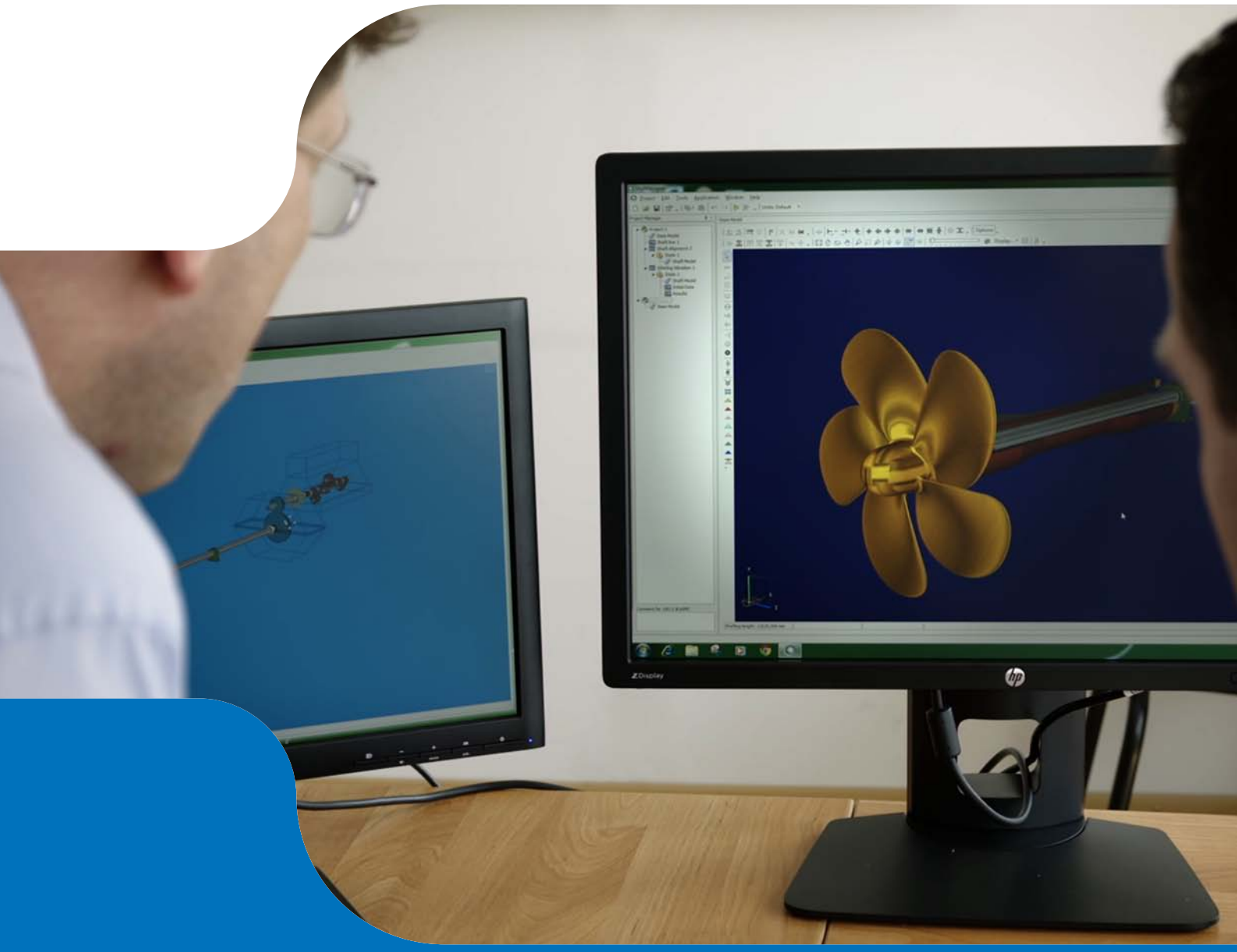
ShaftDesigner

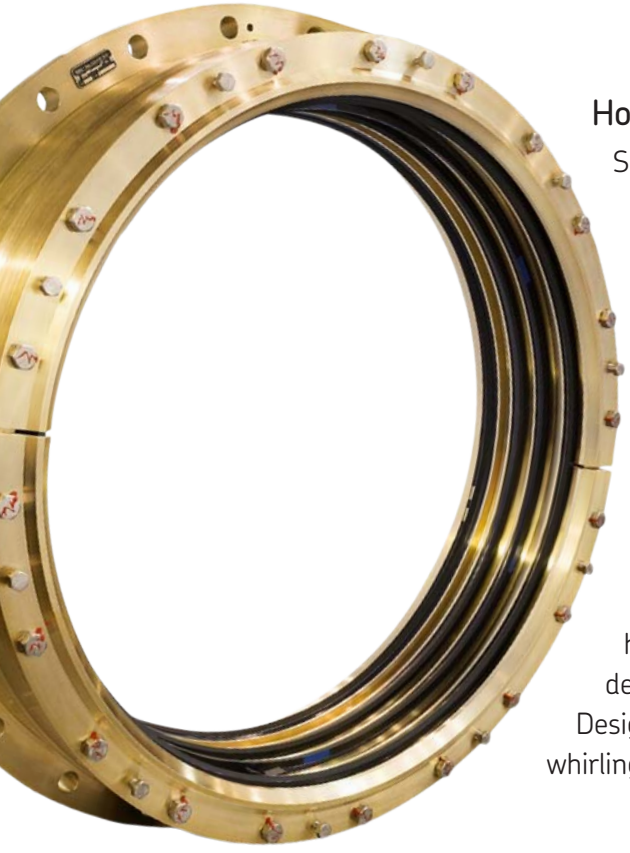
Shaft alignment and vibration calculation software



Detect and prevent alignment problems and harmful vibrations in any propulsion design

Why calculations are important

An optimally designed propulsion installation increases the life time of bearings, seals and couplings, while also reducing energy consumption, noise, vibrations and excessive wear. A well-designed propulsion shaft line can avoid unplanned maintenance and as a result, reduce expensive off-hire time of a vessel. Drawing on decades of theoretical and practical experience with rotating machinery and services for propulsion shaft lines, SKF provides the state-of-the-art ShaftDesigner software package for preventing or solving alignment and vibration issues throughout the entire ship life cycle.



