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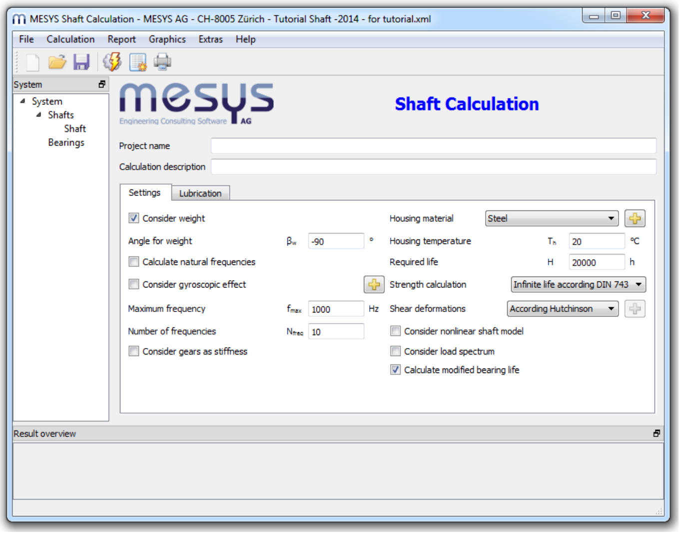
Tutorial: Calculation of two shafts connected by a rolling bearing

This tutorial shows the usage of MESYS shaft calculation with multiple shafts.

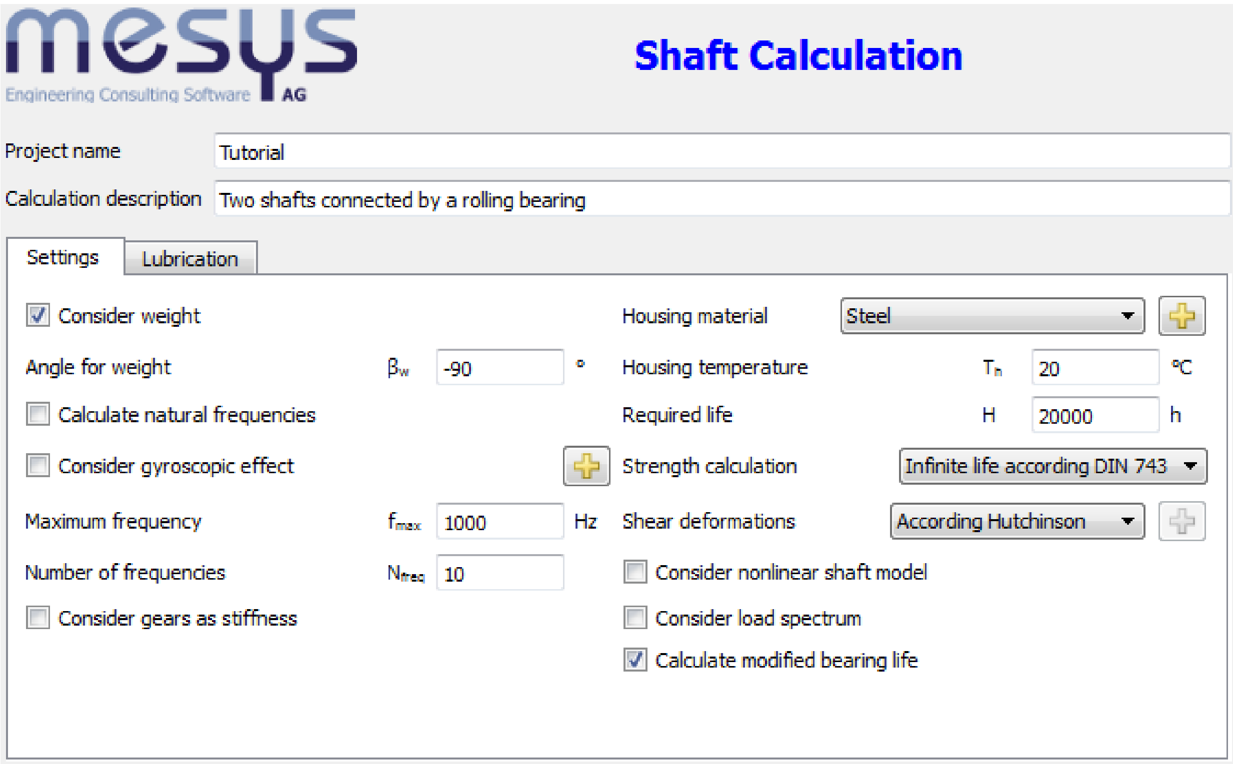
The shaft calculation software provides different views depending on the selection in the tree on the left.

Selecting ‘System’ allows entering general settings and housing material. Selecting the headers ‘Shafts’ or ‘Bearings’ gives a result overview and selecting a single shaft or bearings allows its definition.



System Data

Clicking on the header ‘System’ in the tree view, a ‘Settings’ tab page will be shown by default, we can enter some description for the project and enable the consideration of weight and shear deformations. We are not interested in the calculation of natural frequencies in the first step, so it can be disabled.



