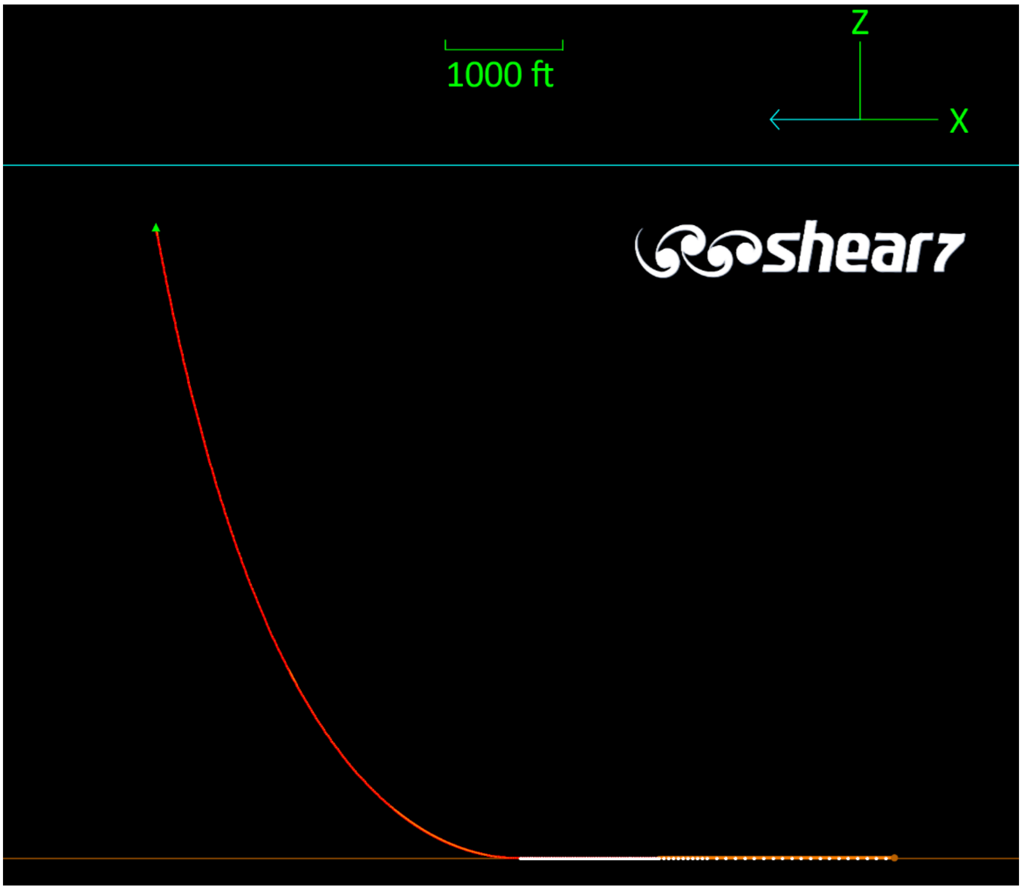
A06 SHEAR7 interface

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.

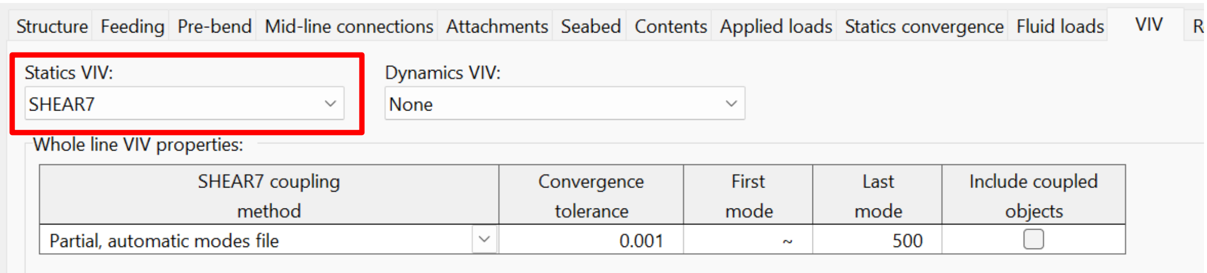
SHEAR7 performs a frequency domain analysis based on the relative flow velocity experienced by the line. Thus, it is not possible to input wave loading, or pass the results of a dynamic analysis to SHEAR7; only steady current is applied.

