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MESYS Shaft Calculation

Introduction

This shaft calculation (version 1.0) calculates the deflections, internal forces and the natural frequencies of several coaxial shafts connected by boundary conditions. The following features are supported:

- Definition of multiple coaxial shafts is possible
- Shaft geometry is defined by cylindrical and conical element
- Inner and outer geometry can be defined independently
- Shear deformation can be considered optionally
- A nonlinear shaft model can be used optionally
- The weight of the shaft can be considered optionally
- An arbitrary number of loads can be defined on each shaft either as point or line loads. Loads (without masses) may be defined outside of the shaft geometry also. Available loading elements are:
    - Force element with three components each for force and moment
    - Excentrical force element with three force components in polar coordinates
    - Helical Gear element using gear data and torque as input
    - Coupling element for entering a torque only
    - Mass elements for introducing weight and inertia for natural frequencies
- An arbitrary number of boundary constraints can either be defined between a shaft and a rigid housing or between two shafts.
- Nonlinear rolling bearing stiffness can be considered
- MESYS Rolling Bearing Calculation is fully integrated in the shaft calculation
- Natural frequencies are calculated considering torsion, bending and axial modes

Installation

When running the installer the installation directory can be selected. The default location is “\Program Files\MesysShaft”. All files are installed into that directory. Also an entry in the start menu is created.

The uninstaller can be called from the start menu. This deletes the installation directory and the entries in the start menu.

Without a license file the software runs as demo version. In the demo version it is not possible to save or load files and a Demo message is shown on each calculation. The demo version may only be used for evaluation of the software.

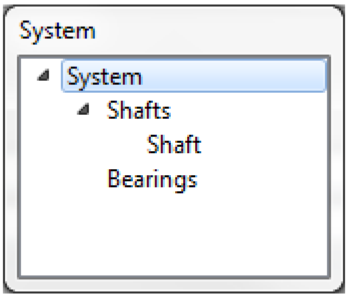
The license file ‘license.dat’ has to be placed in the installation directory (in the same directory as MesysShaft.exe). The name of the license file may not be changed since it will not be found by the software.

Requirements

The rolling bearing calculation is available as 32bit windows program running on Windows XP, Vista or Windows 7. In addition to the 32bit version which can be used on 32bit or 64bit operating system also a 64bit version is available. The minimum required processor is Intel Pentium 4 or above.

About 25MB of hard disk space is required. All dependencies of the software are available in the installation directory. Therefore it can just be copied to other machines or started from network or removable disks.

Input Parameters



The input parameters are shown on several pages which can be selected in a System tree. To run a calculation first the data on all pages is introduced.

Then press or F5 to run the calculation. After all data is defined the calculation can be run from each page. So it is easy to make parameter variations.

There are some special buttons used in the user interface, which are explained in the following table:

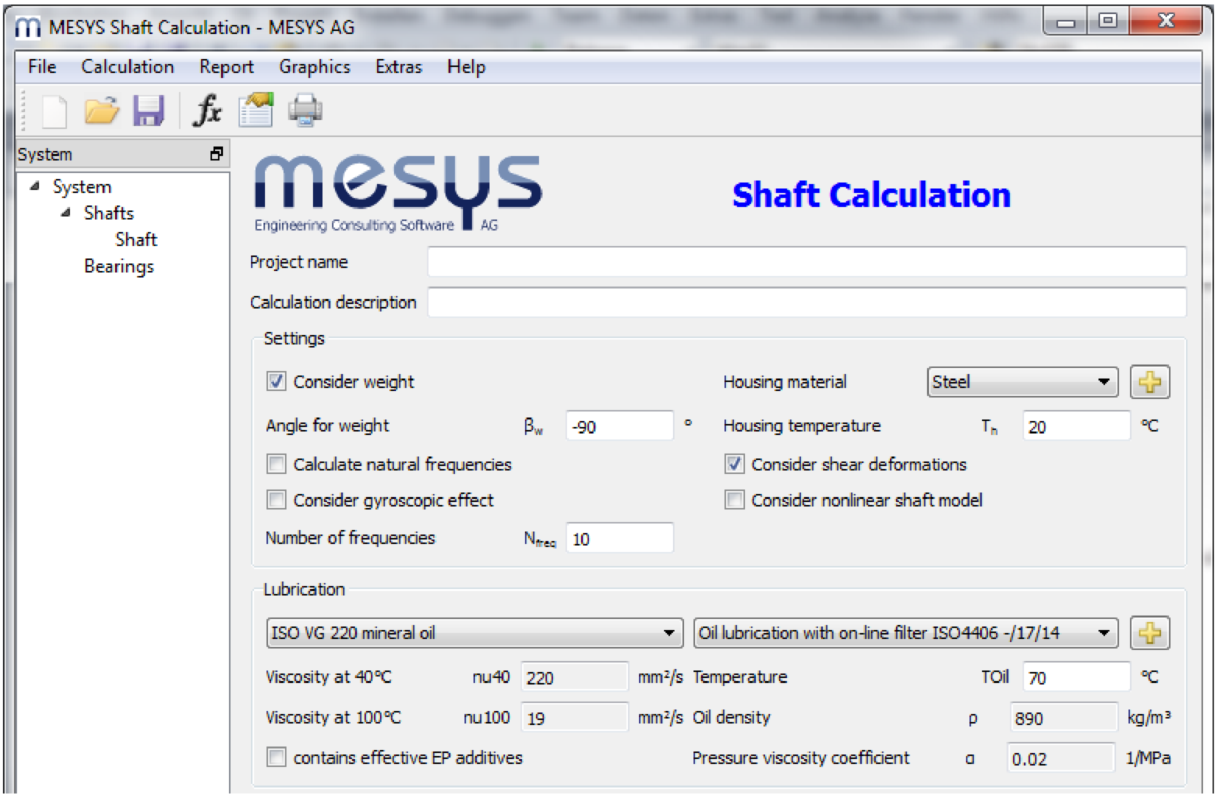
Button	Explanation
	This plus button shows a dialog with additional inputs. Some of these inputs need to be defined, some are just optional.
	This conversion button allows the conversion from other types of input. For example the radial clearance can be converted from an axial clearance
	This proposal button provides a suggestion for an input by the software