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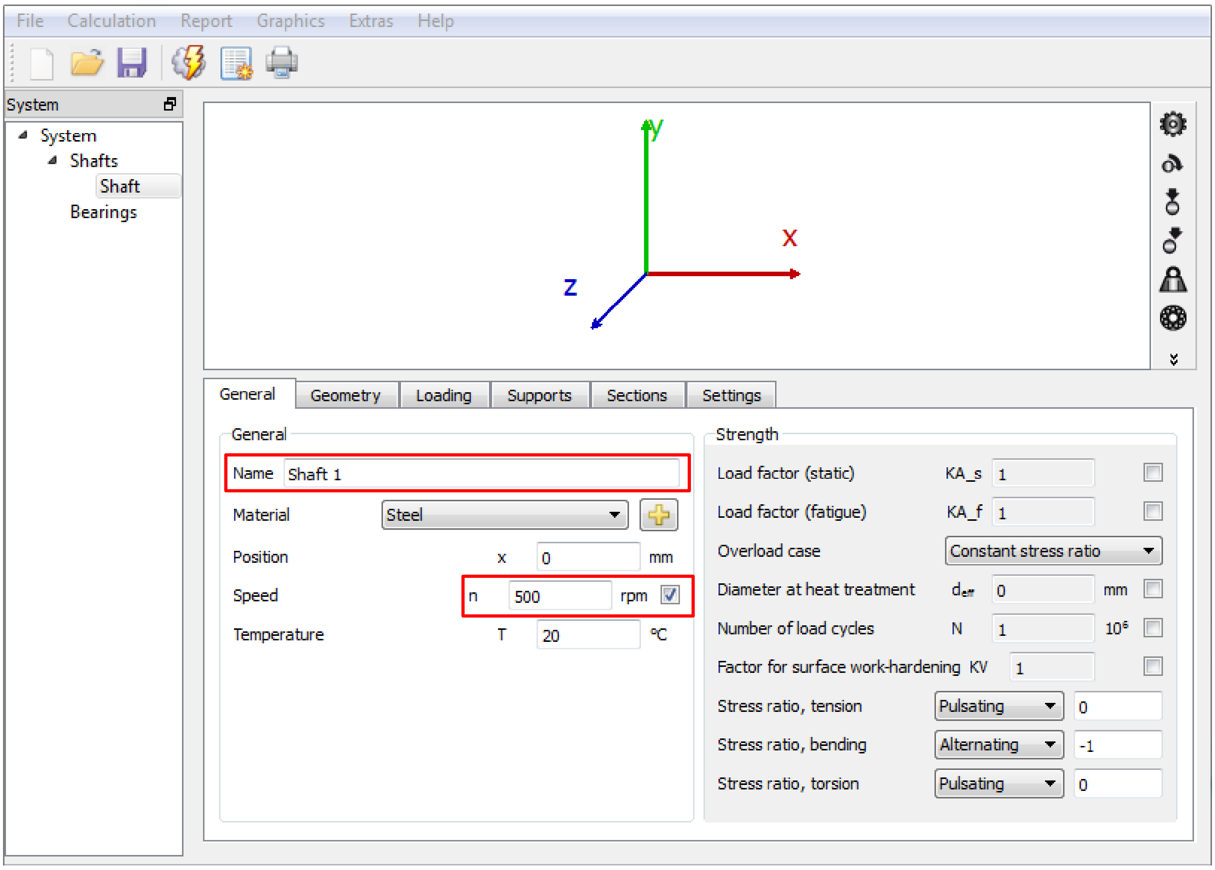
Defining first shaft

We select the existing element named 'Shaft' in the tree. We enter a name 'Shaft 1' and a speed of 500rpm, by activating first the flag next to it. Axial shaft position, material and temperature could be selected on this page too.

