OrcaFlex QA, Testing and Validation
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1 Software Quality Assurance

The Quality Assurance of Orcina software is based on the requirements of BS 5750, 5887, and 5515, and on Defence Standard 00-16. We have written our own QA manual for software development, which lays down methods to be used, procedures, testing and documentation requirements. Our procedures have satisfied on-site QA inspections by several commercial clients.

Orcina programs are written in well-structured and modularised languages (object-oriented Pascal) using a structured software development approach. The software source is developed under a revision control system. This system strictly controls and records all changes to the software and also records the versions of all source files that were used in a given release of the program.

2 Software Testing

All Orcina programs undergo formal, planned testing at the end of development and before release. Whenever developments or changes are made to the program, testing is carried out before release. Full documentation of testing is held by Orcina, including test data files and test results.

Testing can be split into checking the numerical and the non-numerical parts of the program. Testing the non-numerical parts (e.g. editing facilities, graphics, etc.) is done by a formal series of tests covering each feature in turn, followed by extensive in-house use of the program by Orcina analysts on actual analysis work. Because non-numeric errors are generally less critical to the user, this document concentrates on numeric testing, i.e. on how we verify that the numeric results given are correct.

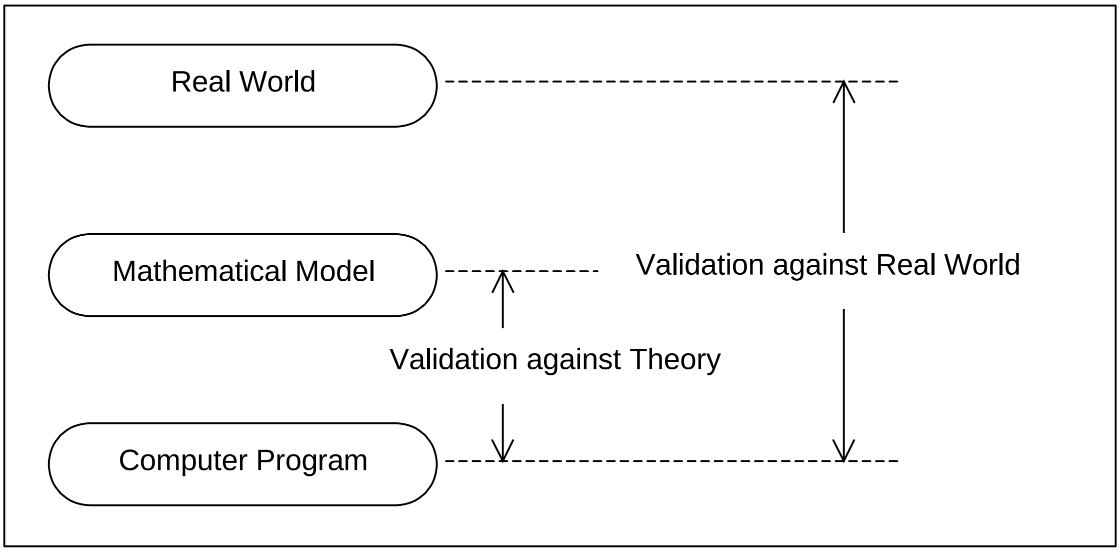
The numerical testing procedure is that, before being released for either in-house or customer use, each new version of a program is tested as follows.

- Firstly, the new version is put through a comprehensive automated test suite that compares the program results with those of the previous version. This OrcaFlex automatic test suite currently consists of over 200 test cases that cover all aspects of the program. This ensures that new developments do not introduce errors into other (existing) areas of the program.

- Secondly, all new features that have been added in this version are individually tested by designing and carrying out new tests that are specifically designed to test that new feature. This proves that the new feature is working correctly.

- Finally, new tests are added to the automatic test suite, so that the new features will be automatically tested in all future releases of the program.

3 Software Validation



The figure illustrates the relationship between a program and the real-world system that it simulates. The computer program calculates the behaviour of a mathematical model of the real world, so validation can include checking the program against mathematical theory and checking against the real world. Finally, validation can also include checking against other computer programs, especially those written by independent companies.

Validation Against Theory

Orcina perform many tests of this type as part of routine testing of every new software release. They form the backbone of our testing and have several advantages:-

- They are generally quite precise, in the sense that quite close agreement can often be obtained. This makes the test very good at detecting even small errors in the program.
- They are generally the easiest to do since data for the comparison is reasonably easily available. For example comparisons can be made against results of other programs that can model similar systems, or against hand calculations.
- They can be done for quite complex and general cases, when other programs are being used to generate the alternative results.

Orcina perform tests against a variety of sources of data, including:-

- Tests against specially-written spreadsheets or test programs. The separate test spreadsheet or program is normally written using a different approach and in a different language.
- Tests of the program against itself, i.e. a self-consistency test. For example the dynamic analysis is checked against the static analysis by running the dynamic

analysis with no excitation and verifying that the system settles to the position predicted by the static analysis. Another common self-consistency test is to check that two different ways of modelling the same system lead to the same results. This sort of test is poor on independence but is often easy to do, and is often a powerful way of detecting and correcting errors.

- Tests against theoretical results from books or other publications, e.g. comparing against results of standard beam theory for simple cases. Often only simple cases can be checked by this method, since analytical solutions are generally not available for complex cases.

Validation Against the Real World

This, of course, is the most important validation, but unfortunately tests of this type are not very common, since real world data are not often available. They also have the disadvantage of often being less precise, since errors are introduced by real world measurement errors and physical effects that are too complex to include in the mathematical model.

Many of our customers have performed validation of our software against real world measurements and have reported good agreement. However the real world measurements and the validation reports are generally not available to Orcina. Such validations have included:-

- Comparisons with test results on physical models. Model data are usually subject to effective quality control and are generally fairly reliable. Comparisons are made at model scale, to avoid scaling errors.
- Comparisons with full scale trials in controlled conditions.
- Comparisons with full scale data obtained under service conditions; this is valuable, but data are rare and often difficult to interpret, making for inconclusive comparisons.

Validation Against Other Programs

Orcina customers often check our programs against other non-Orcina programs. Since other programs generally use a different discrete mathematical model (e.g. by modelling the system using different elements), agreement with the Orcina program implies that both programs are successfully predicting the behaviour of the continuous mathematical model.

4 OrcaFlex Validation

This section describes the OrcaFlex tests that give confidence in OrcaFlex results.