The unit system for the input and output can be selected on the menu ‘Extras->Unit system’ either as metric or US units.

The software is available in English and German language. The language can also be selected in menu ‘Extras’.

System Inputs

If the element ‘System’ is selected in the system tree on the left some general data can be defined.



Project name and calculation description

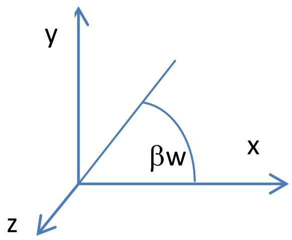
The project name and the calculation description are just inputs which are shown in the report header. They can be used to enter information about the purpose of the calculation for documentation.

Settings

Consider weight

The weight of shafts and additional masses is considered in the calculation if this setting is set

Angle for weight



The direction of the weight can be defined by this setting. The angle is in the x-y-plane, a rotation around z-axis. A value of zero results in a weight in the direction of shaft axis.

Calculate natural frequencies

The calculation of natural frequencies can be activated here. Running a calculation is faster if natural frequencies are not calculated.

Consider gyroscopic effect

If this setting is activated a gyroscopic matrix is considered in the calculation of natural frequencies. The mass inertia around x-axis and the speed of the shaft are required for this gyroscopic matrix.

Number of frequencies

The number of natural frequencies that should be calculated can be specified here. Normally only the first few modes are interesting.

Housing material and housing temperature

The material data of the housing is used together with the temperature of the housing to calculate the axial displacement for boundary conditions connected to the housing. For the shaft calculation only the thermal elongation coefficient is important, the other data is only used to transfer it to the bearing calculation.

Consider shear deformations

Shear deformation should normally be taken into account, since there are these deformations. For comparison with other calculations the shear deformations can be ignored. For nonlinear shaft model the shear deformations should be considered to improve convergence.

Consider nonlinear shaft model

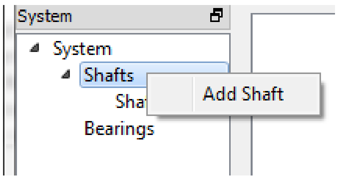
A nonlinear shaft model can be taken into account. The nonlinear model calculates equilibrium of loads in the deformed state.

A beam fixed on one side and radially loaded on the other side will show only radial deflections in the linear model. In the nonlinear model the end point will also move axially and the length of the beam will not increase. A beam fixed on both sides will show an increased stiffness against loading in the center, the stiffness will increase with the loading because of generated axial loads. The nonlinear model is only needed on large deflections; normal shafts in mechanical engineering do not require a nonlinear model.

Lubrication

The data for lubrications is only to transfer it to bearing calculations. For details regarding the inputs please consult the documentation of the rolling bearing calculation.

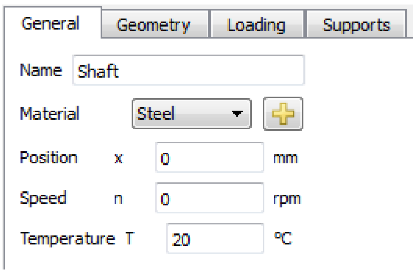
Definition of shafts



In the System-tree using a right click on “Shafts” additional shafts can be added to the system. The shaft can be defined by selecting it in the system tree.

General shaft data

On the first page “General” some general data can be defined for each shaft.



Name

A name for each shaft can defined which is used in the system tree, messages and the report to identify the shaft.

Position

If several shafts are defined they can have different axial positions. The value for position defines the position of the start point or the left end of a shaft. All loads and boundary conditions are then defined relative to this start point.

Speed

The rotation speed of the shaft has an influence on bearing life and natural frequencies with gyroscopic effect.

