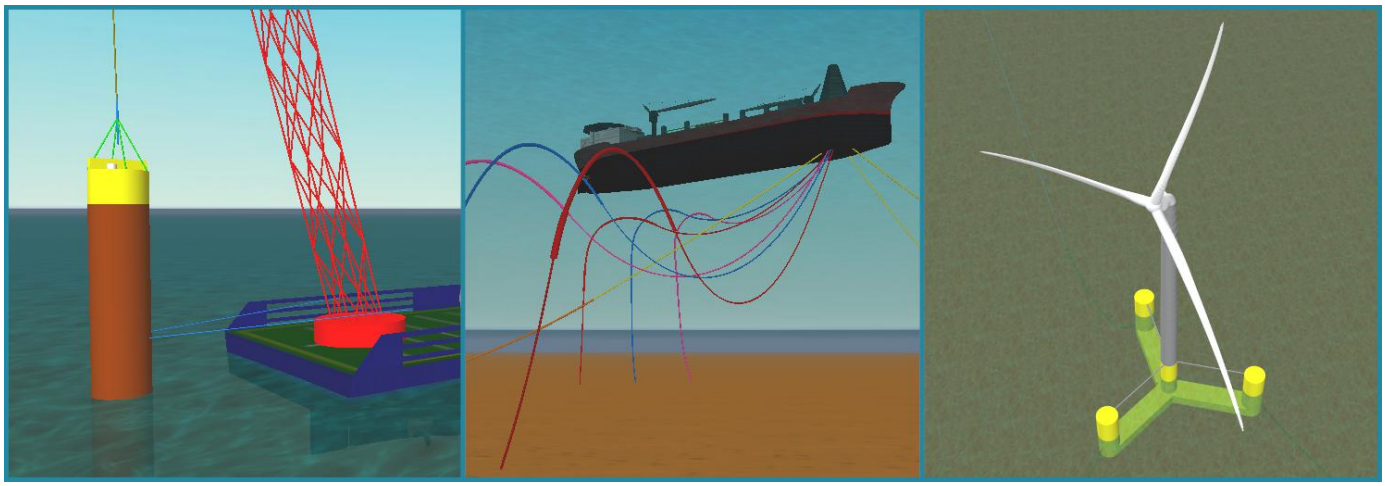
version 11.4

orcaflex technical specification



OrcaFlex is the world's leading software package for the design and analysis of a wide range of marine systems. Typical applications in offshore dynamics include riser systems (SCRs, TTRs, hybrids, flexibles, umbilicals, hoses), mooring systems (spread, turret, SPM, jetty, etc.), marine renewables, installation planning with capabilities across the full range of scenarios, towed systems (bundle dynamics, seismic arrays, towed bodies, etc.), defence, seabed stability and many other types of system.

Summary of key features

- 3D, nonlinear, large displacement analysis
- Fully coupled tension, bending & torsion
- Accurate, efficient and proven FE formulation
- Robust line compression / snatch modelling
- External line-on-line clash & sliding contact
- Internal line-in-line impact & sliding contact
- Modelling of post-contact behaviour
- Linear & nonlinear elastic contact stiffness
- User-defined seabed resistance profiles for lines
- Line slug flow and free-flooding effects
- Tabular contents modelling & expansion tables
- Truss structure modelling tools
- Nonlinear Time Domain (implicit & explicit)
- Linear Frequency Domain (1st & 2nd order)
- Quasi-dynamic analysis
- Restart analysis
- Constraints to fix or impose individual DoFs
- Line feeding (haul in and pay out nodes)
- Fully coupled vessel - line analysis
- Fully coupled wind turbine analysis
- OrcaWave diffraction solver
- Comprehensive vessel load modelling
- Multi-body hydrodynamic coupling
- Full sum and full difference QTFs
- Vessel wave shielding (sea state RAOs)
- Water entry & exit slam loads
- Full description of wind, wave and current
- Flat, 2D or 3D seabed profile
- Linear elastic, non-linear hysteretic & P-y soil
- Binary and / or text input files
- Fatigue analysis
- Extreme value statistics
- Modal analysis
- VIV and Interference analysis
- Pipelay and Riser code checks
- Comprehensive range of automation tools
- Complete Matlab, Python & DLL interfaces
- Parallel processing (at no extra cost)
- Batch processing for volume analyses
- Distributed OrcaFlex optimises multi-licence use
- Full GUI with wire frame and shaded views

Contents

Modelling objects

A wide range of objects, each very powerful, easily allows simple or complex models to be built