DETAILED VALIDATION CASES

We have published a number of detailed validation exercises. These compare OrcaFlex to published analytical and numerical results, results produced by other programs, etc. The reports detailing these comparisons can be downloaded from our website at:

www.orcina.com/SoftwareProducts/OrcaFlex/Validation.

The following validation cases are available:

99#101 A comparison with Flexcom for a typical deepwater SCR. The comparison covered statics, regular wave dynamics and irregular wave dynamics.

99#102 A comparison with published results from a paper published at OMAE 2006. The paper compares OrcaFlex to a code written as part of the author's PhD study. Static and dynamic comparisons are considered.

99#103 A comparison with published results from a paper published at OMAE 2005. The paper compares OrcaFlex to a solution of the governing set of continuous equations for a cable with bending stiffness for a static case. This comparison is a particularly strong validation of OrcaFlex since the authors use the continuous equations rather than the discretised finite element approach of OrcaFlex.

99#104 A comparison with recent published work of Reismann in the International Journal of Non-Linear Mechanics. This paper considers numerical analysis of the large-deflection due to coupled torsion/bending of a weightless cantilever.

99#105 Three separate comparisons with standard theoretical results: (1) the catenary equations, extended to allow for axial stretch; (2) natural frequencies of a beam; (3) deflection of a cantilever beam.

99#106 A validation of OrcaFlex's implementation of frequency dependent added mass and damping for vessels. This compares results from the BMT frequency domain program NMIWAVE with OrcaFlex time domain results. The comparison also provides validation of OrcaFlex's handling of wave load RAOs.

VALIDATION AGAINST OTHER PROGRAMS

Comparisons have been made with other flexible riser programs by Orcina and by independent users. Comparisons known to us include the following and close agreement has been obtained in all cases.

Comparison carried out by	Software used for comparison
Orcina/Seaflex	FENRIS
BP	Riflex
Dunlop	Flexriser
Brasnor	Fenris, Flexriser and others
NOS/Orcina	Flexcom 3D
SBM	Ariane
Wellstream/Orcina	Flexcom 3D, Flexriser

Orcina took part in a major comparison of flexible riser programs initiated by the ISSC (Larsen, 1991). The published results show good agreement between OrcaFlex and the other established programs.

VALIDATION AGAINST THE REAL WORLD

Flexible Risers

A major validation exercise was carried out to compare OrcaFlex with model test results obtained from a joint industry project (Hartnup et al, 1987). Good agreement was obtained.

Steel Catenary Risers

A large-scale test has been carried out in Lake Pend Oreille (1998) under a joint industry project managed by PMB. OrcaFlex results show very close agreement with the test results, including details of behaviour at touchdown.

Towed Fish

OrcaFlex predictions for a towed fish case have been successfully compared with full scale measurements from sea trials.

Pipeline Pull-in

Visual OrcaFlex was used, on the Troll Olje development, to engineer the seabed configurations of two export lines for a deflect-to-connect operation in 330m water depth. The export lines were initially laid down in straight line configurations parallel to each other and 170m to 240m to one side of the export riser base (ERB). The lines were then lifted off the seabed with airbags and chains, slewed across the seabed using a deflection wire deployed from the vessel and pulled into stab connections on the ERB using winches. The chart below shows the final configurations as predicted by OrcaFlex ("Design") and as determined subsequently by ROV survey ("As Pulled"). Maximum differences between predicted and surveyed curvature along pipeline route was less than 0.2%.

(Chart and task description by courtesy of Stolt Comex Seaway, based on operations performed in 1995 on Troll Field for Norsk Hydro.)