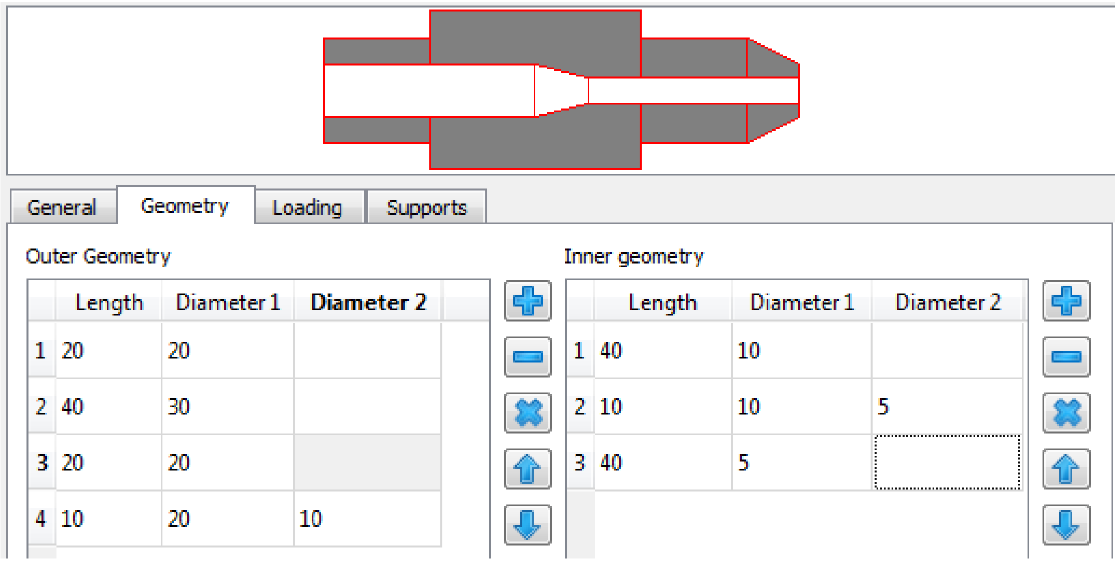
Temperature

The temperature of the shaft can be defined here. The temperature is transferred to the bearing calculation and will induce axial stresses into the shaft.

The reference temperature with no stress field is 20°C.

Geometry data

The geometry data of a shaft is defined on page "Geometry". The geometry can be defined using cylindrical and conical elements for outer and inner geometry.



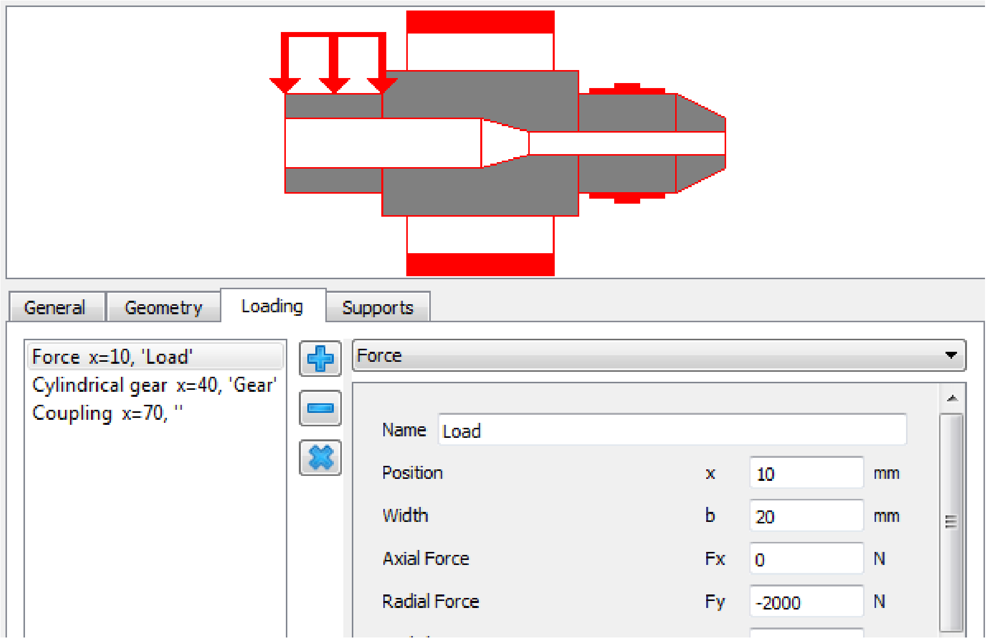
There is an input table for both inner and outer geometry. The plus- and minus-buttons allow adding and removing rows, the arrows can be used to move an element up or down in the table.

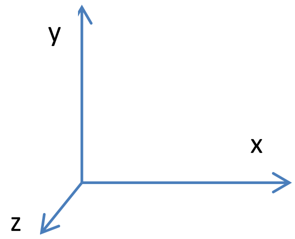
Length and diameter 1 have to be defined for each element. If diameter 2 is left empty a cylinder is used else a cone. No negative values are permitted.

If a hole from the right shall be defined as inner geometry, enter a first element with diameter zero to get to the start position on the hole.

Loading

Loads can be defined on the page “Loading” for each shaft. Loads may be defined outside a shaft; masses may not be outside of a shaft.





Loads can be added by the plus button next to the list. The type of the loading can be selected using the list on the right. Each load element has a name to identify it, a position relative to the left end of the shaft and a width.

The graphical representation just shows a symbol for the load, not the actual direction, as it can have six components. The coordinate system is shown on the right. The shaft axis is in x-direction, the y-axis goes up and the z-axis to the front. The weight is in negative y-directions a default (angle $\beta w = -90°$).

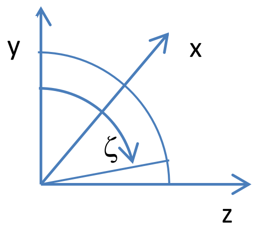
Force

The load element “Force” allows the definition of a force and a moment with three components each. The moments are moments around an axis. So Fx is the axial force and Mx is the moment around the x-axis so it is a torque.