Lines

- Fully coupled bending, torsion and axial stiffness
- Bend Stiffener / Tapered Stress Joint model tool
- Pre-bend (e.g. spool pieces) can be modelled
- Centrifugal internal flow effects included
- Slug flow and free flooding options for line contents
- Tabular contents modelling & expansion tables
- Multiple coatings and linings can be defined
- Bending stiffness, drag & added mass can be non-isotropic
- Axial, bending and torsional stiffness can be nonlinear
- 3D hysteresis model available for bending, axial, and torsional effects
- Rayleigh damping with or without geometric stiffness
- Line CofG may be displaced from geometric centre
- Line lengths and end orientations can be automatically calculated based on end positions, e.g. for truss modelling
- Clumped line attachments, drag chains or flex joints
- Non-isotropic Coulomb friction with seabed & elastic solids
- Line Clashing for external clash modelling between lines
- Line Contact for pipe-in-pipe, piggybacks, J-tube pulls, bend stiffeners, sliding connections, etc., allowing smooth modelling of large relative axial motion including friction
- Line feeding for pay out and haul in of nodes
- Hydrodynamic, aerodynamic & user-defined applied loads
- Wake Interference (Huse, Blevins, user specified)
- Partially submerged lines handled robustly
- Line drag & lift coeffs can vary with Re or seabed proximity
- Added mass as a function of submergence or height above seabed
- Water entry / exit slam loads (per DNV H103, RP-C205)
- Compressibility specified by bulk modulus
- Choice of finite element or analytic catenary representation

Turbines

- Dedicated horizontal-axis turbine object
- Clockwise or anticlockwise spinning rotor
- Aerodynamic loading via Blade Element Momentum (BEM)
- Unsteady aerodynamics models: González/Minnema Pierce
- Flexible blades capturing aeroelastic coupling effects
- Blade pre-bend
- Drivetrain flexibility (main shaft stiffness & damping)
- Collective or individual blade pitch control
- Prandtl tip and hub loss models
- Pitt and Peters skewed wake model
- Øye dynamic inflow model
- Interface via API to blade pitch and generator torque controllers (e.g. Bladed-style DLLs)
- Choice of tower influence / shadow models
- Rayleigh damping on blades
- Spatially varying wind models including full field (turbulent) wind, as well as linear vertical shear, horizontal shear & gust speed variation

Vessels

- Imposed vessel displacements:
  - first order displacement RAOs
  - prescribed and / or harmonic motion
  - time history motion files
  - externally calculated
- Loads for calculated vessel motions:
  - first order load RAOs
  - applied loads (thrusters, ice, etc.)
  - 2nd order (low freq.) difference QTFs: full and Newman
  - 2nd order (high freq.) sum QTFs
  - wave drift damping
  - added mass and damping with convolution
  - 6DoF 'other' linear and quadratic damping
  - manoeuvring, current and wind loads
  - drag from attached Morison elements
  - loads from attached lines (coupled analysis)
- Multi-body hydrodynamic coupling between floaters
- Sea state RAOs (vessel wave shielding, wave jetting, etc)
- Air gap reporting
- Inertia compensation to avoid double-counting for large superstructures e.g. floating wind turbine

Buoys

- Full 3D and 6D modelling of buoys
- Lumped option with overall properties
- SPAR option for co-axial cylinders, each with own properties
- Fluid loads calculated based on the instantaneous wetted surface
- Added mass as a function of submergence
- Water entry / exit slam loads (per DNV H103, RP-C205)
- Wings for lifting surfaces
- User-defined imposed loads
- Compressibility specified by bulk modulus
- Coulomb friction with seabed and elastic solids

Shapes

- Used for modelling boundary surfaces
- Shapes with friction for line & buoy contact
- Plane, cuboid, cylinder (solid/hollow), & bellmouth options
- Trapped water option for moonpool modelling
- Drawing option for visualisation purposes

Winches

- Winches with several length or tension control options

Links

- Links (springs) with linear or nonlinear stiffness & damping

Constraints

- Allow individual degrees of freedom for other objects to be constrained
- Imposed motion via time history or externally calculated

Environmental description

Many options to apply environmental loads

Sea

- User-defined water density, kinematic viscosity, temperature
- User-defined horizontal and vertical density variation
- Temperature can be constant or vary with depth
- Kinematic viscosity can be constant or vary with temperature

Seabed

- Horizontal, sloping, 2D or 3D seabed surface (smooth or linear)
- Choice of soil models:
  - linear elastic
  - nonlinear hysteretic (trenching, suction & re-penetration)
  - P-y models (API RP 2A soft clay & sand & user-defined) for vertical and near-vertical line penetration
- Non-isotropic Coulomb friction in both statics & dynamics