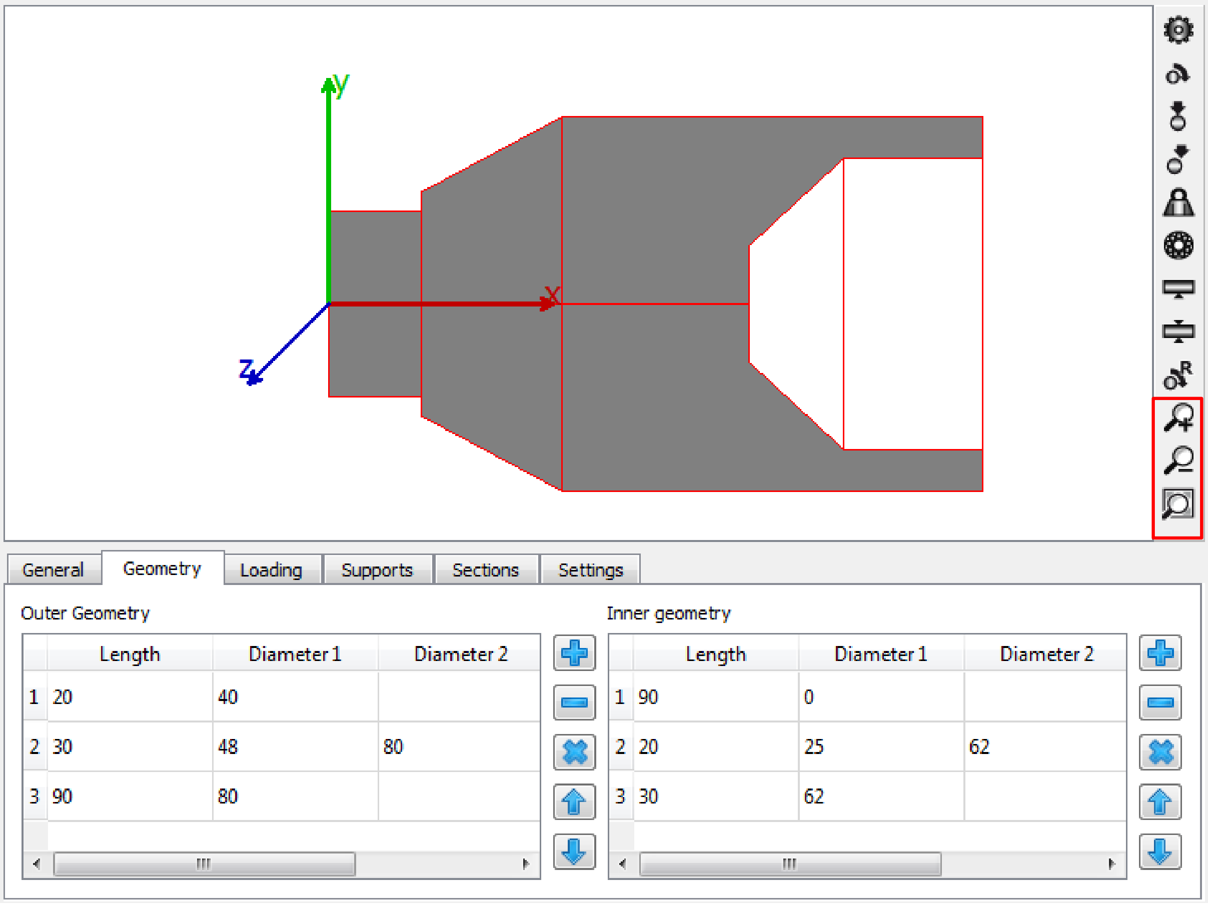


Shaft geometry

On the tab page 'Geometry' the geometry of the shaft can be defined allowing either cylindrical or conical shapes for both the outer and inner geometry of it. By clicking on the -button, a default geometrical element is created and a corresponding row for its input data is added to the table. The -button removes any selected row and the -button clears the whole table.

We will first proceed with the 'Outer geometry', by which a shoulder will be created on the shaft in order to support a rolling bearing. Moreover, a significant diametric step will be overcome with a tapered shape. In order to take up this design, three rows need be added to the corresponding table 'Outer Geometry'. At the second row, both 'Diameter 1' and 'Diameter 2' are employed, thus allowing us to create a tapered shape.

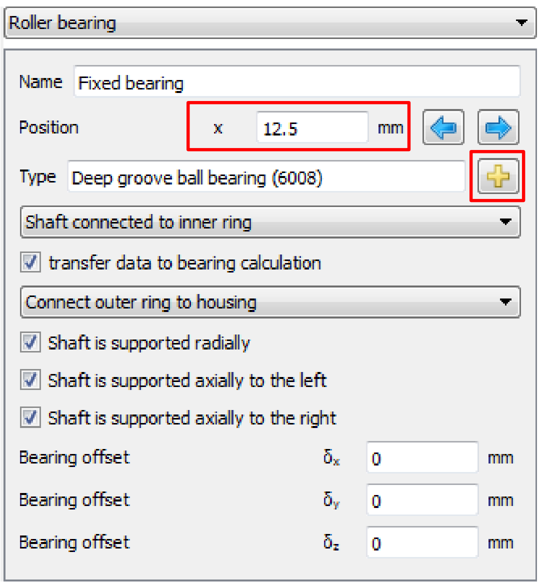
Since we want to connect this shaft to a second shaft, we will create a tapered bore from the right into the shaft, wherein a rolling bearing will be housed. To do so, it is needed to define a first cylinder of diameter zero at 'Inner geometry', which will be drown as a horizontal red line. This line, let us to define the origin of the actual tapered bore's location, whose construction will consist of steps, that is an initial cone, which will be followed by a cylinder. Enter the data as shown below to see the result:



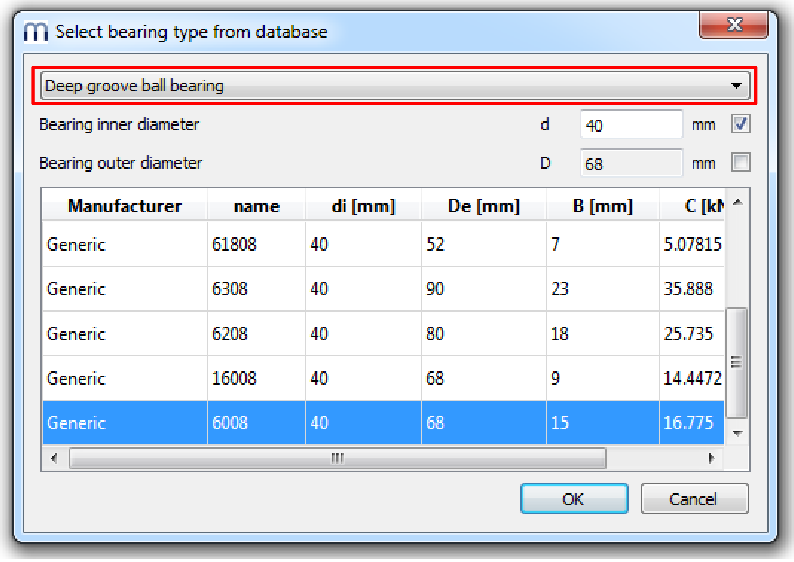
Handling the shaft view can be done by using the pointed out buttons in the red box.

Shaft supports

On the tab page ‘Supports’ we can define the two bearings, so click first on the +-button twice to create them. For each of them, we select ‘Roller bearing’ from the drop-down list on the top and place them at their positions along the shaft, by entering x = 12.5 mm and x = 80 mm respectively. Through the activation of flags, we set the left bearing as axial and radially fixed, and as for the right bearing, only the radial constraint is activated.