Coupling

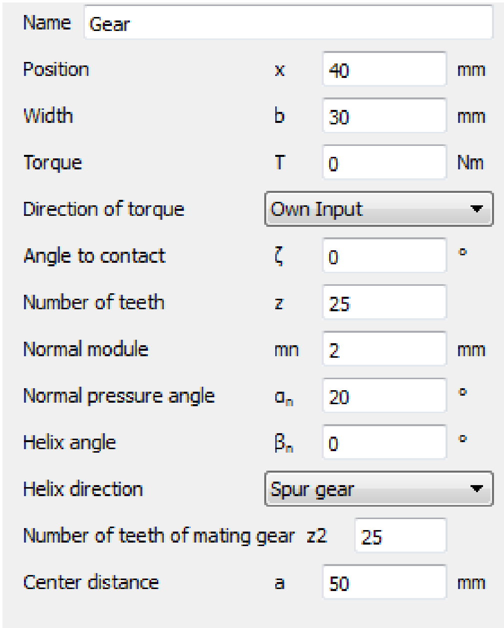
The coupling only allows a definition of a torque. The direction on the torque can either be defined by its sign or by the selection “Shaft is driven” (torque has the same sign as the rotation speed) or “Shaft is driving” (torque has different sign than the rotation speed).

Cylindrical gear



The load can be defined be entering data for a cylindrical gear and a torque.

The direction of torque can either be defined by its sign or by the selection “Shaft is driven”/Shaft is driving”. The contact point is given by an angle of contact, which is zero on the y-axis and 90° on the z-axis.



The gear is defined by the usual data on a gear drawing: Number of teeth, normal module, normal pressure angle, helix angle with its direction. Optional inputs are the number of teeth for the mating gear and the center distance. If they are given the loads are calculated for the operating center distance, which is more accurate than on the reference diameter.

For internal gears the number of teeth has to be entered as negative value, the center distance is always positive as defined in ISO 21771 for gear geometry.

Excentric force

The excentric force allows entering a force with three components at a point which is not on the shaft axis. The point and the force are defined in polar coordinates. The angle is defines in the same way as the angle of contact in the cylindrical gear (see above).

The radial force is positive if away from the shaft center, the tangential force is positive in the direction of the angle. Moments are calculated by the points and forces given.

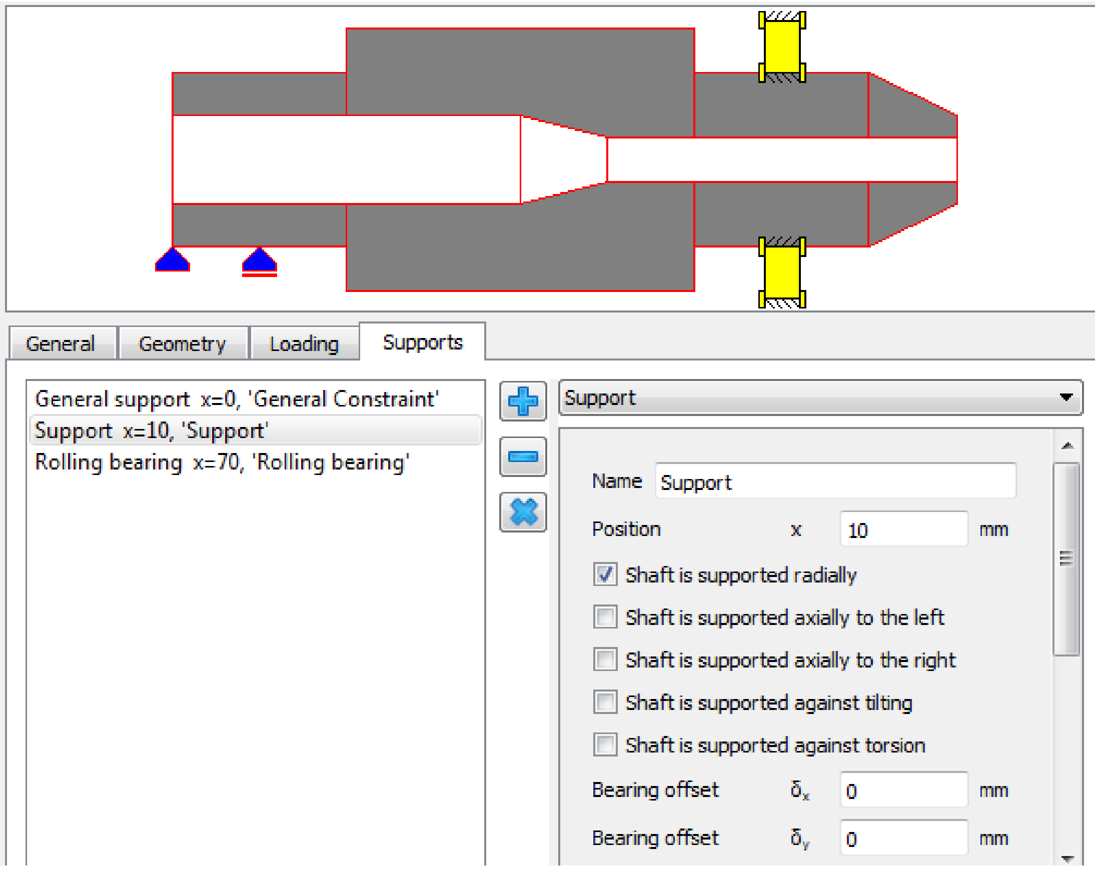
Mass

Additional mass can be defined using the “Mass” element. In addition to its mass also the mass moment of inertia around three axes can be defined. The weight of the mass is considered and it is considered in the calculation of natural frequencies.