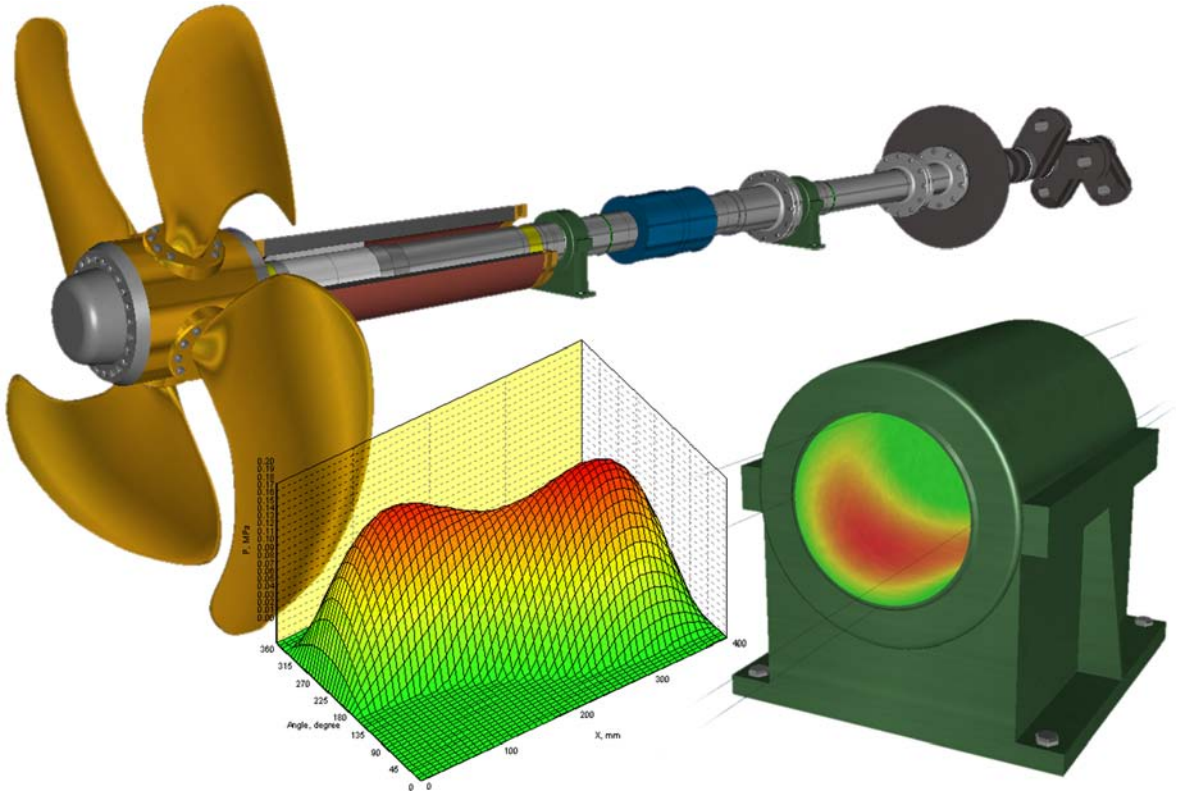
How these issues can be avoided or solved

ShaftDesigner is a computer-aided engineering system, which enables the user to quickly optimise marine propulsion designs and installations. This software package can help to understand and to avoid potentially harmful shaft alignment and vibration problems in a propulsion design, by exploring alternative materials and geometries that can verify and optimise designs. It further helps personnel to quickly analyse and solve alignment and vibration issues for existing vessels during the maintenance and repair phases.

What is ShaftDesigner software?

The user-friendly Windows-based and 3D modelling interface can handle multiple simultaneous projects, multiple shaft lines in one design and several vessel operating and draft conditions. The ShaftDesigner software uses a single base model to calculate shaft alignment, whirling/lateral vibration, axial vibration and torsional vibration.

SKF



ShaftDesigner software enables the user to:

- Get quick, specific and accurate results while minimizing chances of input errors
- Prevent potential alignment problems and harmful vibrations in any propulsion design
- Reduce the chance of shaft component malfunctioning and warranty claims
- Select the appropriate number of shaft components in a quotation phase
- Optimise shaft propulsion designs and alignment/installation procedures
- Save time while troubleshooting alignment and vibration problems on any vessel
- Apply the latest insights, rules and regulations as a result of continuous software development

The software's main features are:

- Shaft alignment calculations using an FEM model under all operating conditions of a vessel
- Calculation of whirling/bending, axial and torsional vibration including ice impact feature
- Drag and drop modelling including component library and history/undo feature
- 3D graphical user interface and a single base model for all calculations
- Classification society independent
- Following of IACS standards and specific classification society rules and regulations
- Customizable reports with export options and all required input to obtain classification society approval

Shaft alignment calculations

The goal of the shaft alignment calculation is to determine the positions of shaft line bearings at the time of alignment, or to optimise the bearing load of shaft lines. Both of these goals provide safe operation of the vessel's propulsion train under all specified operating conditions.