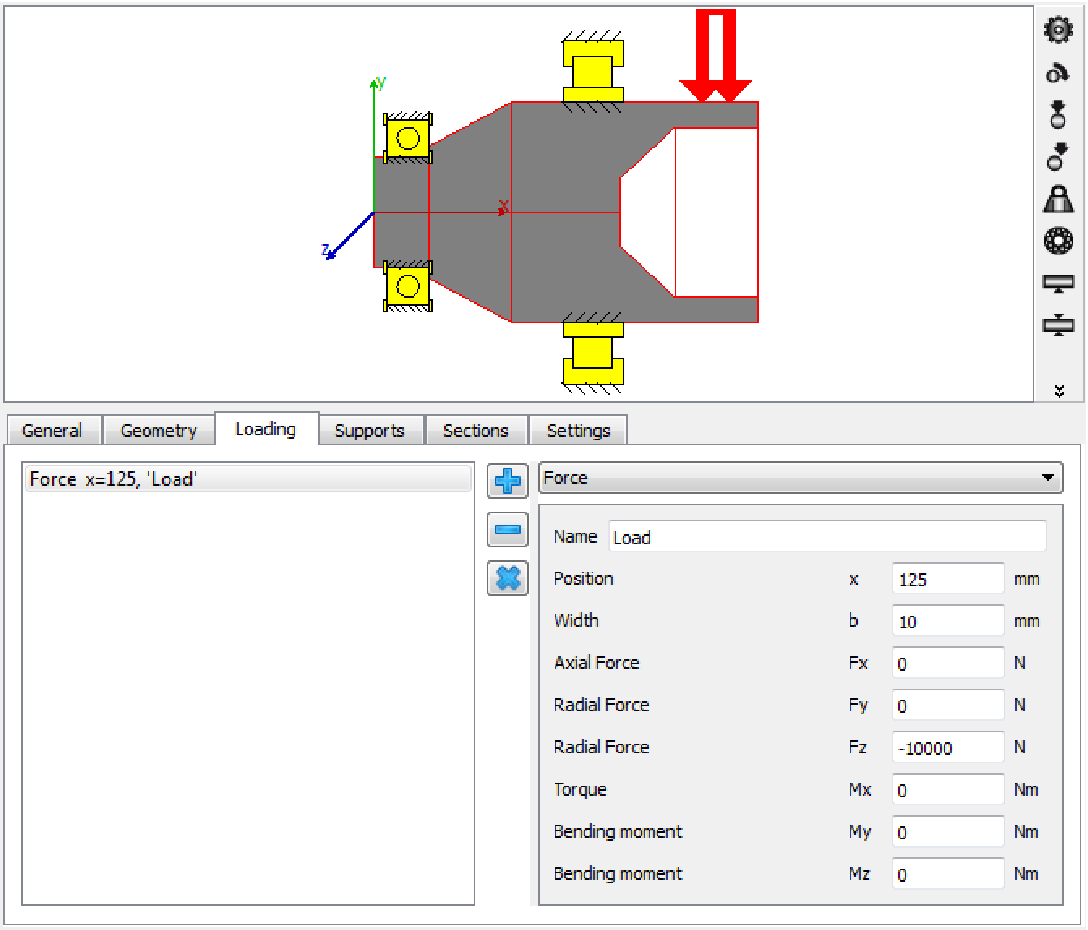
By clicking on the +-button, a pop-up window is opened to show us the bearing data base, in which is possible to set bounds for diameters with the purpose of helping out with the search of the desired geometry. A drop-down list offers a wide range of bearing types. We choose a ‘Deep groove ball bearing (6008) for the left bearing, and a ‘Cylindrical roller bearing (NU1016)’ for the right one.



Loading

On the tab page 'Loading', different kind of loads are available. Select a generic 'Force' from the drop-down list. The load's coordinates are relative to the start of the shaft. In this example we define a Radial force of Fz = -10000 at position x = 125 mm and a Width of b = 10 mm.

Now with one shaft defined statically, we can run the calculation using the - button on the toolbar. No error message should be shown.



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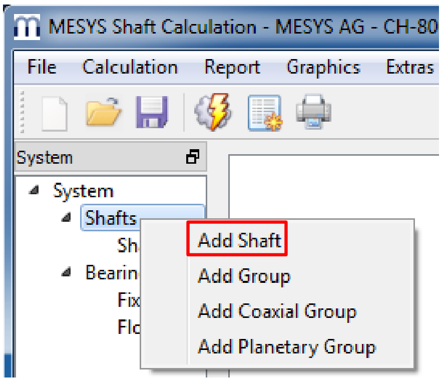
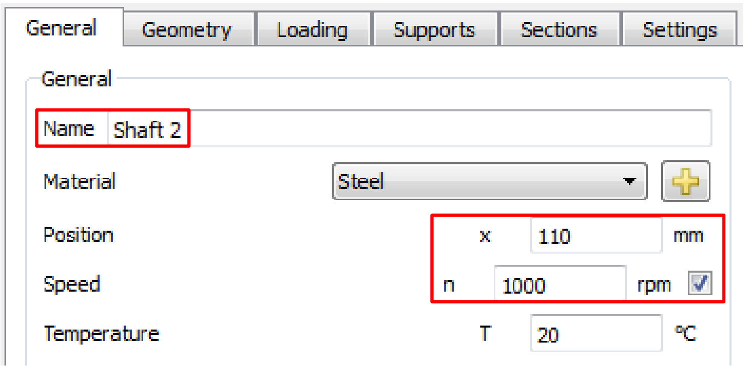
Defining second shaft

Now the second shaft will be defined. To add a second shaft click the right mouse button on the 'Shafts' header in the tree on the left and select 'Add Shaft' from the context menu.