If a width is entered the mass is equally distributed on this line. The total mass inertias of this distributed mass are the input values, which results in a minimum value for Jyy and Jzz. A message will be shown if the input values are too small.

Supports

Boundary conditions can be defined on the page “Supports”.

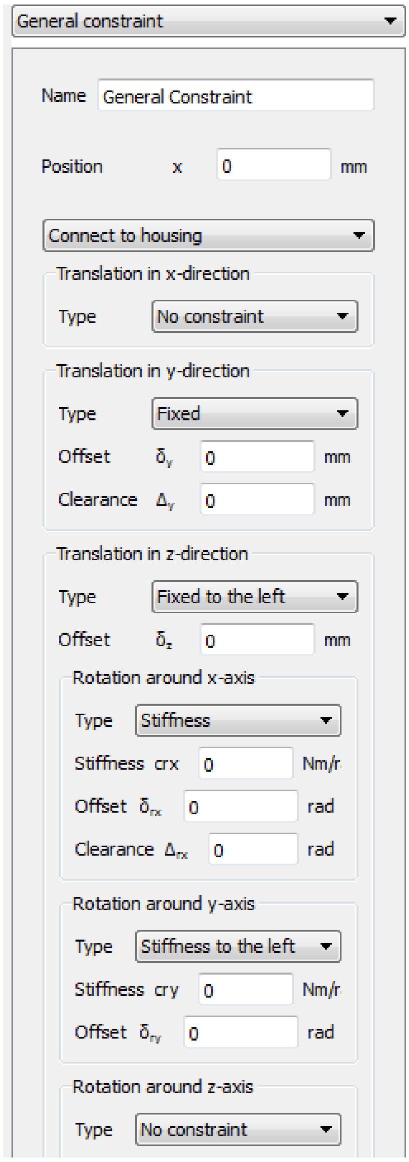


Support

The “Support” element is an easy to use element which allows defining constraints between the shaft and the housing. There are five checkboxes to define in which directions the shaft is supported. For axial direction the movement to the right and to the left can be constrained independently.

A bearing offset can be defined for the three directions. An offset means that the point on the housing is moved in this direction. The resulting force on the shaft is in the direction of the offset.

General support



The "General support" allows the definition as constraints between a shaft and the housing or between two shafts for all six degrees of freedom independently.

First a selection can be done to which element the shaft is connected to. It can be the housing or a second shaft.

For each degree of freedom a type of constraint can be defined then:

No constraint

No constraint in the direction is defined.

Fixed

The degree of freedom between both elements is coupled in both positive and negative direction. An offset or a clearance can be defined optionally.

A positive value for the offset results in a movement of the current shaft in this direction, or a force on the selected shaft in this direction.

The clearance is either zero or a positive value, it may not be negative.

Fixed to the left/Fixed to the right

The selection "Fixed to the left" means than the selected shaft is constrained only in the negative direction (left on a horizontal axis).

"Fixed to the right" is the constraint in positive direction only. For the unidirectional constraint an offset can be defined.

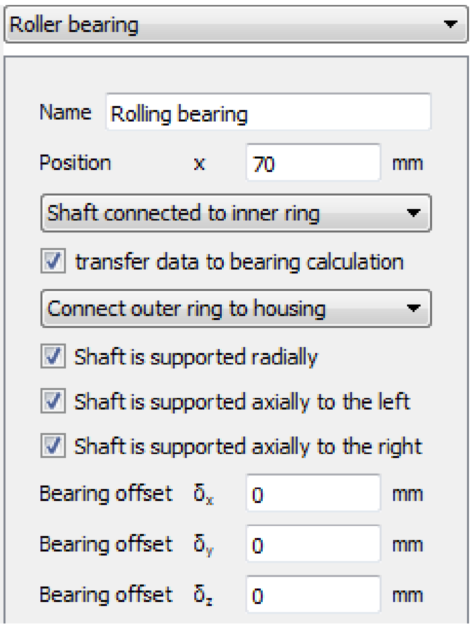
Stiffness

The "Stiffness" acts like a spring. An offset and a clearance can be defined.

Stiffness to the left/Stiffness to the right

Like the rigid constraint also stiffness can be defined in just one direction. The stiffness and an offset can be defined.

Rolling bearing



The element "Roller bearing" defines a connection to the rolling bearing calculation.

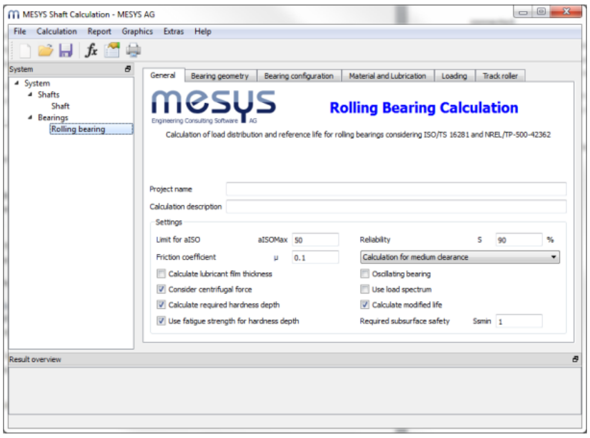
The current shaft can be connected to the inner or to the outer ring of a roller bearing. The other ring of the bearing can be connected to either the housing or another shaft.