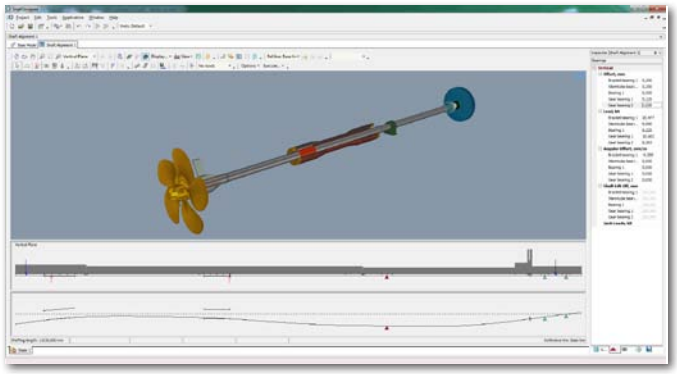
The position of the shaft line bearing axis is defined by vertical and horizontal offsets of the bearing bush centre point, and by the bearing bush inclinations relative to the reference line. Shaft line deflections are calculated automatically when the application is run. The application model is automatically constructed from the base model. Any changes made to the base model will automatically update the shaft line's deflections.

Shaft alignment techniques supported by ShaftDesigner are direct calculation, full bearing contact area calculation, offset exploration and geometric/catenary alignment. Furthermore, hull deflections, propeller forces, gear tooth loads and hydrodynamic lubrication of plain bearings are all taken into account.

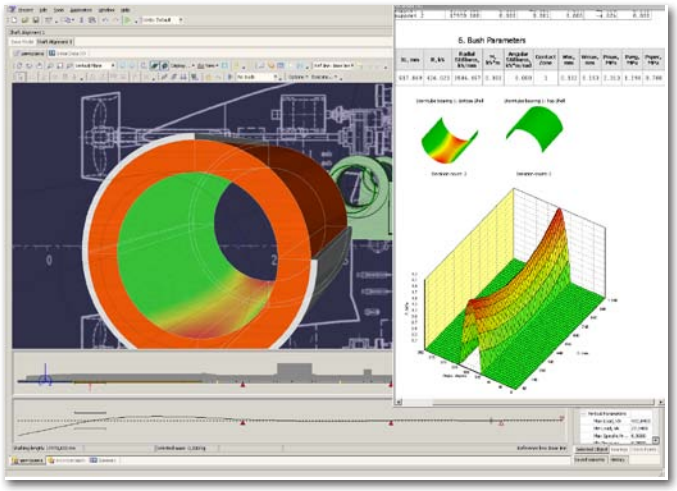
The application model can be further developed to meet specific application requirements. The user can add additional objects such as concentrated forces, temporary supports, theoretical gap-sag values and jack load verification points in order to verify theoretical alignments in practice. Placing additional supports and forces into the software starts an immediate automatic shaft line deflection recalculation.

The ShaftDesigner **shaft alignment module** enables the user to:

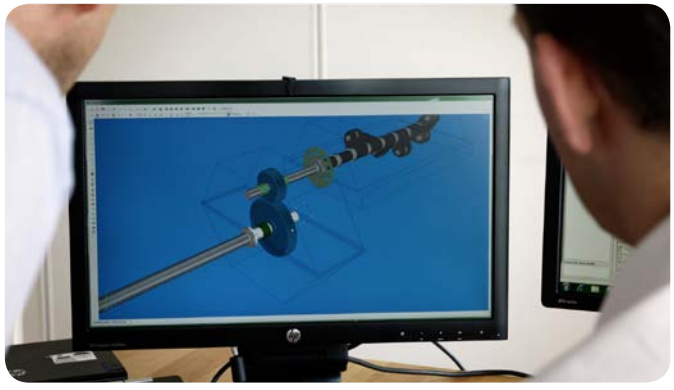
- Determine the radial positions of shaft line bearings
- Optimise the bearing load of shaft lines
- Take into account all specified vessel operating conditions
- Perform direct calculation, full bearing contact area calculation, offset exploration, geometric/catenary alignment
- Take into account hull deflections, propeller forces, gear tooth loads and hydrodynamic lubrication of plain bearings
- Verify theoretical alignment in practice
- Perform quick recalculation of shaft line deflections