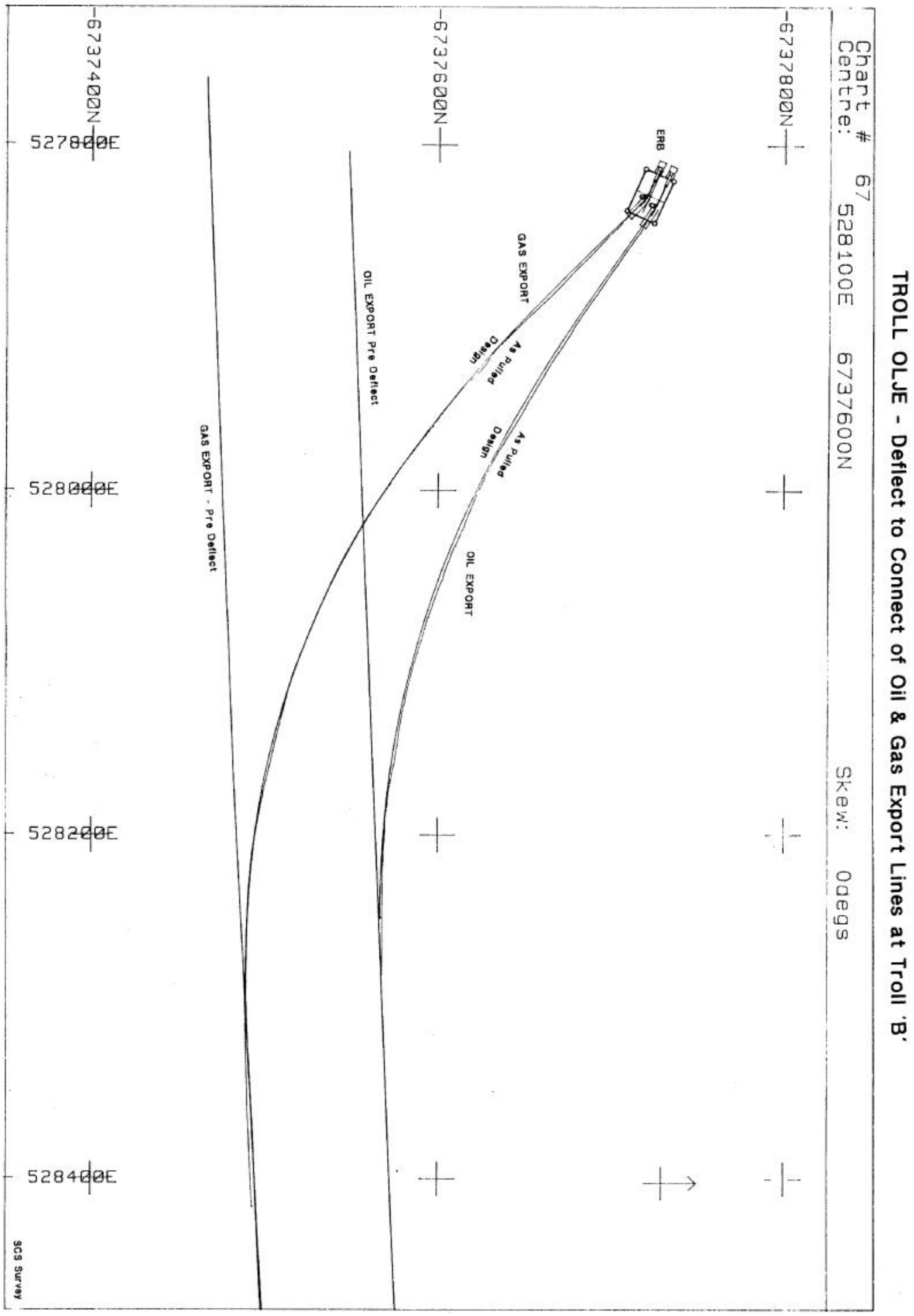


Chart: OrcaFlex prediction compared to actual "As Pulled" position.

References

API. Comparison of Analyses of Marine Drilling Risers. *API Bulletin.* **2J.**

Chapman D A, 1984. Towed Cable Behaviour During Ship Turning Manoeuvres. *Ocean Engineering.* **11**, No. 4.

Hartnup G C, Airey R G and Fraser J M, 1987. Model Basin Testing of Flexible Marine Risers. *OMAE Houston*.

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Pode L, 1951. Tables for Computing the Equilibrium Configuration of a Flexible Cable in a Uniform Stream. *DTMB Report.* **687**

Roark R J, 1965. Formulas for Stress and Strain. *4th edition McGraw-Hill*.

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5 Validation Against API Bulletin 16J

5.1 Overview

A validation of OrcaFlex against other computer programs has been performed using the test cases described in the American Petroleum Institute's (API) Bulletin on 'Comparison of Analyses of Marine Drilling Risers' (Bul 16J). Orcina has constructed OrcaFlex models of a number of the test cases and the results obtained have been compared with the results published by the API, which represent a summary of results from other riser programs. Details of the test cases are given below in the section *Description of API Cases*.

In general, the OrcaFlex output falls within the range of results obtained from the other programs. Further details and graphs are given in the Results section below.

5.2 Description of API Cases

The API test cases are of a multi-factorial design, covering a range of different likely operating conditions. Common element is a riser which starts from a point some 30ft off the seabed rising up to a vessel, to which it is connected some 50ft above the mean water level.

The differing factors covered in the test cases have the following alternatives:

- Water Depths: four different water depths (500ft, 1500ft, 3000ft and 6000ft);
- Waves:
  - Periodic Waves: two different current profile/wave height combinations for the 500ft, 1500ft and 3000ft cases (only one current profile/wave height for the 6000ft case);
  - Random Waves: one current profile/wave height
- Connections:
  - Connected cases:
    - Lower End: lower ball joint pin connection;
    - Upper End: pin connection to a tensioner ring with two different top tensions for the 500ft, 1500ft and 3000ft cases (only one top tension for the 6000ft case) –

with a different static offset per water depth. Additionally, for the 1500ft cases there two alternative Vessels;
  - Riser filled with drilling mud;
- Disconnected cases:
  - Lower End: Lower Marine Riser Package (LMRP) – incorporating a lower ball joint;
  - Upper End: no tensioner ring, simply pinned – no static offset;
  - Riser filled with seawater;

For the 3000ft and 6000ft cases additional buoyancy is added to the riser. In addition, the riser is of a different dimension for the 6000ft case. For more detailed information on the API test cases see the API bulletin.

A subset of tests has been selected which incorporate most of the possible alternative factors. In setting up the OrcaFlex models it was found that the description of some of the factors mentioned above were either ambiguous or lacking in sufficient detail. This is an inevitable feature of these types of general purpose test-cases, but it does lead to the need to make certain assumptions which may result in the tested model differing slightly from the originally intended concept.

5.3 Results

Comments

Both static and dynamic results are detailed in the API bulletin. We concentrate here on the dynamic results. The following section contains graphs for all six of the tests performed by Orcina. The graphs show both the output obtained from OrcaFlex and representations of the output obtained from the other programs involved in the original API test.

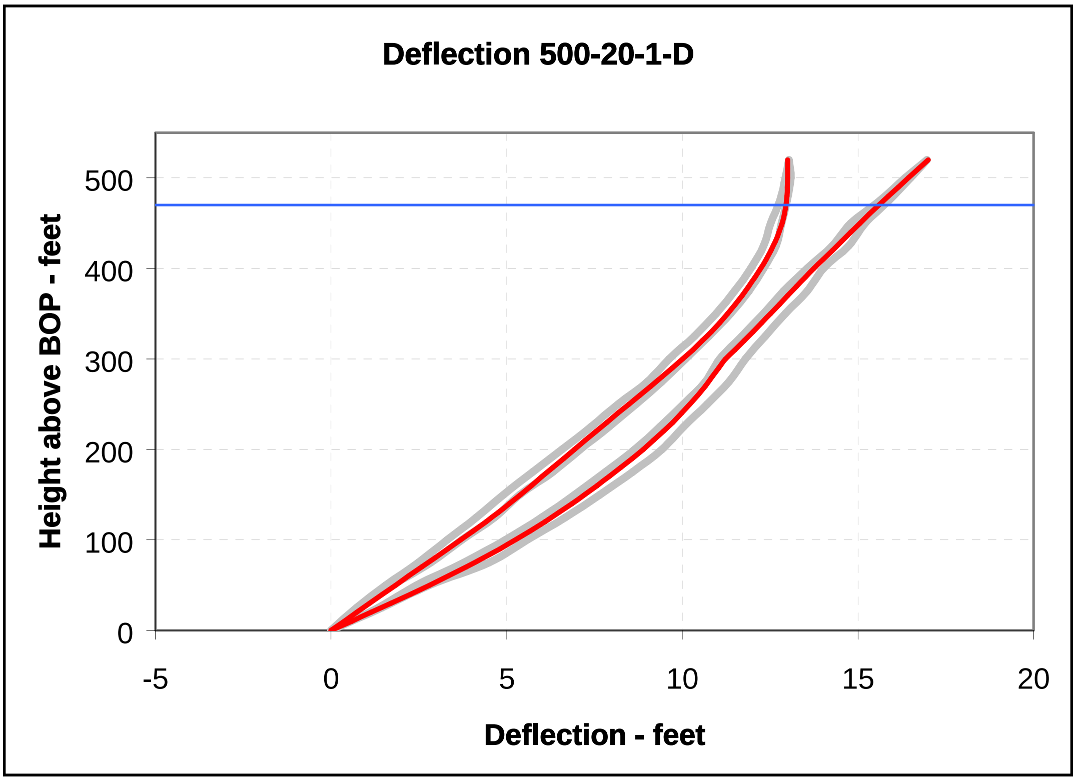
Each graph contains two sets of 3 lines representing the minimum and maximum values of the indicated variable, against arc length, observed over a wave period. Of the three lines in each set one represents the OrcaFlex output (shown as a thick (red) line) and the other two form an envelope (of two-standard deviations width) about the average value from the tested programs (though not all programs were included in forming these averages).