Wind

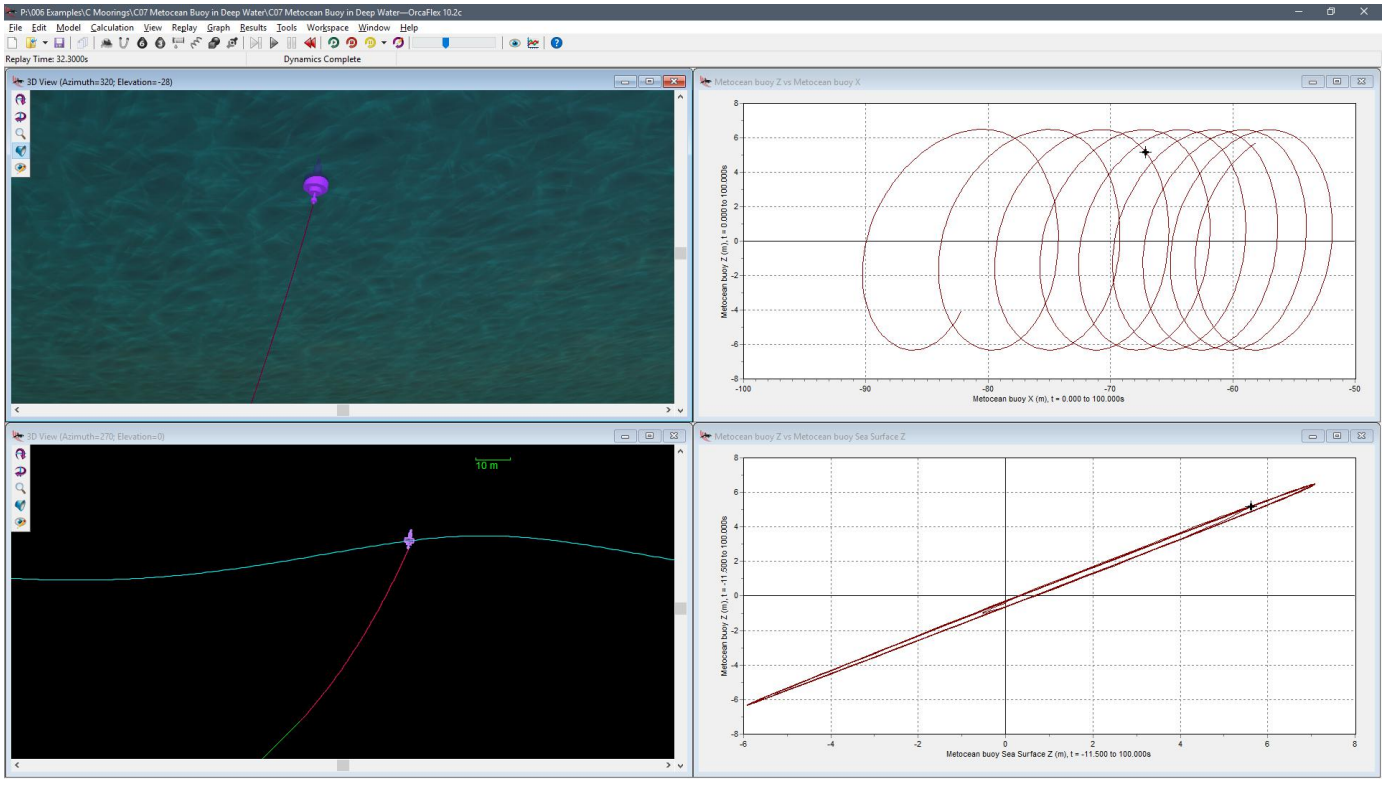
- User-defined air density
- Wind velocity can be constant, NPD, API or ESDU spectra
- Wind can be a user defined spectrum or user defined components, and can also be a time history file of speed and direction
- Vertical variation factor specified as a profile
- Full field wind (varies with both space & time)

Waves

- Regular: Airy, Stokes' 5th, Dean Stream Function, Cnoidal
- Irregular: ISSC, JONSWAP, Ochi-Hubble, Torsethaugen, Gaussian swell, user-defined, Time History
- Multiple wave trains for combination sea states
- Fluid stretching (Wheeler, kinematic or extrapolation)
- Irregular waves have directional wave spreading option
- Preview and selection of irregular wave profile
- Wave kinematics choice (with individual specification for 3D & 6D buoys and lines):
  - Exact (all nodes/buoys, every time step)
  - Grid interpolation at instantaneous object positions
  - Calculation at object static positions only
- Various wave spectrum discretisation methods:
  - equal-energy (user-defined bounds & interval)
  - equal spacing (arithmetic progression)
  - geometric progression

Current

- 3D, non-linear
- Both magnitude and direction can be time varying
- Horizontal variation factor on magnitude



Effects on the position of a buoy shown simultaneously through 3D views and time history results

User interface

The OrcaFlex UI gives unrivalled flexibility in model building and analysis

Graphical user interface (GUI)