ShaftDesigner alignment 3D user interface showing shaft model and shaft line deflections



Advanced analysis of bush contact pressure and hydrodynamic lubrication



Detailed presentation of shaft line components helps to minimize risk of input errors

Vibration calculations

The ShaftDesigner software calculates all shaft-related vibrations, using separate modules for whirling (lateral), axial and torsional vibrations. All modules use the single 3D base model for performing the specific vibration calculations. The torsional vibration module further includes a mass-elastic system modeller, which makes it possible to use this torsional vibration module as a separate software solution without the need for any other modules.

Basic lateral vibration module

The main result of the basic lateral vibration calculation is an overview of critical speeds within the installation, due to the rotation of the propulsion shafting or excitations from the propeller, main engine or gearing. The lateral vibration application calculates free vibration characteristics such as natural frequencies, mode shapes and resonance speeds. The results are presented in a resonance table and graphically as a Campbell diagram.

The ShaftDesigner **basic lateral vibration module** enables the user to:

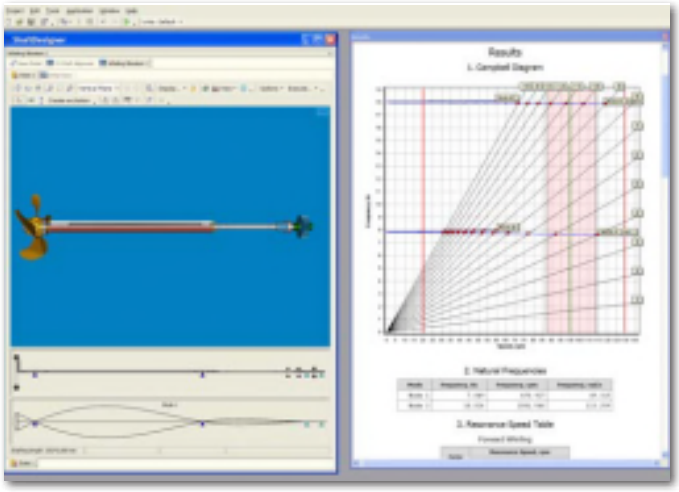
- Get an overview of critical speeds that can cause excessive vibrations due to, imbalance of the propulsion shafting or excitations from the propeller, main engine or auxiliary machinery
- Calculate free vibration characteristics such as natural frequencies, mode shapes and resonance speeds

Advanced whirling vibration module

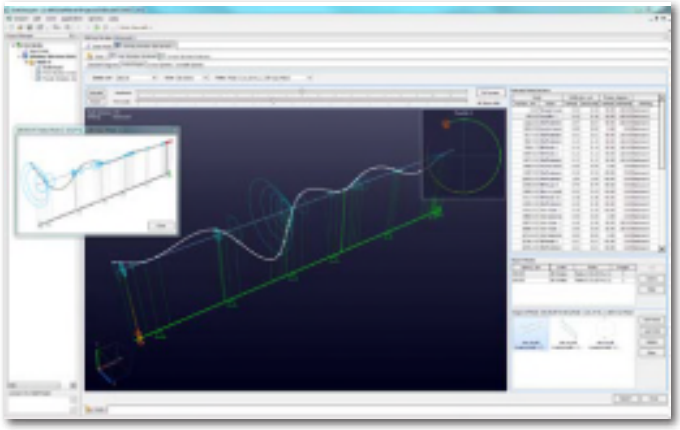
The advanced whirling vibration module further enhances results of the basic lateral vibration module, by adding calculations of damped natural frequencies, mode shapes and Campbell diagrams. This module uses an anisotropic bearing model, allowing the user to input bearing support properties depending on direction. Furthermore, this module is capable of calculating forced whirling vibrations, resulting in actual shaft displacements (orbits) and dynamic bearing loads at critical shaft speeds. This module provides an indication of whether a critical speed will result in noise or harmful vibrations. Results can be shown as a 3D animation.