If the setting "Transfer data to bearing calculation" is active, shaft diameters, material data and lubrication data are transferred to the bearing calculation. Displacements and loads are always connected.

The shaft is can be supported radially and axially to the left and the right. This setting changes the connection of the bearing outer ring to the shaft/housing. If the bearing cannot constrain a certain movement, there won't be reaction forces in that direction.

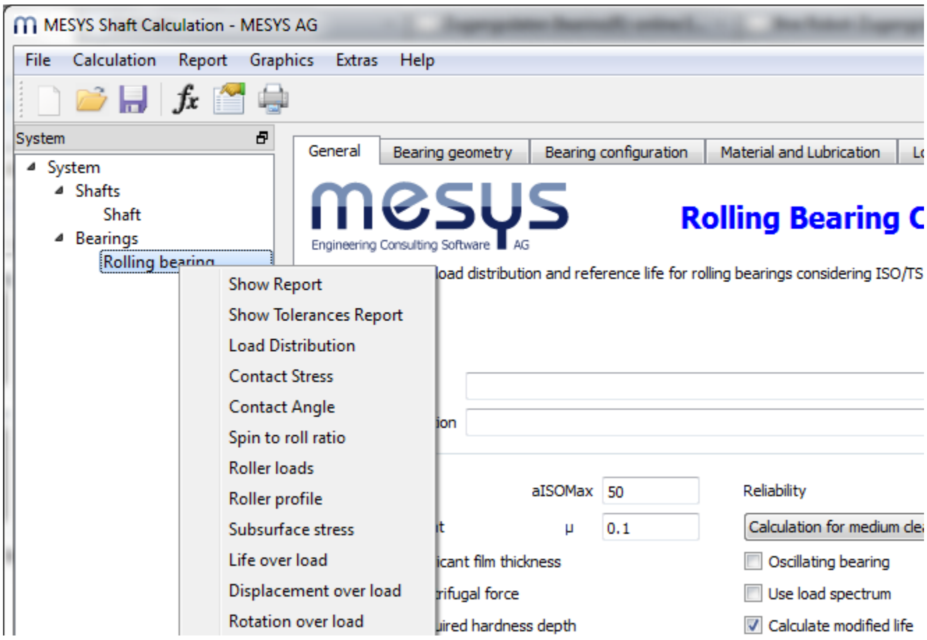
The bearing offsets will again generate forces to the current shaft in the direction of the offset. The offset can be used to generate bearing pretension in axial direction or to take misalignments of the housing into account.

If a rolling bearing element is added an entry for the bearing in the system-tree will be added. If this element is selected the dialogs of the rolling bearing calculation are active to define the bearing.



Interface to rolling bearing calculation

The dialogs of the MESYS Rolling Bearing Calculation are fully integrated into the shaft calculation.



While the bearing calculation is open the functions for file operations, calculation and report generation are used for the bearing calculation only. Only the bearing will be calculated and you will get results for the bearing in the results overview.

Graphics and the tolerance report can be opened using the right mouse button in the system tree. So graphics from different bearings can be shown at the same time.