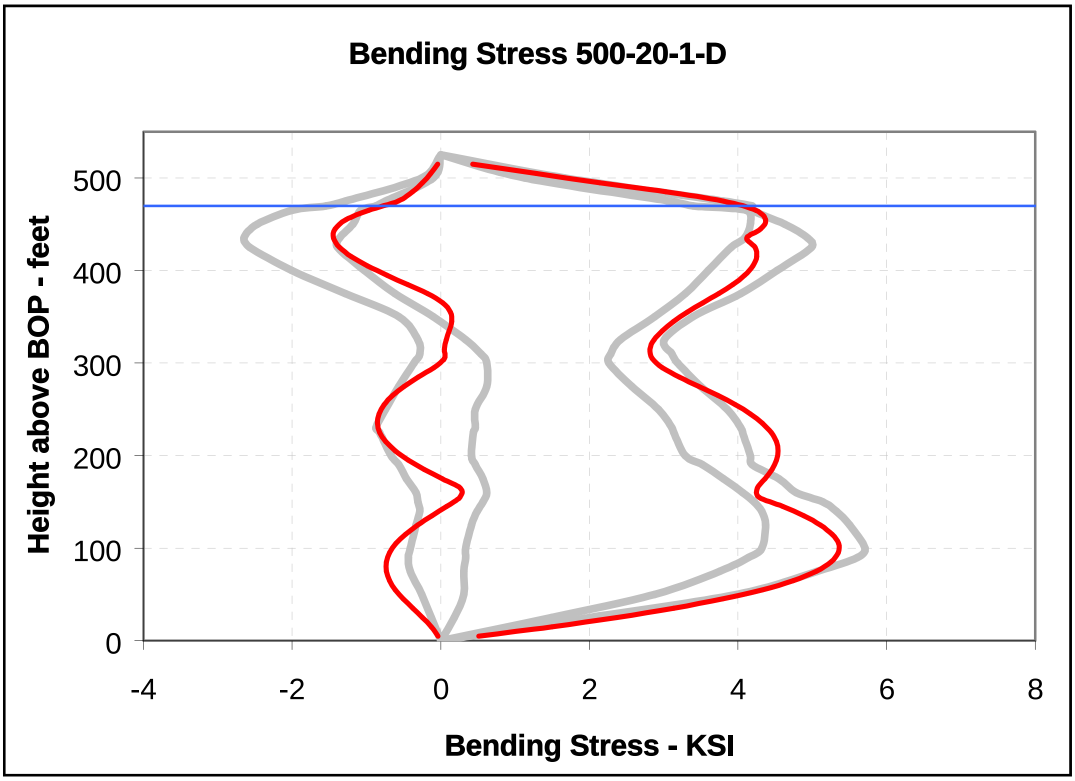
In general, and with few exceptions, the OrcaFlex output lies comfortably within the envelopes.

Possible causes of discrepancies:

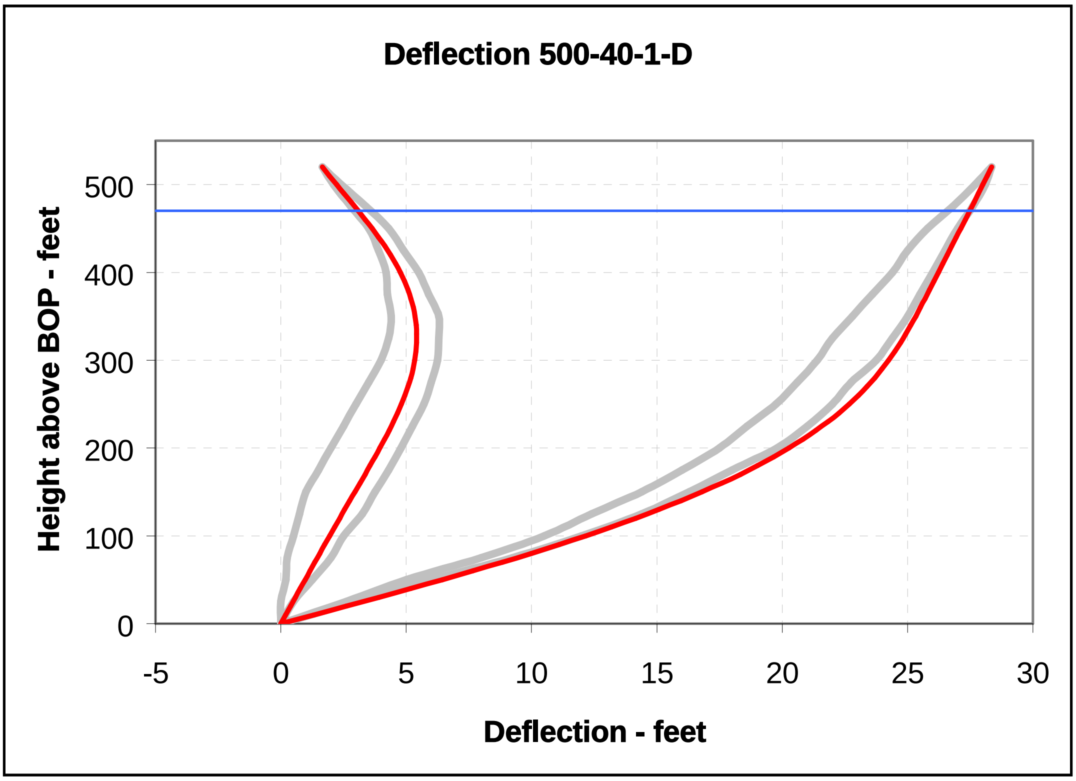
- Necessary assumptions in the set-up of the models due to ambiguous specifications in API bulletin.
- Many of the programs used in the API tests are of the frequency-domain type and so have inherent linearisation limitations, whereas the time-domain approach adopted by OrcaFlex allows for more sophisticated modelling of non-linear effects.
- The results presented in the API document are derived from the full results through a selective reporting procedure which excluded several programs, on a case by case basis. The basis on which specific results were accepted or rejected is not discussed in the API document, and no justification is presented.