The ShaftDesigner **advanced whirling vibration module** enables the user to:

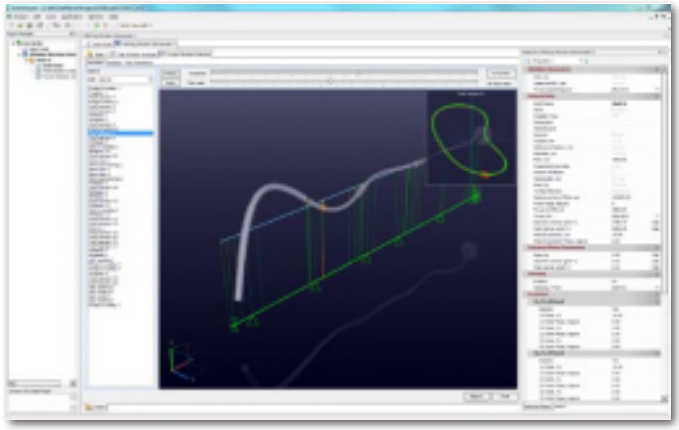
- Add calculations of damped natural frequencies, mode shapes and Campbell diagrams
- Calculate forced whirling vibrations, resulting in actual shaft displacements and dynamic bearing loads
- Gain insight into whether a critical speed will result in noise or harmful vibrations
- Present whirling vibrations as a 3D animation



Lateral vibration window showing mode shapes and Campbell diagram results



Advanced free whirling vibration result window showing mode shapes and orbits



Advanced forced whirling vibration window showing results as a 3D animation

Axial vibration module

The main features of the axial vibration module are free and forced axial vibration calculations. The free axial vibration calculations show an overview of the various critical speeds with their corresponding mode shapes. The forced axial vibration calculations show actual shaft displacement and thrust bearing loads in relation to the running speed of the installation. Different options are available to set excitation, stiffness and damping parameters for all relevant equipment.

Torsional vibration module

Using the mass-elastic system of the complete propulsion installation, the torsional vibration module calculations result in dynamic torsional loading of the installation.

Included in the results are angular deformations between components, torsional moments and stresses in shaft elements, gear hammering in geared connections and power loss in flexible elements and dampers. Results are presented graphically, showing the vibration parameters depending on shaft speed. These can be easily compared to OEM and classification society limits, rules and regulations using the included acceptance criteria manager. Time waveform and critical component analysis can also be performed.

For diesel engines, different excitation modes are available for normal and misfiring conditions, including excitation based on harmonic coefficients. Worst case misfiring conditions can be automatically presented by the software.

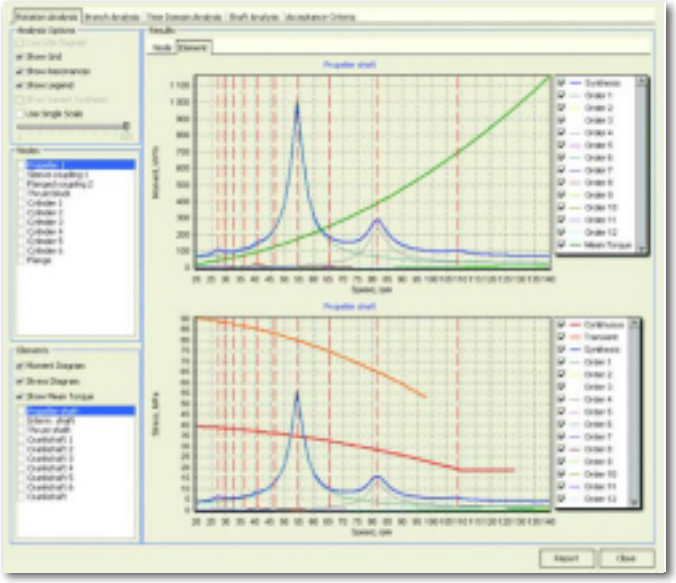
The ShaftDesigner **torsional vibration module** enables the user to:

