted.

Damage calculation

Homogeneous pipe stress

Stress factors

Mooring

Histograms

SHEAR7

Externally calculated stress

Units:

System	Length	Mass	Force	g (m/s <sup>2</sup> )
SI	m	te	kN	9.80665

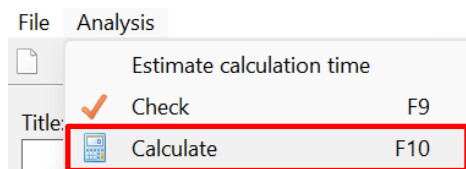
Load cases | Analysis data | Results | In-house

Number of load cases:  Add load cases... Remove load cases

No.	Load case file name	Exposure time (hours)
1	load case 1.s7plt	584.2
2	load case 2.s7plt	1841.5
3	load case 3.s7plt	2667.29
4	load case 4.s7plt	1596.01
5	load case 5.s7plt	26.1045
6	load case 6.s7plt	1224.05
7	load case 7.s7plt	279.845
8	load case 8.s7plt	56.6251
9	load case 9.s7plt	406.781

Some further output options can be defined in the [analysis data](#) and [results](#) pages of the fatigue data form. Full information on the available options can be found in the appropriate sections from the OrcaFlex help pages [Fatigue analysis | Analysis data](#) and [Fatigue analysis | Results for damage based methods](#).

The total fatigue damage is obtained in the usual way - by selecting the [calculate](#) option from the [analysis](#) menu or toolbar.



The total damage is also presented in the same way as for a regular OrcaFlex fatigue calculation – either through graphs or tables of the variation in damage and/or life against arc length.