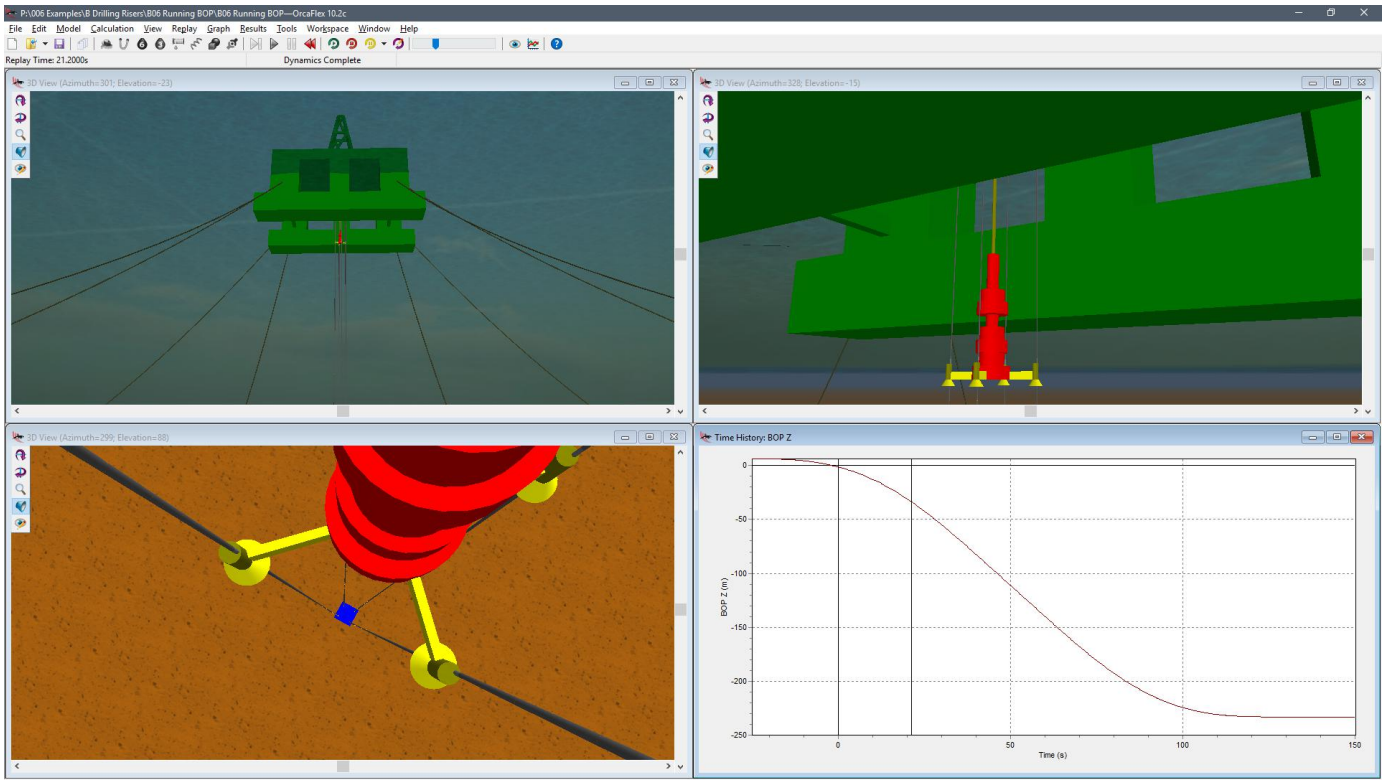
- Fully interactive native user interface
- Separate fully interactive user interface for OrcaWave diffraction solver
- Visualisation as wire frame and / or shaded graphics
- Shaded has perspective, lighting, hidden line, etc.
- Moving camera option to track large-scale object motion
- Add text labels at any point in 3D space or attach to objects
- Powerful dockable Model Browser to:
  - organise and manage complex models
  - group objects in logical collections
  - copy / paste objects or groups within or between files
  - show / hide, move and locate objects or groups
  - compare object data
- Compare files with built-in or user-specified compare tools