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

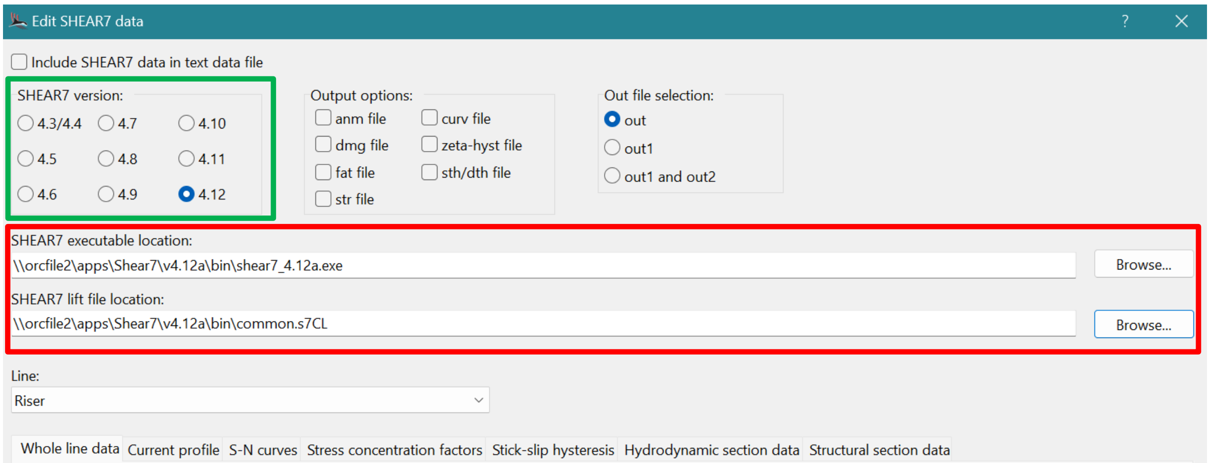
To enable the interface, "SHEAR7" should be selected for the *statics VIV* option on the *VIV* page of the line data form, as highlighted here:-



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.

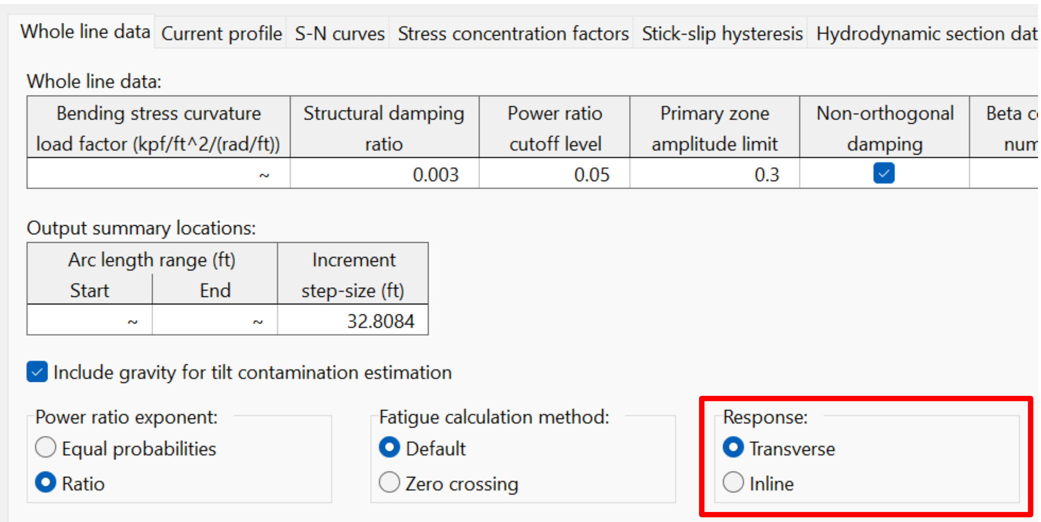
As an example, the following screenshots highlight where the version number (green box) and file locations (red box) are defined:-



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:-



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.