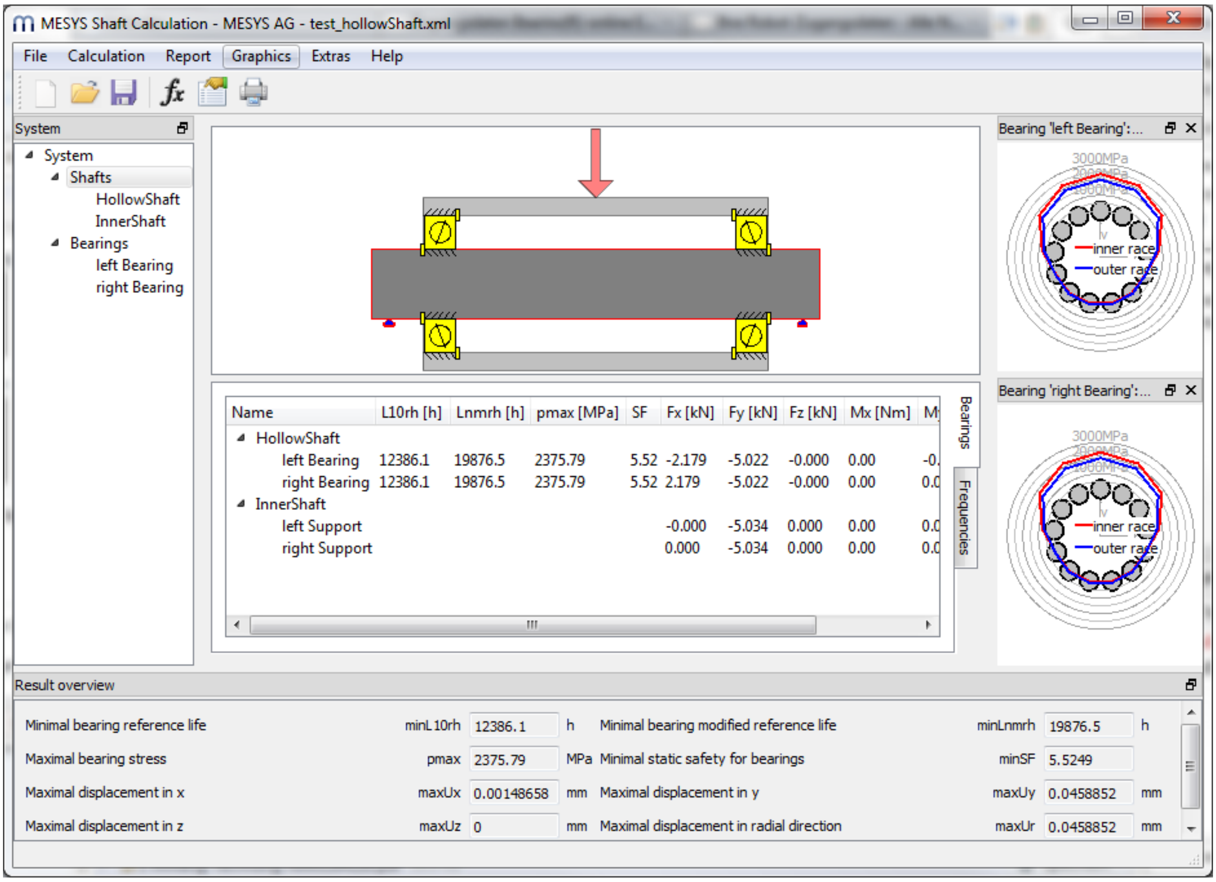
Results

Results are available in different outputs. There is the default result overview on the bottom of the user interface, an overview of bearing forces and natural frequencies, several graphics and the report.

Results Overview

The results overview on the bottom of the window shows minimal bearing life, minimum static bearing safety and maximum shaft deflection. The results overview can be configured under Extras->Results overview

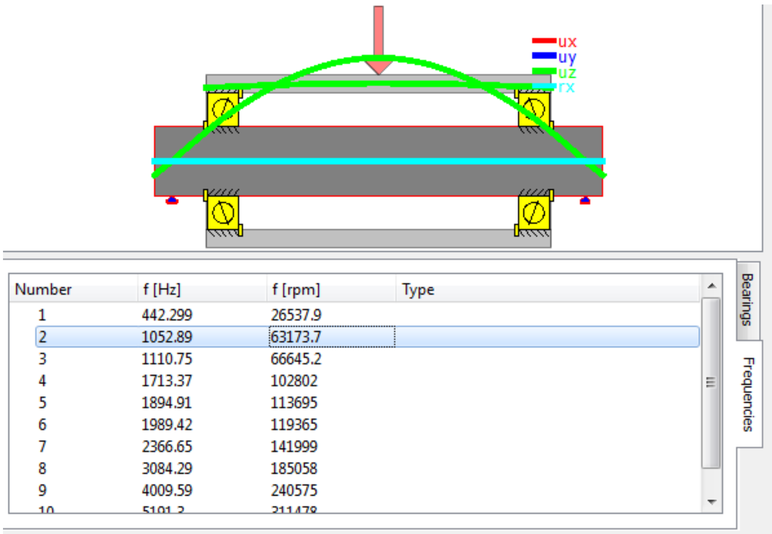
Overview of bearing forces



If “Shafts” or “Bearings” is selected in the system tree a results overview of all bearings and supports is shown. The sign convention for the loads is that the force from the shaft to the bearing is shown.

For rolling bearings the life and pressure is shown in addition to forces and moments.

In the results overview also the natural frequencies can be shown. If a frequency is selected the corresponding mode is shown in the graphics. Three displacements and the torsion angle are shown.



Report

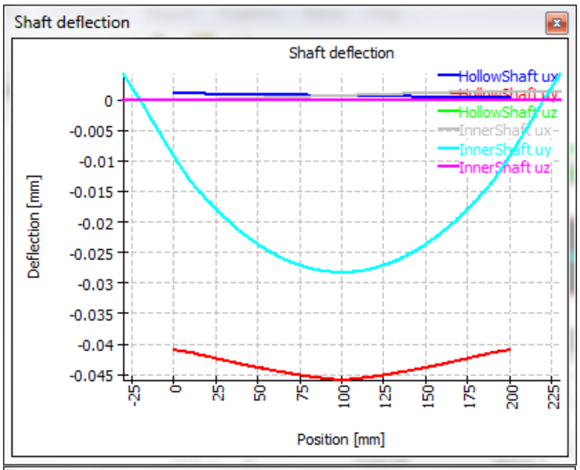
Using the toolbar button or Report->Show Report a report for the shaft calculation is generated which only gives an overview for the bearing results.

There is also Report->Full report which is generating a full report with results of the shaft calculation and the full reports of the bearing calculations.

Graphics

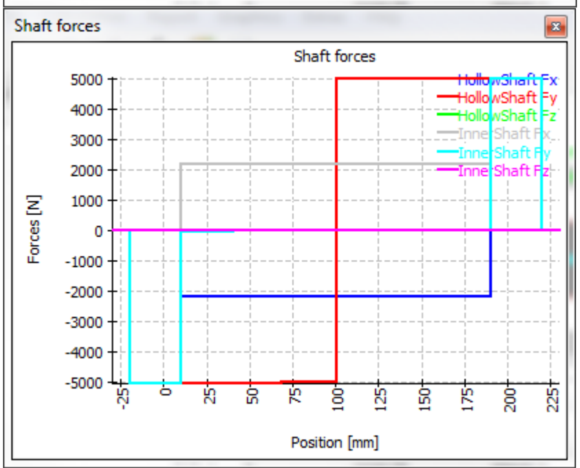
Shaft deflection

The deflection of the shafts is shown for the three displacement coordinates for each shaft.