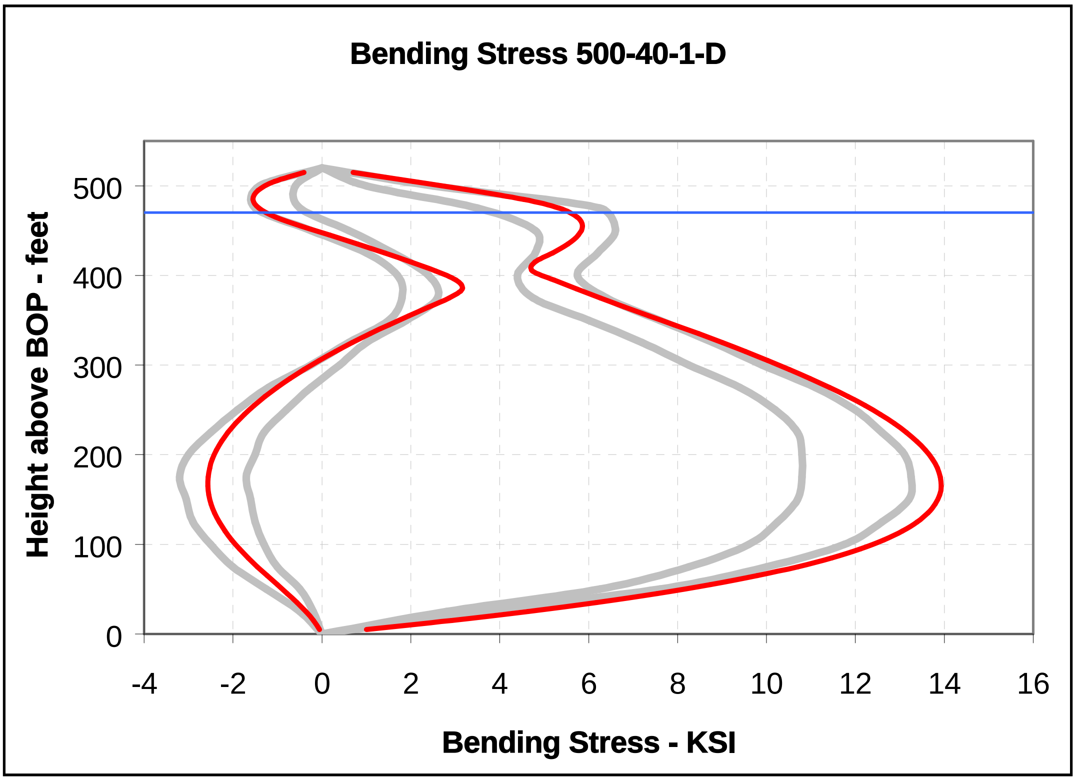
Case 500-20-1-D



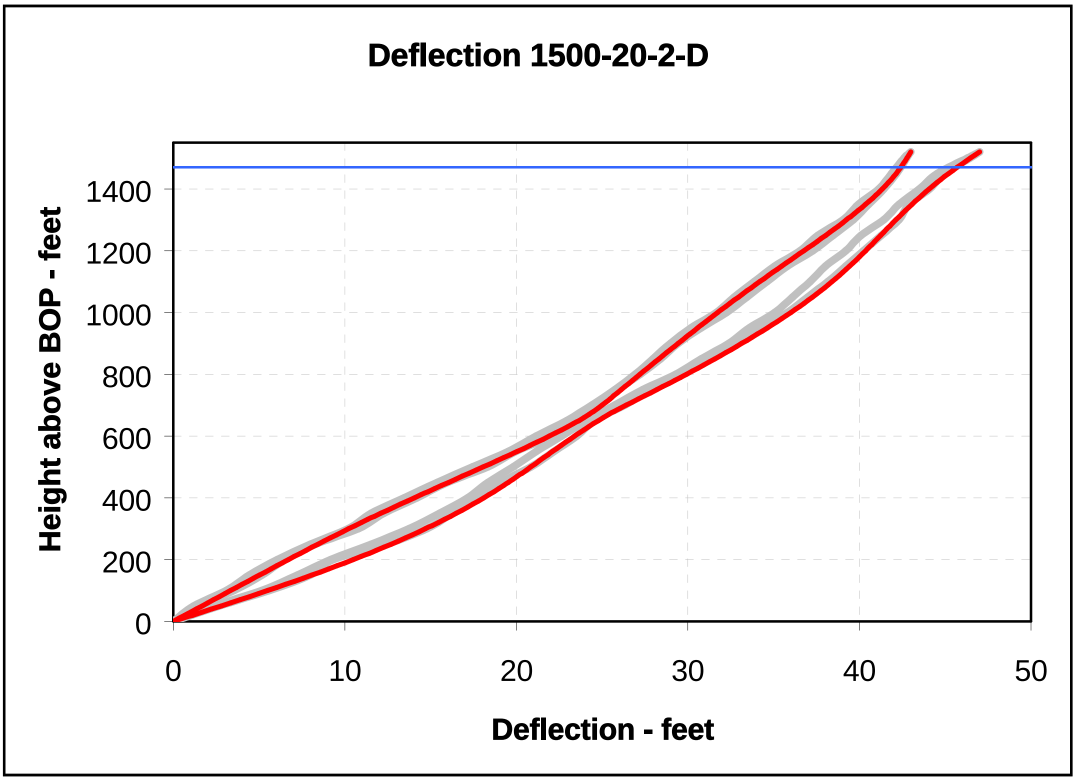


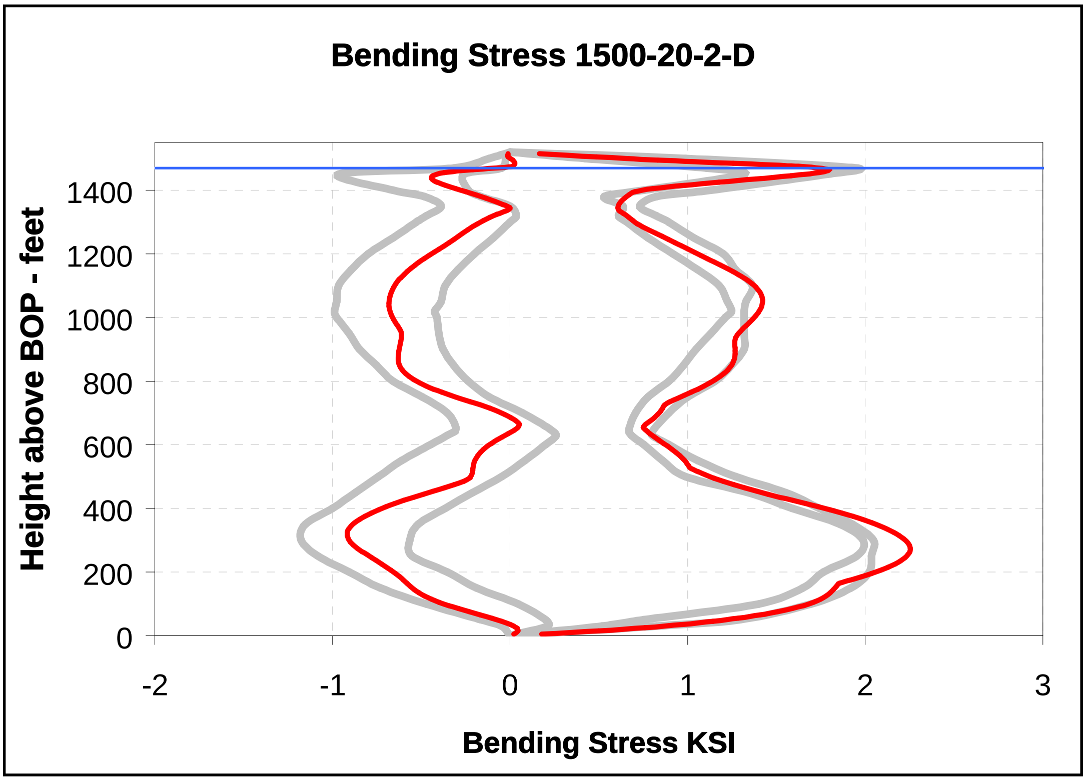