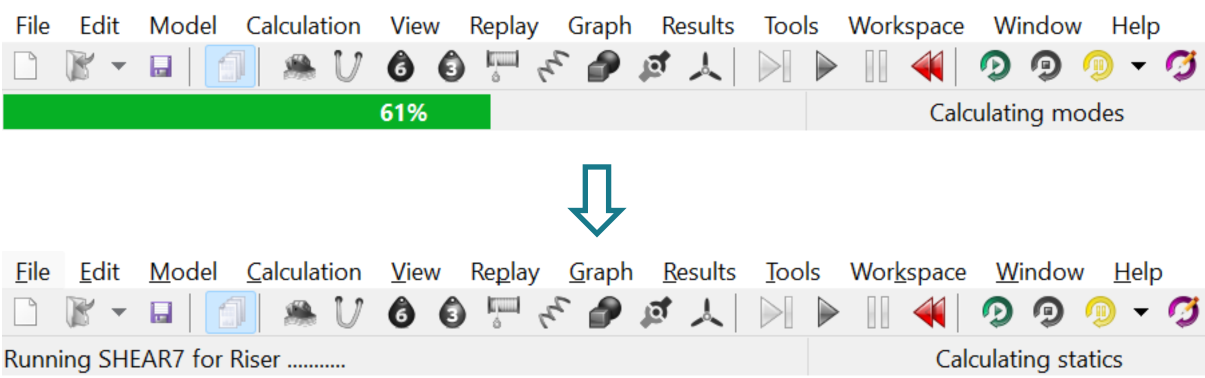
If the *include coupled objects* option is checked, OrcaFlex will determine whether any other objects are coupled to the line, by examining the system mass and stiffness matrices – any such couplings will then be included in the line modal results output to the SHEAR7 modes file. This option is not required 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).