- Calculate dynamic torsional loading
- Calculate angular deformations, torsional moments and stresses, gear hammering and power loss
- Easily compare results with OEM and classification society limits, rules and regulations
- Perform time waveform and critical component analysis
- Analyse diesel engine excitation modes for normal and misfiring conditions, including harmonic coefficients
- Present worst case misfiring conditions

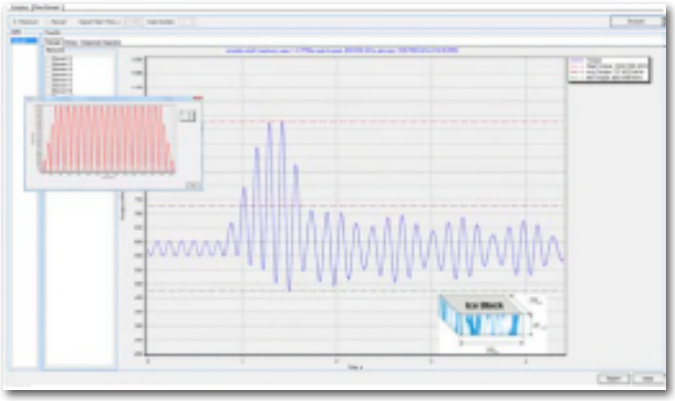
For users having both the axial and torsional vibration modules, an additional tool is provided to calculate the coupled axial-torsional vibration parameters required for direct coupled diesel engines.

Ice impact transient torsional vibration module

Using the mass-elastic scheme made in the torsional vibration module, the ice impact module is able to calculate the time domain transient torsional loads within the entire propulsion line due to ice-induced excitations on the propeller, without any simplification of the model. The three classification societies' defined excitation load cases on the propeller can be easily selected using the ice class database, allowing quick selection of a specific ice class. Results for all load cases are calculated simultaneously and presented as time domain response graphs, showing torsional loads at different shaft speeds. Response diagrams are used to show the critical load cases and critical elements within the installation.



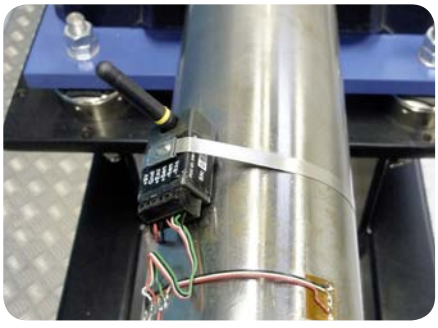
Torsional vibration forced result window showing vibration amplitudes and acceptable limits



Ice impact transient torsional vibration time domain response graphs

The ShaftDesigner software was initially developed for the Marine Service Division of SKF. It was created as a bridge between theoretical expertise and practical experience in the field of shaft alignment and vibration measurement and analysis. SKF engineers provide problem solving services around the globe every day. The ShaftDesigner software, in combination with various measurement methods, enables them to quickly find the cause of problems on board. SKF is also able to provide shaft alignment and vibration calculations as a service, enabling customers to access the calculations without having to invest in software licences or training. The SKF marine service portfolio further includes static and dynamic shaft alignment measurements, 3D laser tracking and scanning, chocking of machinery using epoxy resins or SKF Vibracon adjustable steel chocks, shaft component installation and on-site machining.