Case 500-40-1-D



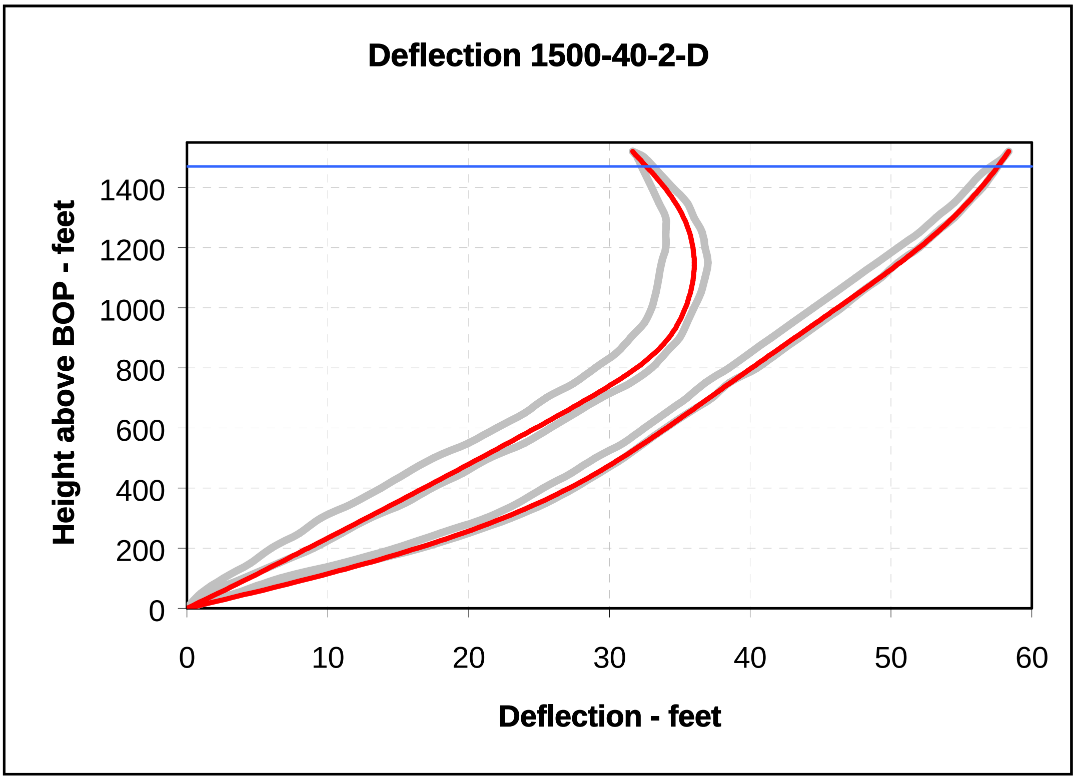


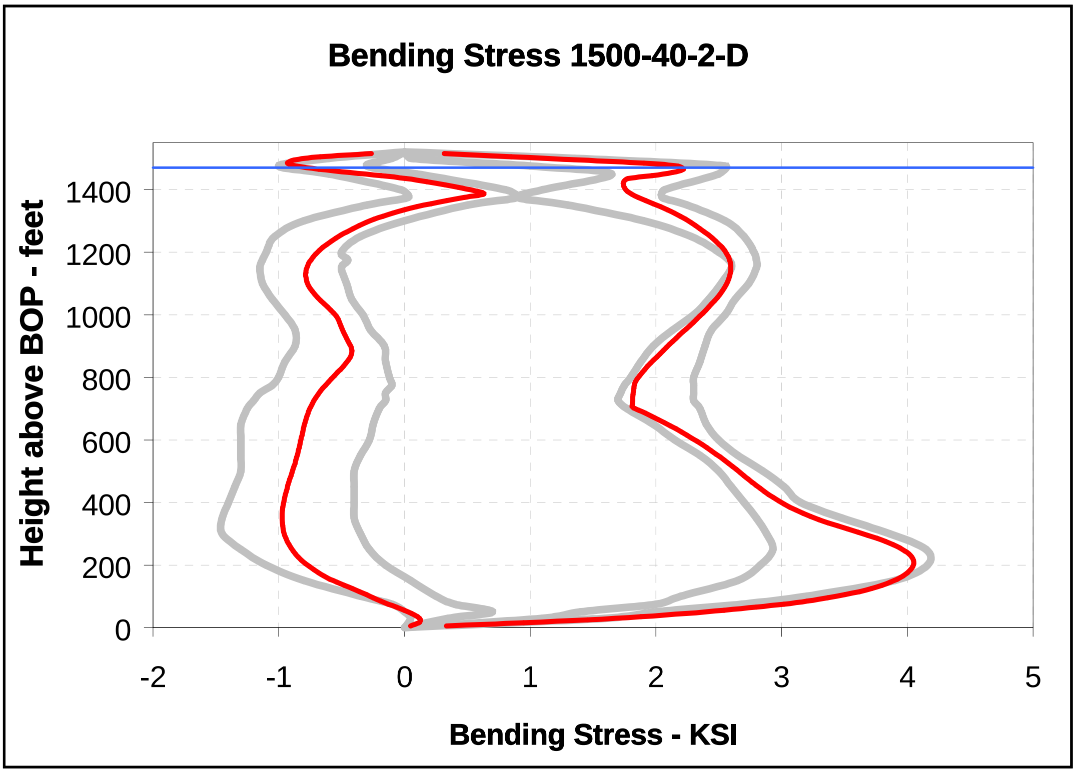
Case 1500-20-2-D



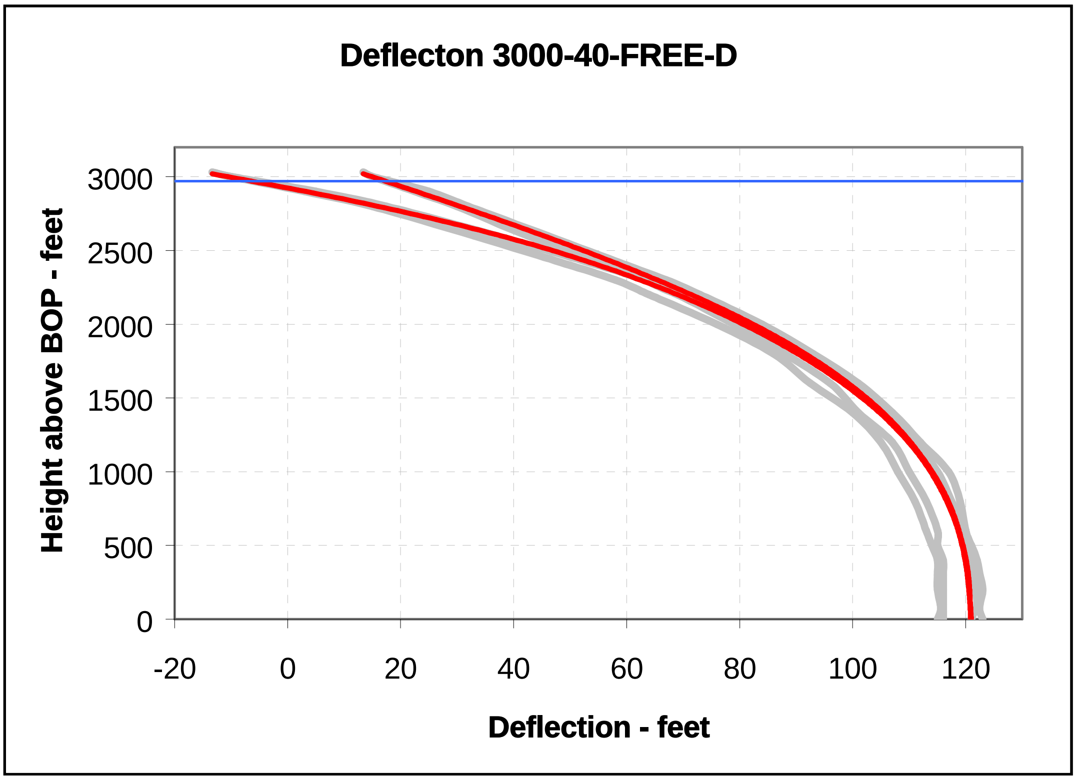