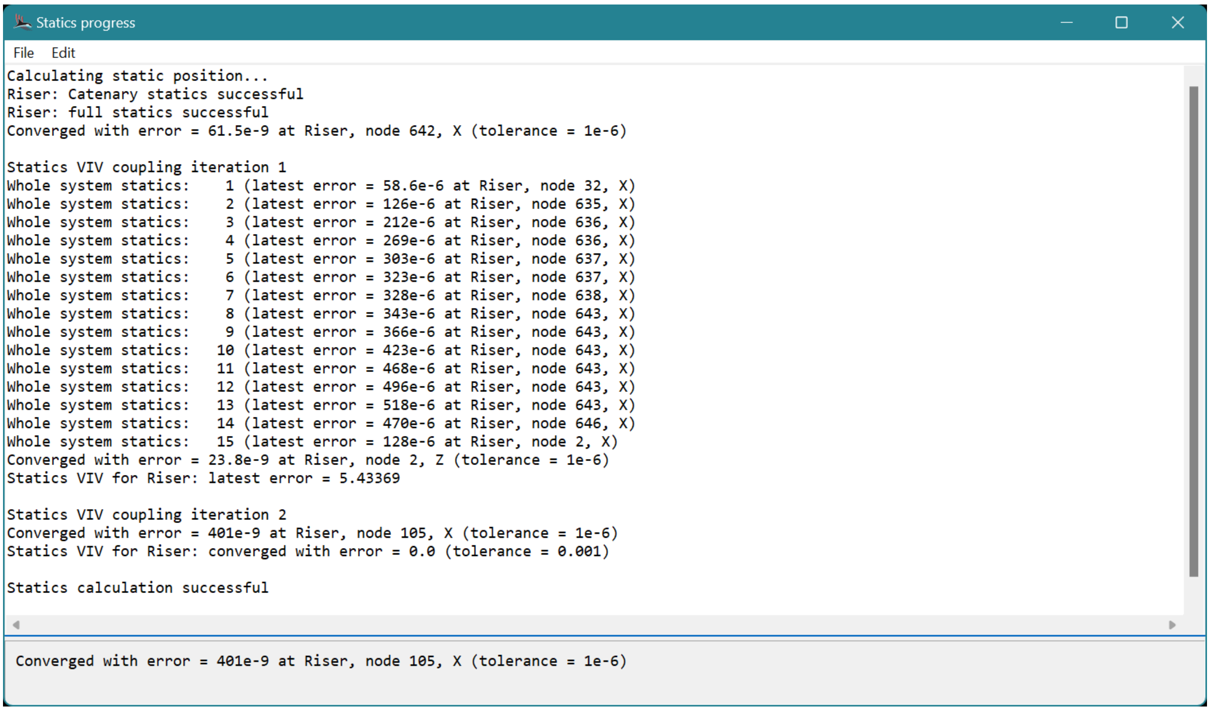
Performing the calculations

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.

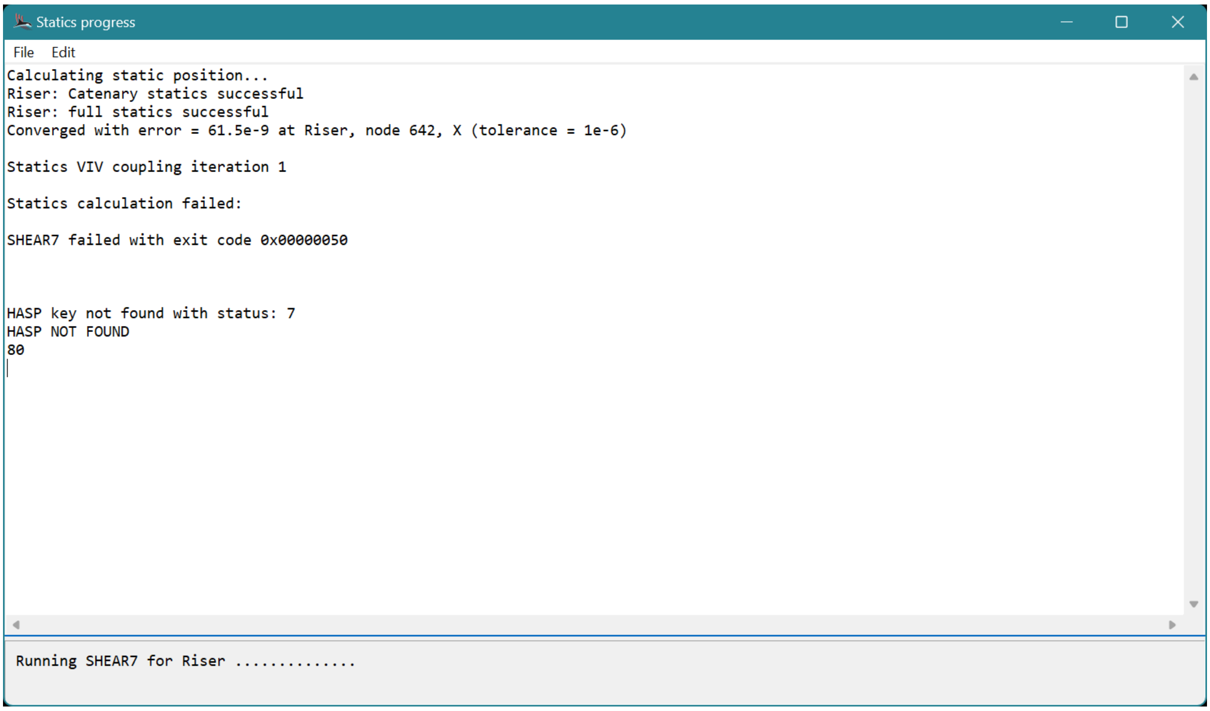
While statics is solving, the calculation progress can be viewed through the OrcaFlex *status bar*. For example, as shown in the following screenshots:-