GUI data input

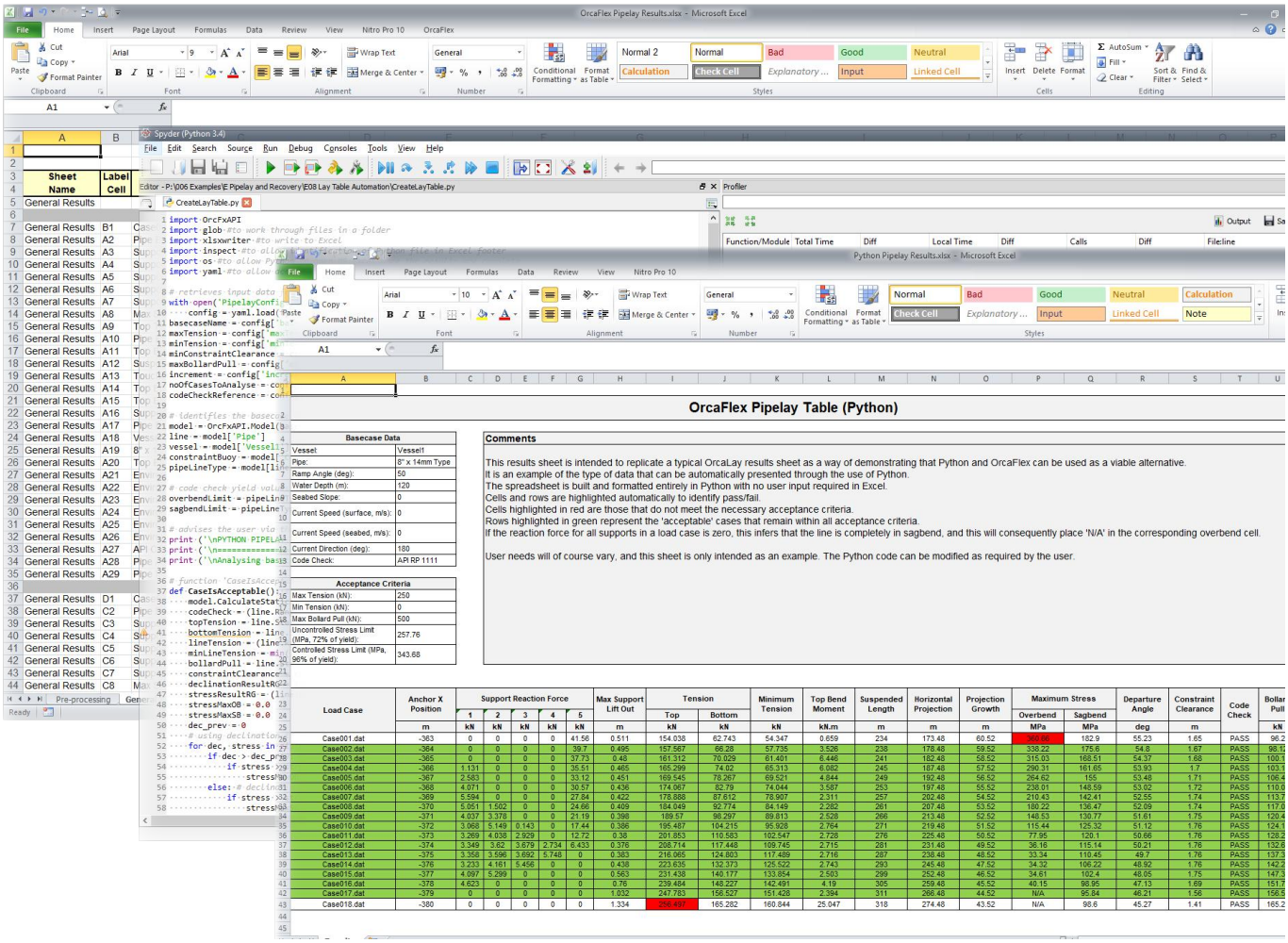
- Readable, structured and self-documenting text files
- Binary files with strong version compatibility
- Drag-and-drop model import from other OrcaFlex files
- Auto import for OrcaWave, AQWA and WAMIT hydrodynamic data
- Generic text file import for other diffraction data
- Graphical RAO realism checks
- Generic line properties through built-in properties wizard
- Wizard for (hysteretic) non-linear moment-curvature data
- Variable Data for non-constant data (drag vs. Re, etc.)
- External functions admit user-defined calculations
- Time history data import for:
  - vessel motions
  - wave elevation
  - wind speed & direction
  - constraint motions
- SI, US or user-defined units
- Full and comprehensive context sensitive help
- Additional dedicated UI for building pipelay roller supports

GUI results

- Multiple simultaneous 3D views, results graphs & tables
- Workspace facility to manage windows
- Replay wizard to animate multiple simulations
- AVI file export of animations
- Results displayed at run time and / or simulation replay
- Results storage optimised to minimise file size
- User-defined results can be created if not available as a standard result
- Optional embedded Python in OrcaFlex installation, for use with external functions, post-calculation actions, user-defined results, etc.
- GUI output can be:
  - graphical (time histories, range and X-Y graphs)
  - values (in Excel spreadsheet format)
  - statistical analysis (incl. extreme statistics)
- GUI graphs and 3D views can be copy / pasted
- Vessel spectral response reported at any point
- Vessel disturbed sea state and air gap reported at any point