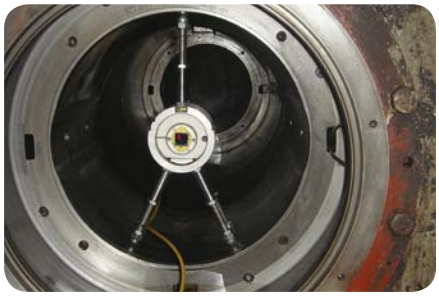
Shaft jack up test to check bearing loads and to validate theoretical calculated loads



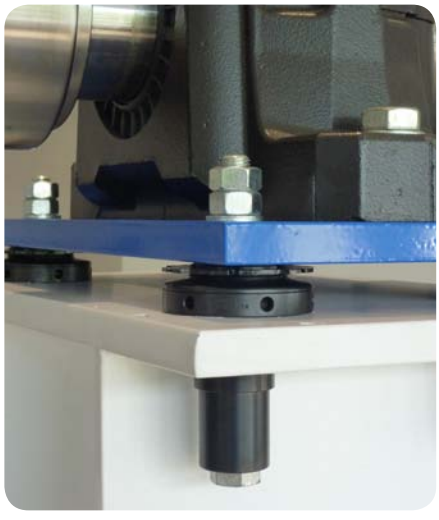
Strain gauge measurement which eliminates the need to decouple shafts for alignment and enables dynamic measurements

On-site machining of a stern tube

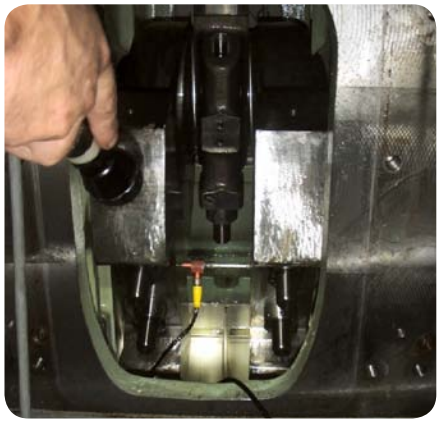
Load cell and hydraulic jack near shaft bearing



Stern tube alignment using laser alignment equipment



SKF shaft bearing mounted with SKF Vibracon adjustable steel chocks and SKF spherical washers



Crank web deflection measurement using an electronic gauge

SKF Marine Monitoring Kit

3D measurement in combination with on-site machining

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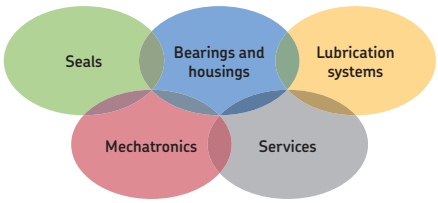

The Power of Knowledge Engineering
Combining products, people, and application-specific knowledge, SKF delivers innovative solutions to equipment manufacturers and production facilities in every major industry worldwide. Having expertise in multiple competence areas supports SKF Life Cycle Management, a proven approach to improving equipment reliability, optimizing operational and energy efficiency and reducing total cost of ownership.

These competence areas include bearings and units, seals, lubrication systems, mechatronics, and a wide range of services, from 3-D computer modelling to cloud-based condition monitoring and asset management services.

SKF's global footprint provides SKF customers with uniform quality standards and worldwide product availability. Our local presence provides direct access to the experience, knowledge and ingenuity of SKF people.

Optimizing the ship life cycle

Specification
- Calculations
- Simulations
- Verifications
- Engineering consultancy services

Design and develop
- Propulsion shaft design
- Application engineering
- Engineering consultancy services

Manufacture and test
- Bearings and housings
- Sealing solutions
- Couplings and bolts
- Lubrication systems
- Stabilizers
- Oily water separators
- Steering gears
- Chocking solutions

Install and commission
- Complete propulsion line installation
- Supervision of alignment and installation
- Mounting and alignment services and systems
- Lubrication systems
- Coupling services

Operate and monitor
- Condition-based maintenance programmes
- Condition monitoring hardware
- Condition monitoring software
- Data analysis and reporting
- Remote monitoring

Maintain and repair
- Emergency service
- Alignment services
- On-site machining
- Engineering services
- Root Cause Failure Analysis
- Design improvement
- Asset management services

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