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



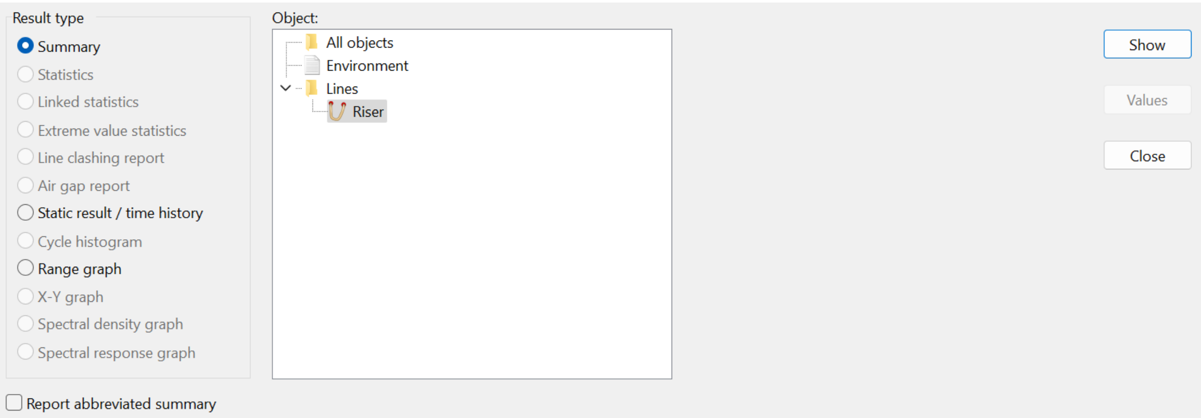
If the calculation aborts for any reason, error messages received from SHEAR7 will be echoed into the statics progress window. For example, the following screenshot of the statics progress window shows the error seen when a SHEAR7 licence is not available to the process:-



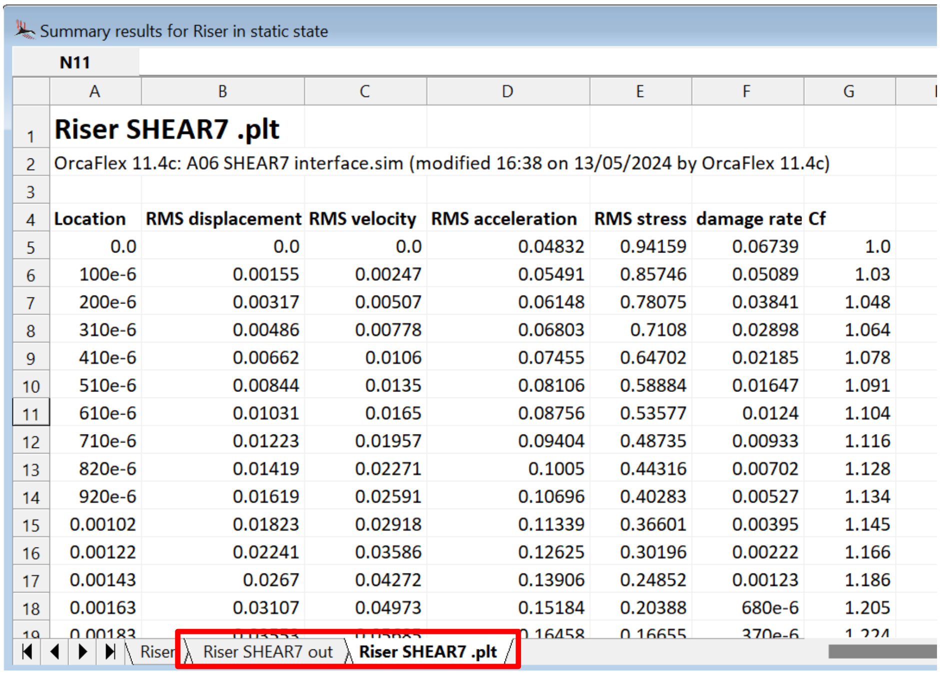
If a number of SHEAR7 calculations are to be performed, e.g. for a number of different current profile conditions, it can be more efficient to run the files through the OrcaFlex batch processing form. You can ensure that only the static calculation is performed for each file by unchecking the *dynamics 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.