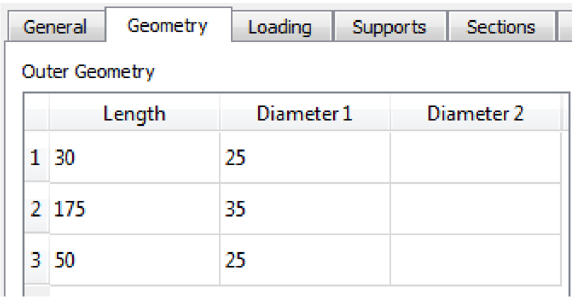


Then the following general data can be entered for the second shaft:



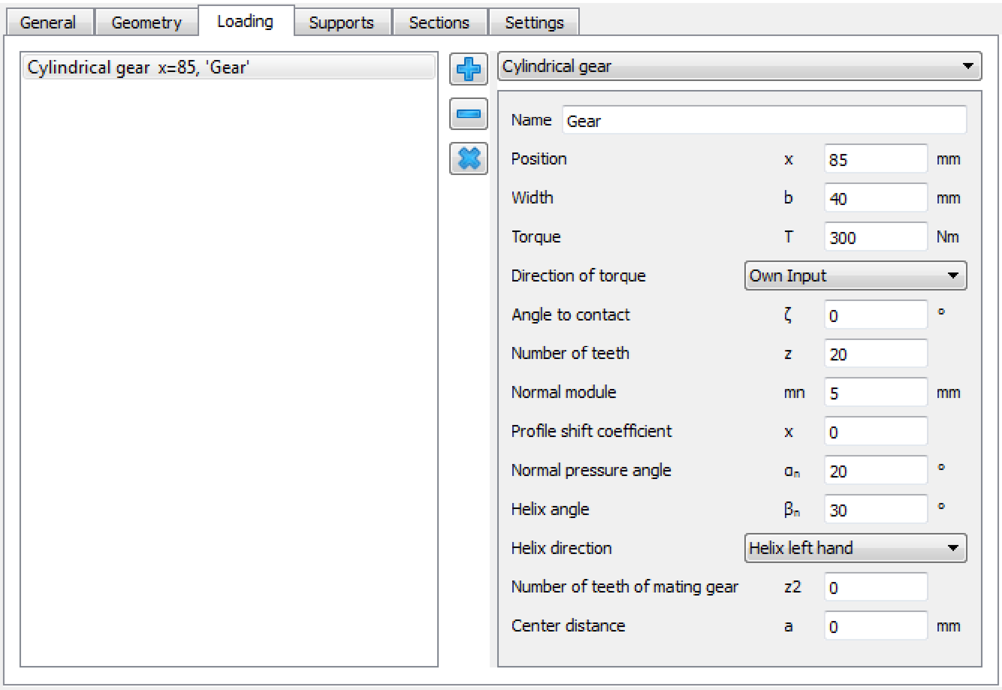
Shaft geometry

As we proceeded before, we define now the geometry for the second shaft, for which only an outer geometry needs to be created as shown below:



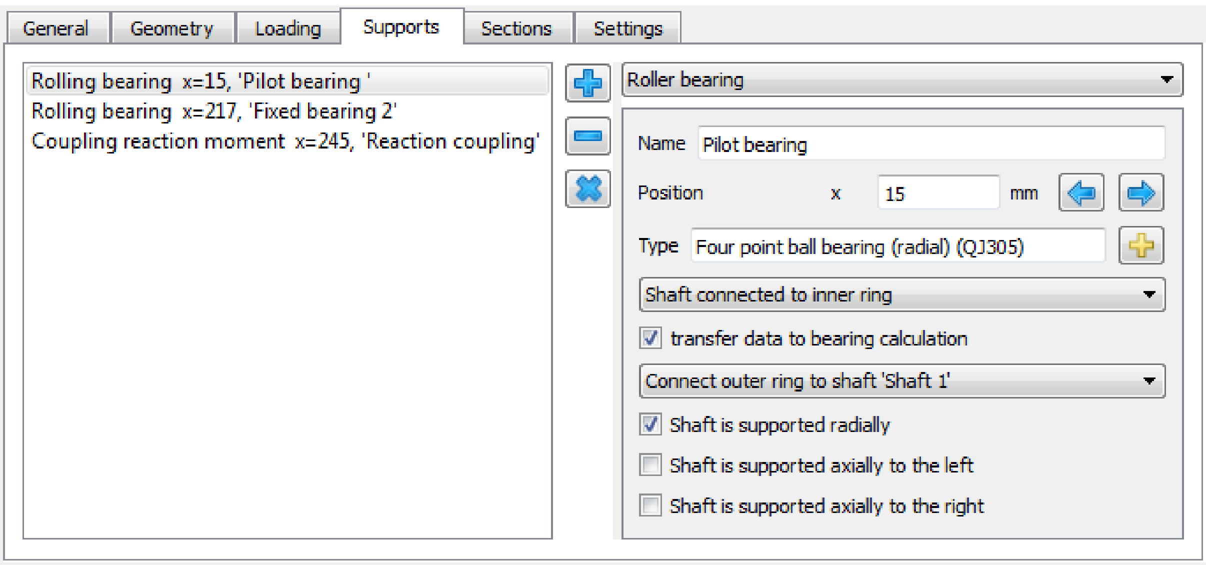
Loading

We will load the second shaft with a ‘Cylindrical gear’, fill the out the data as the figure below:



Bearings

On the second shaft also two bearings will be defined. The first one will be a floating ‘Four point ball bearing (radial) (QJ305)’ located at x = 15 mm, whose outer ring is connected to ‘Shaft 1’. The second one will be a fixed ‘Deep groove ball bearing (double row) (4305)’ placed at the position x = 217 mm, whose outer ring will be connected to the housing. As the torque of the cylindrical gear needs an output, we must add a ‘Coupling for reaction torque’ to the list of supports. It will be located at x = 245 mm and have a Width of b = 10 mm.