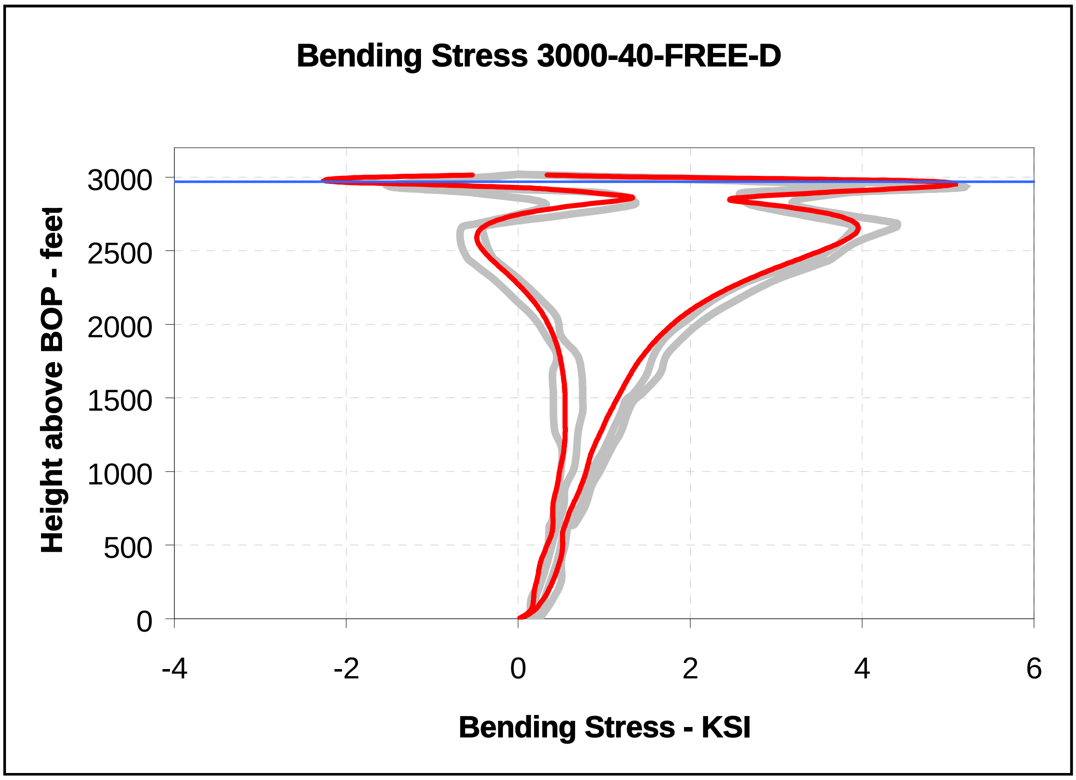
Case 1500-40-2-D



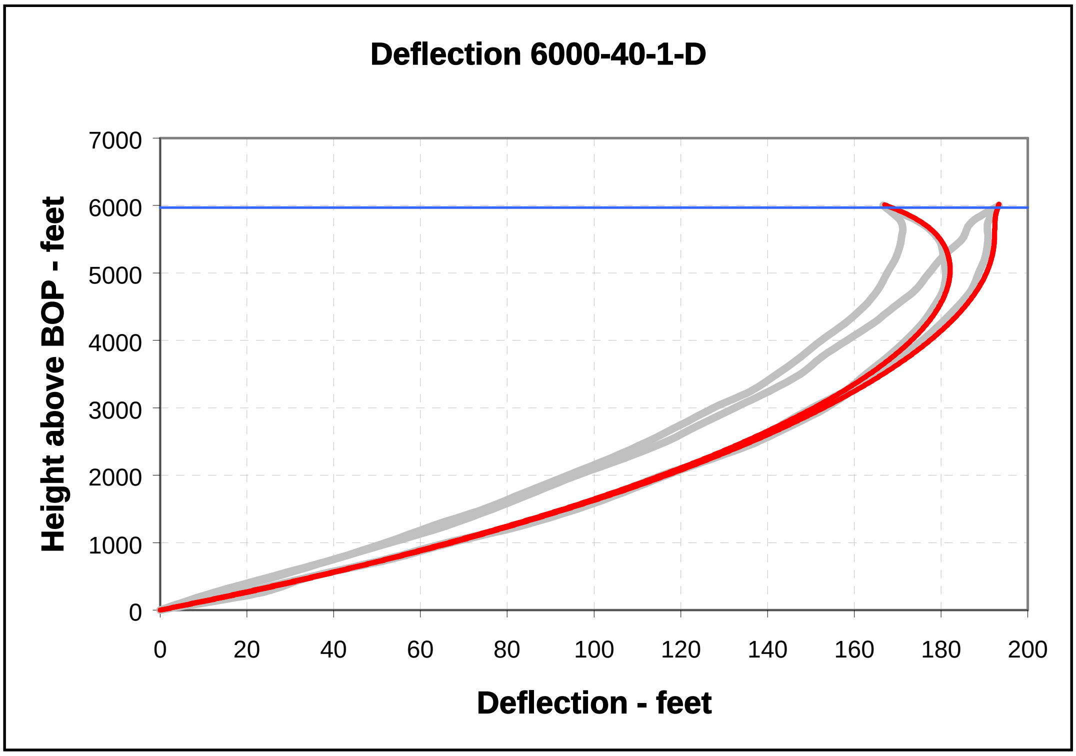


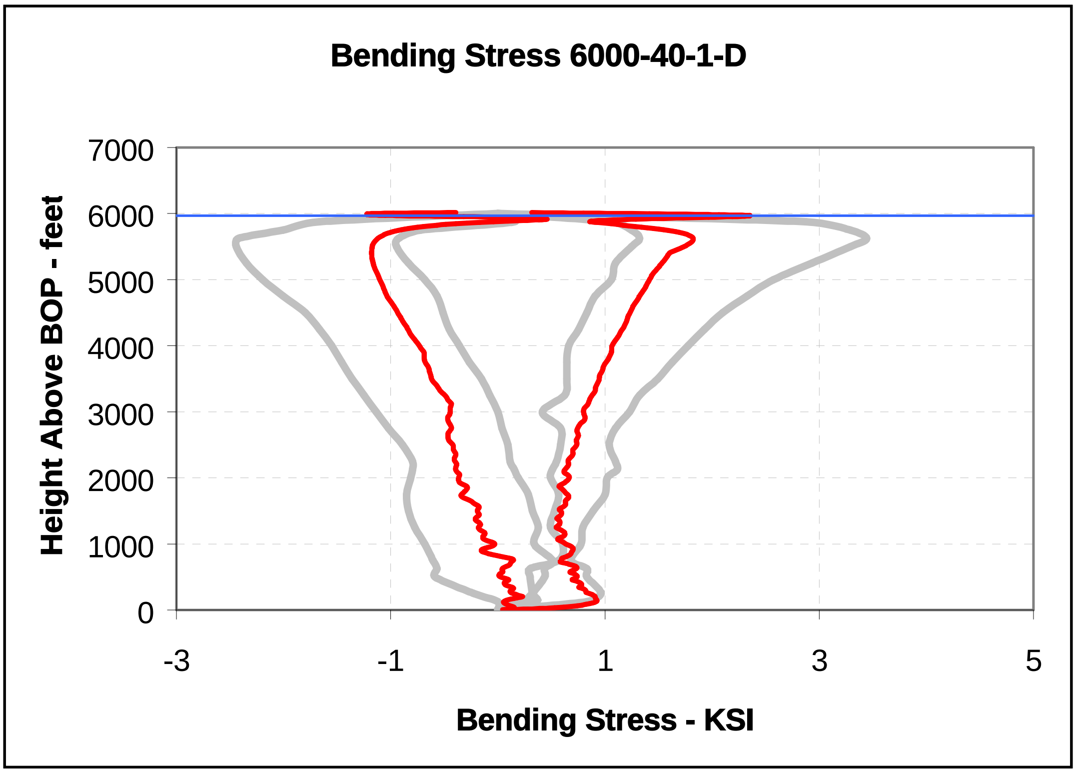
Case 3000-40-FREE-D





Case 6000-40-1-D





References

API. Comparison of Analyses of Marine Drilling Risers. *API Bulletin.* **16J.**