Location	RMS displacement	RMS velocity	RMS acceleration	RMS stress	damage rate	Cf
0.0	0.0	0.0	0.04832	0.94159	0.06739	1.0
100e-6	0.00155	0.00247	0.05491	0.85746	0.05089	1.03
200e-6	0.00317	0.00507	0.06148	0.78075	0.03841	1.048
310e-6	0.00486	0.00778	0.06803	0.7108	0.02898	1.064
410e-6	0.00662	0.0106	0.07455	0.64702	0.02185	1.078
510e-6	0.00844	0.0135	0.08106	0.58884	0.01647	1.091
610e-6	0.01031	0.0165	0.08756	0.53577	0.0124	1.104
710e-6	0.01223	0.01957	0.09404	0.48735	0.00933	1.116
820e-6	0.01419	0.02271	0.1005	0.44316	0.00702	1.128
920e-6	0.01619	0.02591	0.10696	0.40283	0.00527	1.134
0.00102	0.01823	0.02918	0.11339	0.36601	0.00395	1.145
0.00122	0.02241	0.03586	0.12625	0.30196	0.00222	1.166
0.00143	0.0267	0.04272	0.13906	0.24852	0.00123	1.186
0.00163	0.03107	0.04973	0.15184	0.20388	680e-6	1.205

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:-

```
*** BLOCK 3. current data ***
    profile data pts: 300  probability: 1.000E+00  profile ID:        1
    location (x/L) and velocity (ft/s): 0.000    0.9749
    location (x/L) and velocity (ft/s): 0.003    0.9750
    location (x/L) and velocity (ft/s): 0.007    0.9749
    location (x/L) and velocity (ft/s): 0.010    0.9748
    location (x/L) and velocity (ft/s): 0.013    0.9747
    location (x/L) and velocity (ft/s): 0.017    0.9745
    location (x/L) and velocity (ft/s): 0.020    0.9744
    location (x/L) and velocity (ft/s): 0.023    0.9743
    location (x/L) and velocity (ft/s): 0.027    0.9741
    location (x/L) and velocity (ft/s): 0.030    0.9740
    location (x/L) and velocity (ft/s): 0.033    0.9738
    location (x/L) and velocity (ft/s): 0.037    0.9737
    location (x/L) and velocity (ft/s): 0.040    0.9735
    location (x/L) and velocity (ft/s): 0.043    0.9734
    location (x/L) and velocity (ft/s): 0.047    0.9732
    location (x/L) and velocity (ft/s): 0.050    0.9731
    location (x/L) and velocity (ft/s): 0.054    0.9729
    location (x/L) and velocity (ft/s): 0.057    0.9728
    location (x/L) and velocity (ft/s): 0.060    0.9726
```

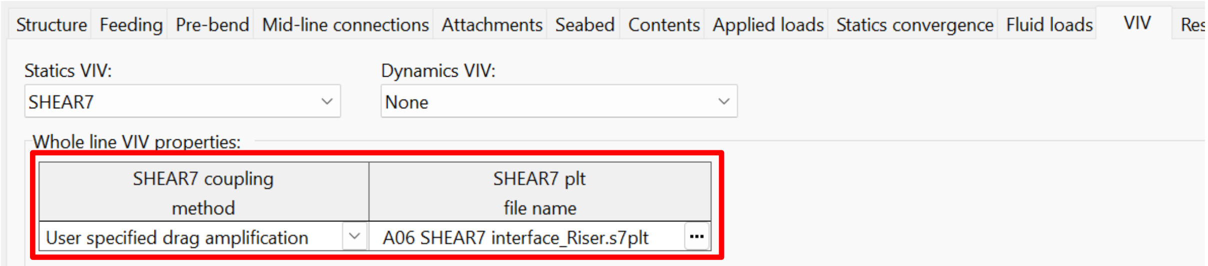
Note that the velocity values are not equal to the applied slab current velocity of 0.984ft/s. Instead, the velocity decreases from 0.965ft/s at End A (the top of the line) to zero at End B. SHEAR7 requires the relative velocity in the direction normal to the line axis – thus, OrcaFlex will determine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