Multiple shaded graphics views and results windows running concurrently



Automation options including pre and post-processing via Excel and Python

Automation and productivity

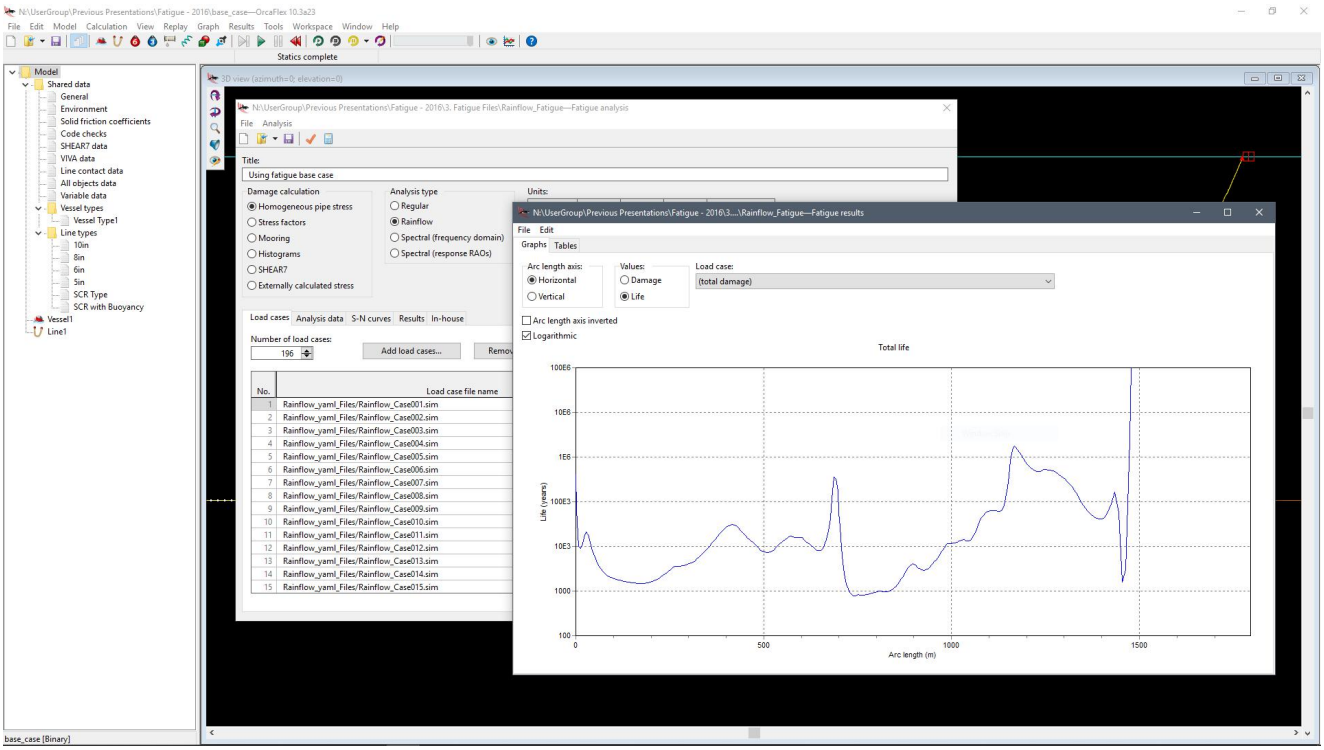
OrcaFlex offers a wealth of automation and productivity-enhancing features

- OrcaFlex comes with both 32- and 64-bit executables
- Integral parallel processing for multi-core / processor hardware
- OrcaFlex Excel spreadsheets for:
  - pre-processing for parametric variations of input data (either binary or text files)
  - post-processing to extract results from many output files
- Fully multi-threaded, unattended, batch processing for:
  - data files (binary or text) for static and dynamic analysis
  - batch script files
  - fatigue analysis
  - OrcaFlex post-processing spreadsheet
  - post-processing with Python or command script
- Batch processes above in correct order in case of dependencies
- Low level programmatic interface, targeting C, C++ or Delphi (allows integration with 3rd party applications)
- High-level programmatic interface, targeting Matlab or Python
- Automated execution of SHEAR7 and VIVA from OrcaFlex
- Conversion of storm scatter tables to regular wave scatter tables
- Automation for model building, including:
  - wave search facility
  - Line Type and Plasticity Wizards
  - Line Setup Wizard
- Automation for results, including:
  - vessel response reports
  - fatigue analysis
  - extreme value statistics
- Distributed OrcaFlex optimises use of spare processor time:
  - only of benefit in a multi-licence environment
  - server program co-ordinates and allocates jobs to clients
  - clients can be set to accept or reject jobs
  - client jobs run at low priority (min. impact on other tasks)
  - client jobs can be aborted and server will re-allocate
- Orcina Licence Monitor allows monitoring of OrcaFlex use

Fatigue analysis applications

Comprehensive fatigue analysis for all applications

- Fatigue calculations are all multi-threaded
- Regular, rainflow & spectral (frequency domain and response RAOs) fatigue analysis options
- 5 fatigue damage calculation options:
- homogeneous pipe (S-N curves)
- stress factors for different cross-section layers (S-N curves)
- mooring (T-N curves)
- SHEAR7 (damage results collated & presented in OrcaFlex)
- user-defined externally calculated stress (via external functions)
- S-N and T-N curves can be tabulated or set parametrically
- S-N curves have option of 3 mean stress models
- Analysis at multiple circumference points on ID and OD
- Analysis at multiple line positions, each with different:
- stress concentration factors
- thickness factors
- S-N curves (or T-N curves for moorings)
- Damage results as tables and / or graphs for overall damage or damage from individual cases
- Histogram collation and individual results also available



Rainflow fatigue analysis

Vortex induced vibration (VIV)