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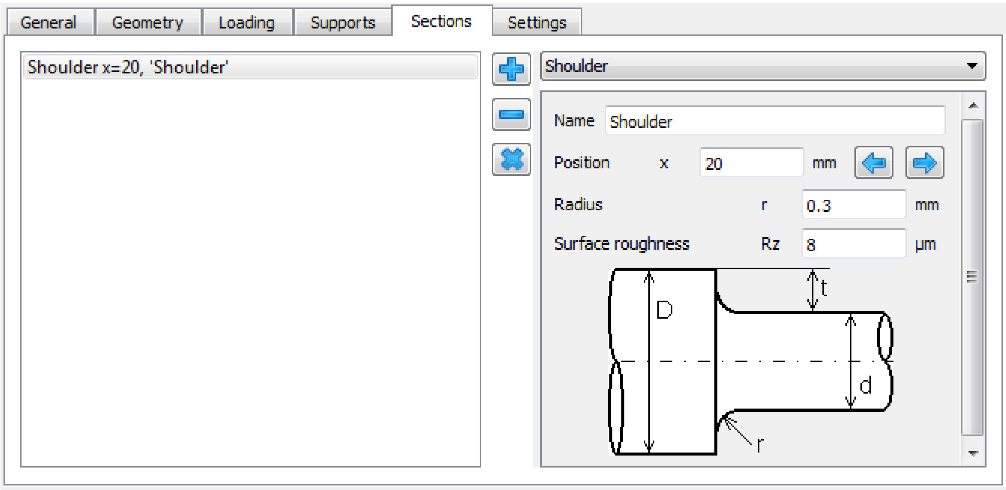
Shaft sections

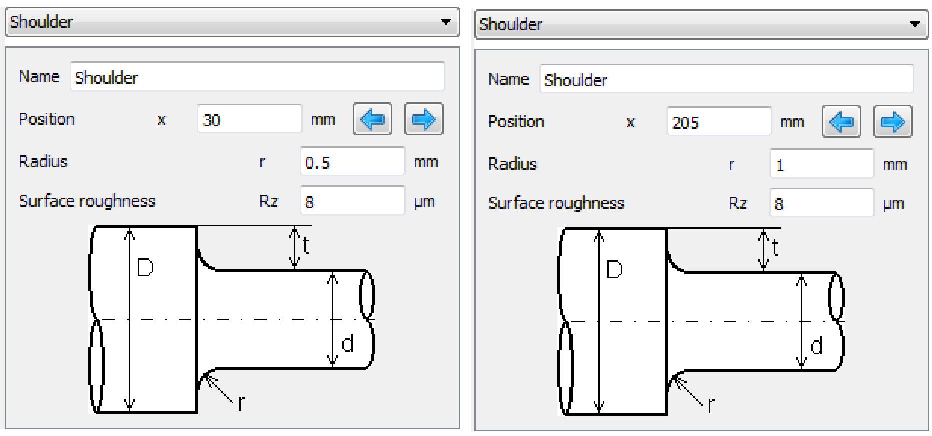
For a more appropiate calculation of the shafts, stress concentrations must be taken into account. To do so, the software offers the possibility to define different notch cases at the tab page ‘Sections’ for each shaft. In our example, we will focus the analysis on those points where exist a diameter’s change, i.e. we set one section at the ‘Shaft 1’, and two more for the ‘Shaft 2’.

Use the +-button to add a section and ‘Shoulder’ from the drop-down list, then fill out the data as shown:

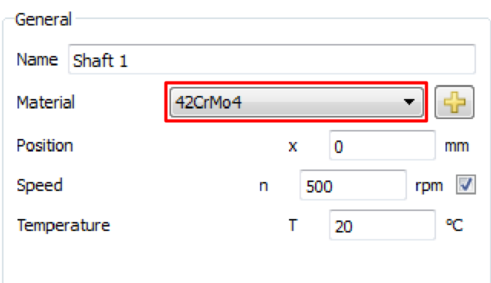
Shaft 1



Shaft 2



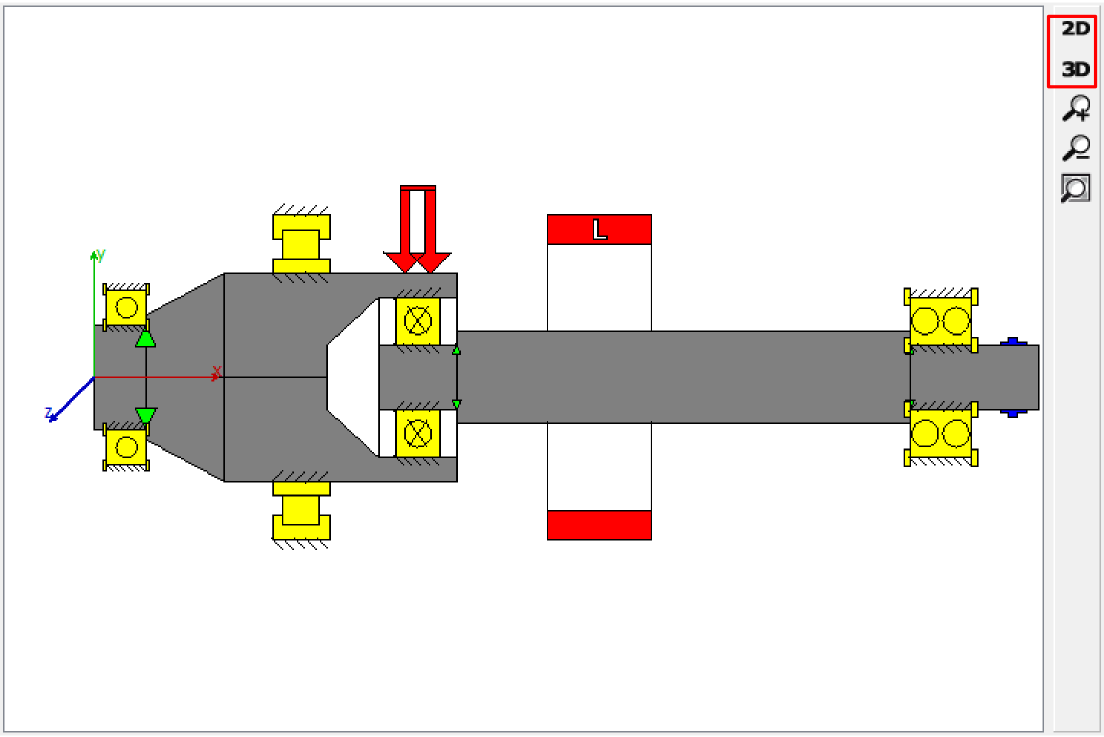
We will also change the material of the shafts, so go to the tab page ‘General’ for each shaft and select ‘42CrMo4’ from the drop-down list:



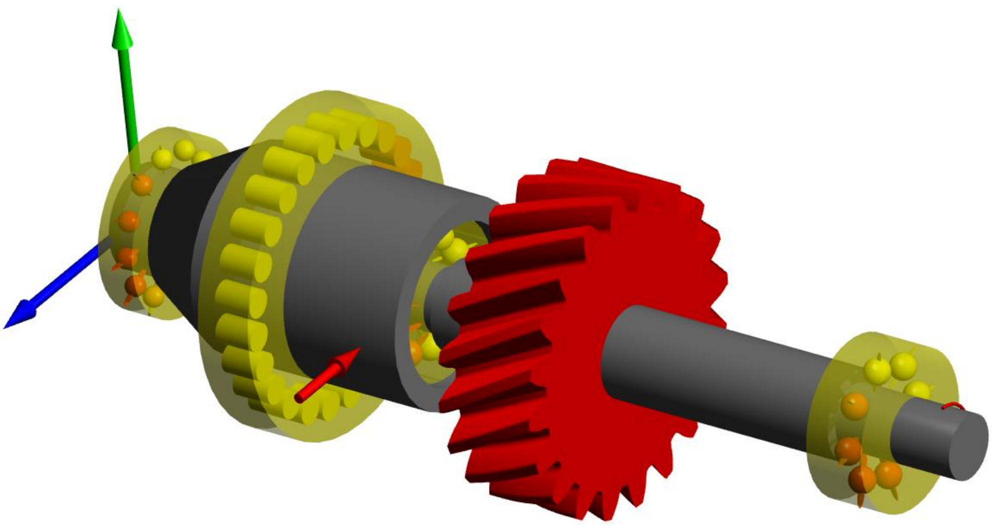
Results

Click on the 'Shafts' header at the system tree, and run the software to have a look at the results of the example. Please note that if the user clicks on a header corresponding to any of the created bearings, the functionality of the toolbar is only valid for the bearing calculation, i.e. when pressing on the - button, the software will just run a bearing calculation.

Now, the overview of the system geometry should look as shown:

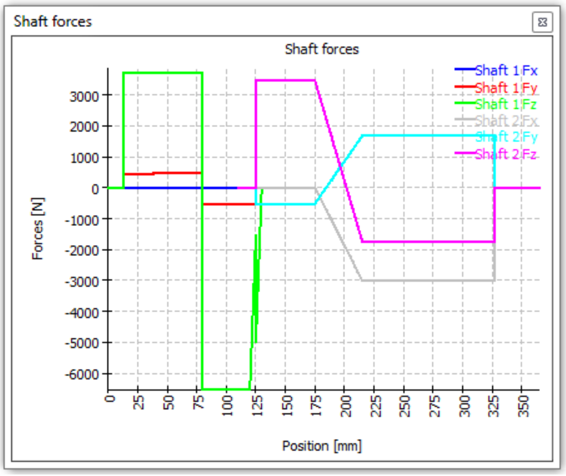


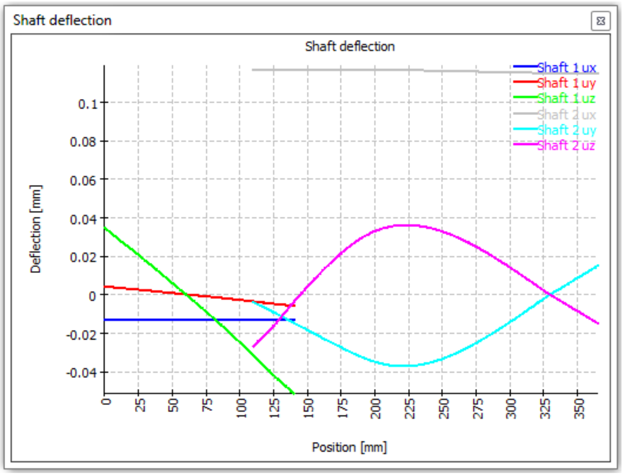
The green arrows point out the analyzed sections of the shafts. The blue element at the right end of the second shaft is the 'Reaction coupling' that we added previously on the corresponding tab page for the supports.



For a 3D-view, click on the 3D-button at the view toolbar.

The shaft calculation provides some graphic results, like shaft deflections, forces and moments. Click on 'Graphics' at the menu bar in order to show them.