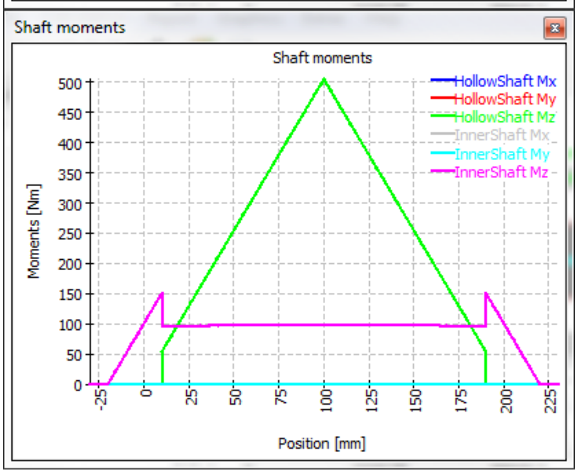
Shaft forces

The three force components are shown for each shaft.



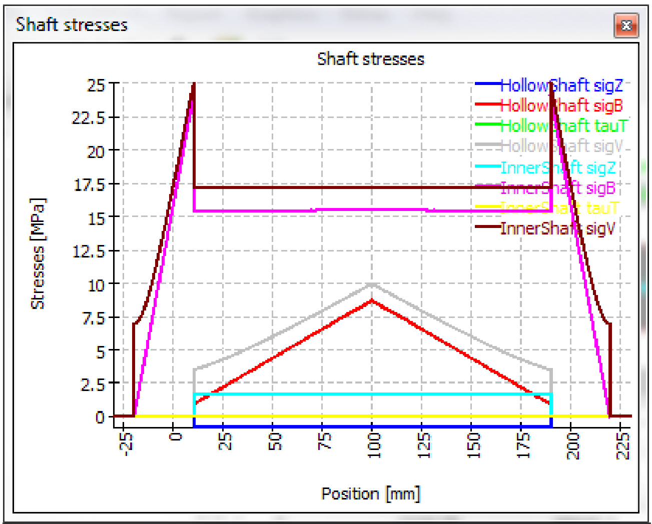
Shaft moments

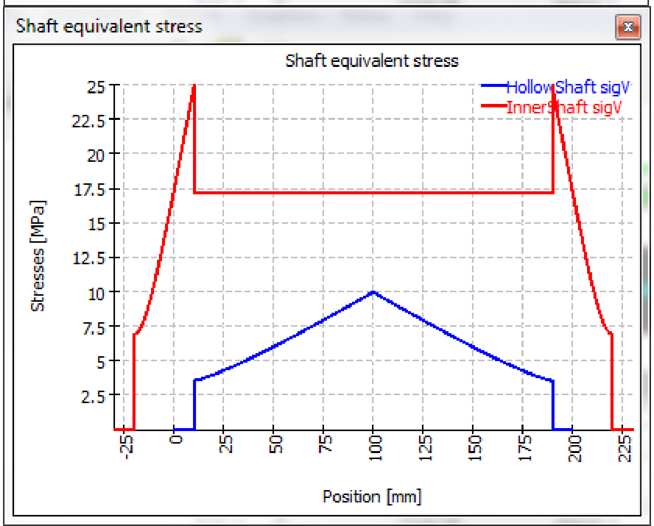
The two bending moments and the torque are shown for each shaft.



Shaft stresses

The stress components are shown for all shafts. Since there are too many curves in that diagram is several shafts are used there is also a diagram which only shows the equivalent stress.

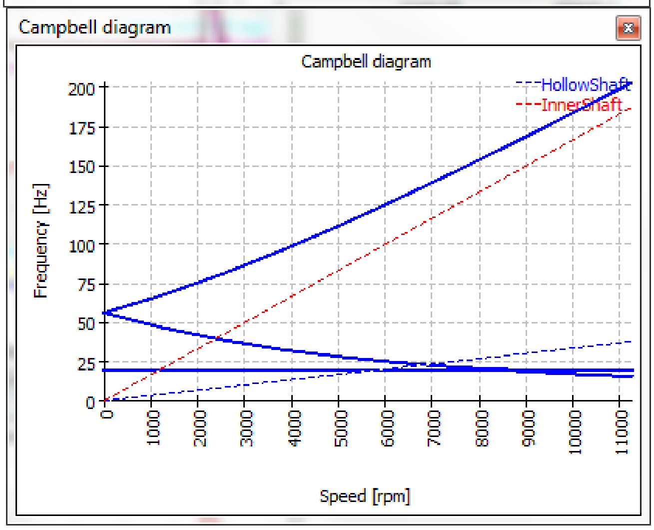




Campbell diagram

The Campbell diagram shows the change of natural frequencies over the shaft speed. The speed of all shafts is multiplied by the same factor in this calculation. The speed of the shafts is shown using dashed lines.

This calculation is always done considering the gyroscopic effect.



Diagrams for bearing analysis

In addition there are several diagrams for bearing analysis. Please check the documentation of the bearing analysis for details.