Simply the most comprehensive set of VIV tools in one program

Overview

- Uses the leading methods for the analysis of VIV
- All methods are coupled, applying VIV loads to the line
- Generalised to 3D behaviour (not just 2D)
- Highly efficient as all VIV models use same FE model
- Tested and fully documented SHEAR7 and VIVA interfaces
- Quality-assured implementation of time domain models
- Consistent results comparison from different VIV models

Shear7 & VIVA interfaces

- Export input data to run SHEAR7/VIVA off-line
- Call either directly from OrcaFlex with either a user-specified or OrcaFlex-derived mode shape file
- Auto-selects transverse modes for mode shape file
- OrcaFlex statics couples with SHEAR7 / VIVA enhanced drag
- Results (incl. fatigue) presented in OrcaFlex; for SHEAR7, optionally aggregate fatigue damage via the OrcaFlex fatigue form

Wake oscillator models

- Milan or Iwan and Blevins wake oscillator models
- Model VIV suppression by turning off for selected line sections
- In-line drag enhancement included

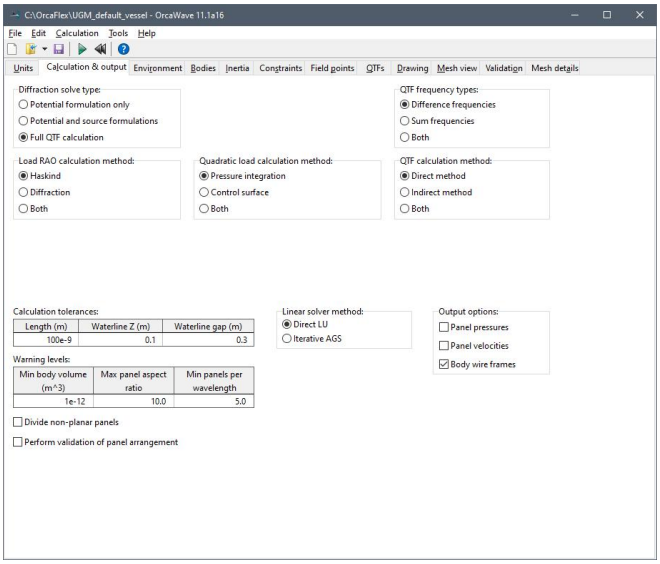
Vortex tracking models

- Two approaches which model the physics of VIV
- Both in-line and transverse VIV effects included
- Boundary layer theory for stagnation and separation points
- Inviscid Navier-Stokes equation used outside the boundary layer
- Much less computationally demanding than full CFD

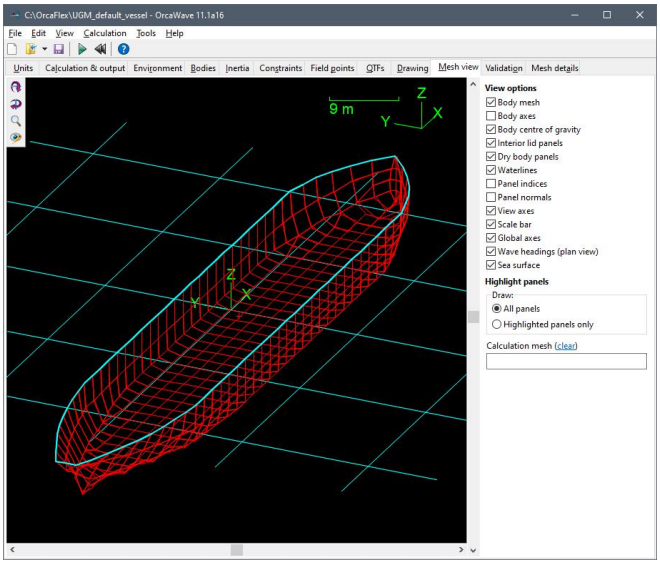
Diffraction analysis (OrcaWave)

OrcaWave is a stand-alone diffraction program included with OrcaFlex

- Calculates loading and response for wet bodies due to surface water waves
- Utilises potential flow theory, outputs include:
  - load RAOs (choice of Haskind or diffraction methods)
  - displacement RAOs
  - added mass and damping matrices
  - Newman QTFs (choice of pressure integration or control surface methods)
  - full QTFs (sum and/or difference frequencies, direct or indirect methods)
  - sea state RAOs
- Can include dipole panels for thin walled structural elements with fluid on both sides e.g. strakes or heave plates
- Can include Morison elements
- Single or multibody analysis
- Bodies can be rigidly connected e.g. for modelling the separate hulls of a semisub or catamaran
- Choice of direct or iterative linear solvers
- Support for multiple mesh file formats (WAMIT.gdf, Nemoh.dat, Aqwa.dat, Sesam.fem, Hydrostar.hst, Gmsh.msh, Wavefront.obj)
- Mesh view and validation tool allows easy checking of mesh geometry
- Intermediate results to enable first-order calculations to be reused in related analyses for processing efficiency
- Seamless transfer of data to OrcaFlex
- Batch processing
- Automation via OrcFxAPI



OrcaWave calculation page



OrcaWave mesh view

Numerical procedures

OrcaFlex is the most robust and therefore most widely applicable in its peer group