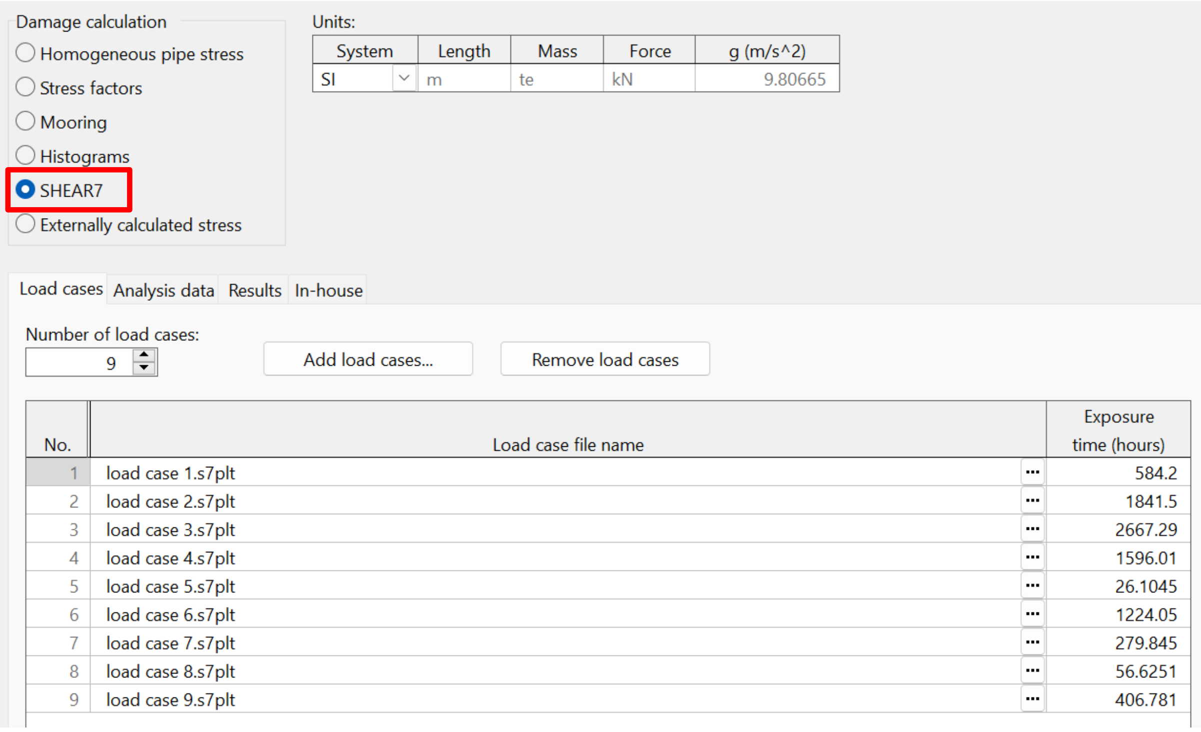
Fatigue post-processing

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.

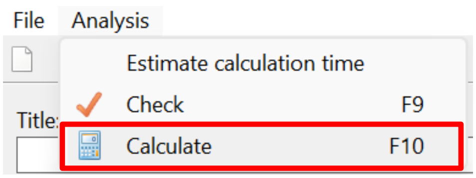
The OrcaFlex fatigue analysis tool can be used to perform this collation. Note that no fatigue calculations are performed by OrcaFlex in this case - instead, the damage rate is extracted from the *.s7plt* file results for each load case. This damage rate is then combined with a defined *exposure time* 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.



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.