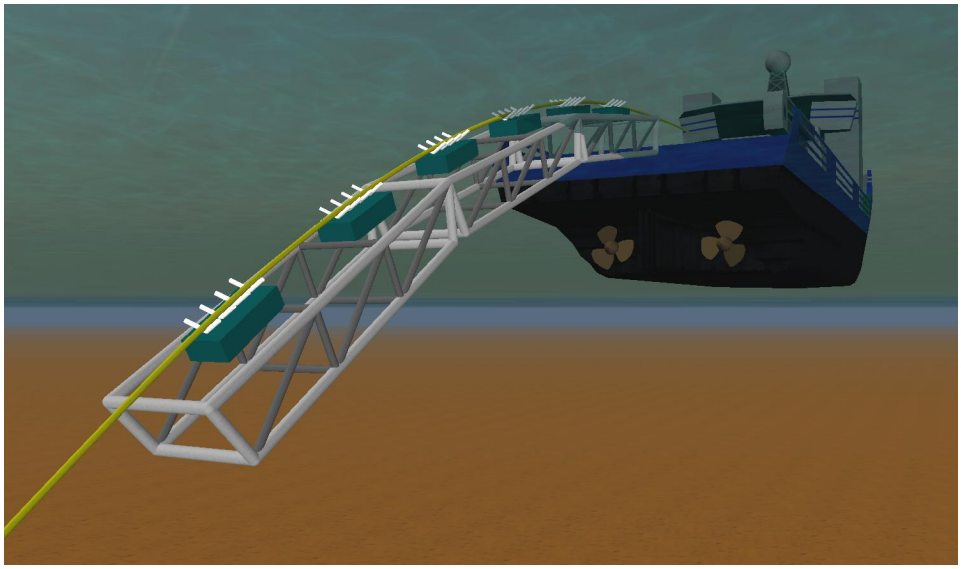
- Finite element with 6 DoF at each node
- Constraints to fix or impose individual DoFs
- Connect mid-Line nodes to other objects
- Optional 3 DoF line element for optimal performance
- Element formulation is extremely robust and accurate
- Element is proven and widely applicable
- Fully coupled tension, bending and torsion
- Full 3D model building and analysis
- Non-linear large displacement analysis
- Variety of dynamic solution methods*:
  - Nonlinear time domain implicit (constant or variable Δt)
  - Nonlinear time domain explicit
  - Linear frequency domain (1st & 2nd order)
- FFT reconstruction of wave field from wave elevation time history
- Fluid forces based on Morison and cross-flow assumptions
- 3 optimisations for wave kinematics calculations
- Extremely quick and robust static analysis
- Dynamics ramped-up (to eliminate starting transients)
- Robust line compression and snatch load modelling
- Line and system modal analysis (shapes and loads)
- Contact, clashing and clearance analysis
- Linear & non-linear elastic contact stiffness for seabed, elastic solids, line contact and supports
- Vessel manoeuvres (forward speed and turn rate)
- Coupled and uncoupled vessel / line analysis
- Surface piercing fully modelled
- Setup Wizard to set line length for target end conditions
- Pressure effects on line EI can be separate for statics & dynamics
- Code checks (API RP 2RD, API RP 1111, DNV OS F101, DNV OS F201 and PD 8010)

* Time domain allows inclusion of all listed effects. Frequency Domain can't include time dependent effects, nor effects which can't be sensibly linearised.

Commercial options

OrcaFlex's commercial structure is widely recognised as the most cost-effective in its peer group

- OrcaFlex is not modular - all features are integral to the program, including multi-threading and the OrcaWave diffraction solver
- Comprehensive Maintenance, Upgrade & Support (MUS) contract with very responsive client support
- Very competitive pricing, with highly attractive tiered multi-copy discounts on purchases and MUS
- Group agreements allow affiliates to pool their licences achieving greater multi-copy discounts
- Purchases always include a free MUS period (1 year for 1st purchase); later purchases include pro-rated MUS
- Very flexible leasing, inclusive of MUS, with a 1 month minimum lease period
- Attractive lease-to-purchase option with majority of last 3-years' lease charges counting towards purchase
- All licensing is on a world-wide basis – clients are free to move licences at will to best suit their purposes



About Orcina

Founded in 1986, Orcina is now widely recognised as a global leader in its field, with a well-established reputation for innovation, excellence and real-world capability.
At the heart of our activities is our unique Orcaflex software, which has set a new industry standard where dynamic analysis is concerned. OrcaFlex is primarily used by naval architects, engineers, consultants and designers to analyse and solve engineering problems.
Our software and approach is flexible enough to accommodate the needs of large corporates requiring hundreds of licenses and individuals who just require one.
The core sectors we serve are focused on research, analysis and engineering in oil & gas, wet renewables, oceanographic, seismic, defence, and aquaculture. However we are constantly developing our software to meet the needs of evolving engineering challenges and new market requirements.

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