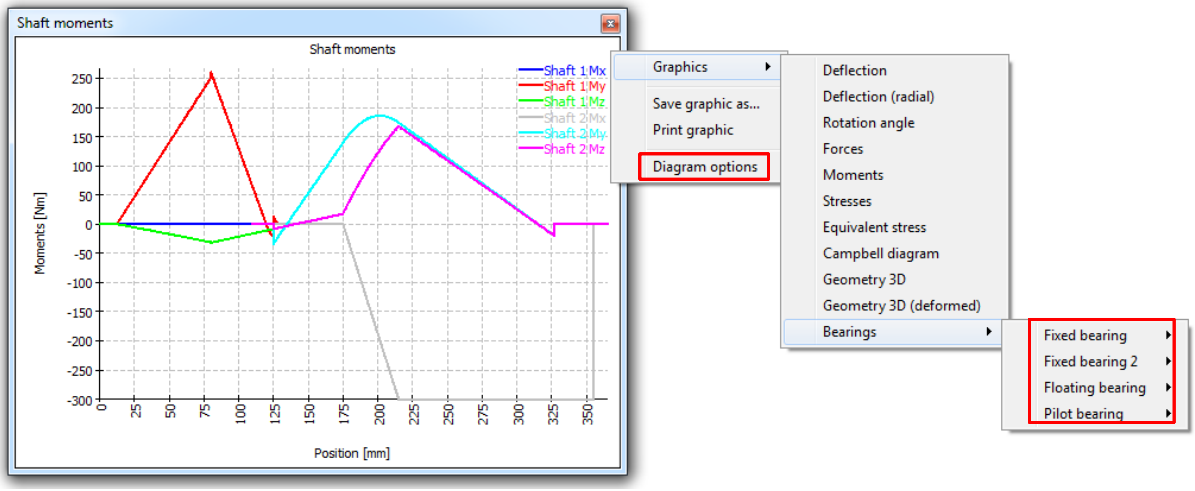




The second shaft in under compression due to the axial force of the helical gear, see the grey line 'Shaft 2Fx'.

The user can see a gap between the deflections in z-direction of the two shafts. This is because of the bearing stiffness of the connecting bearing. The pilot bearing is at the global position x = 125 mm, so there is almost no bending moment taken by the bearing.

By doing a right-click in an opened graphic window, the user can directly have access to any other graphic results of the shaft calculation as well as for the bearings. For instance, we can have a look at the "Load Distribution' and 'Contact Stress' for both the 'Fixed bearing' and the 'Pilot bearing'.



Note that the graphics can be handled by using the 'Diagram options' at the context menu. It allows the user to change units, bound values and choose the desired chart.

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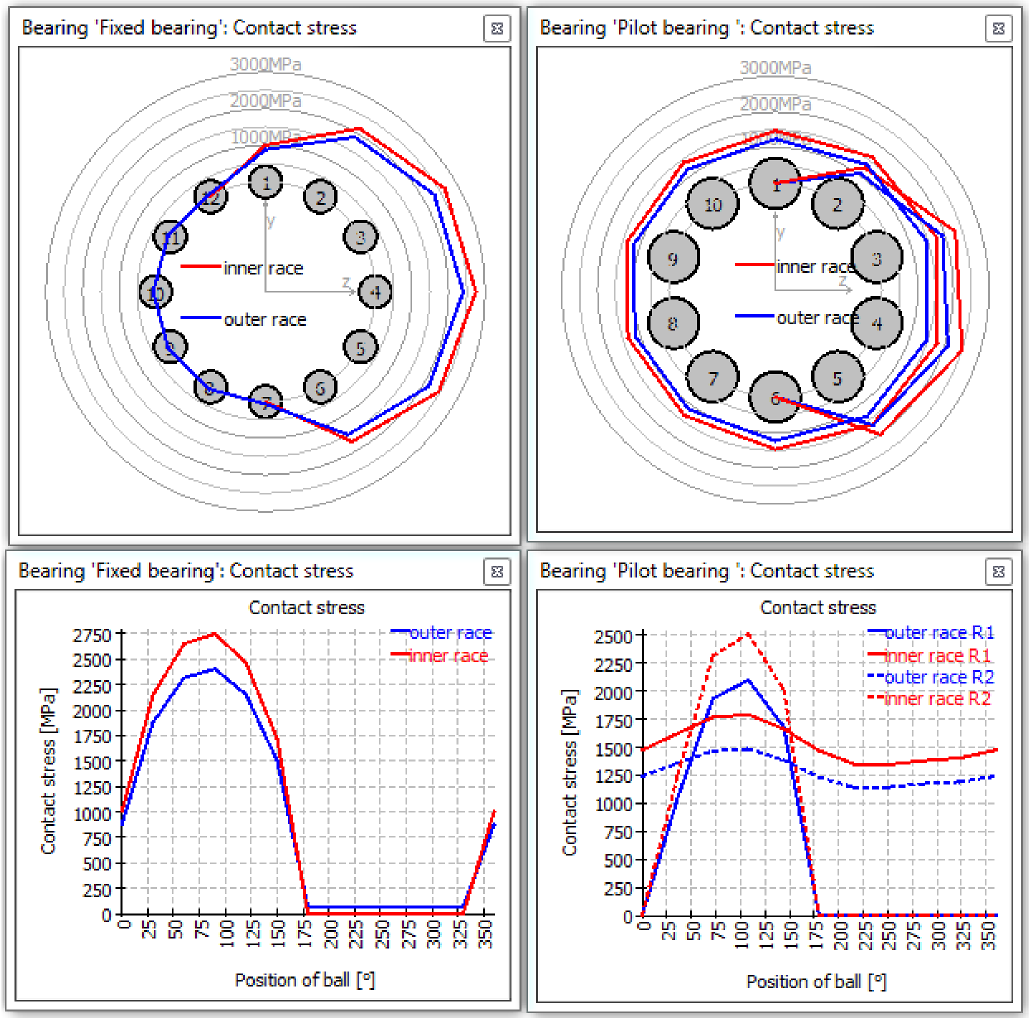
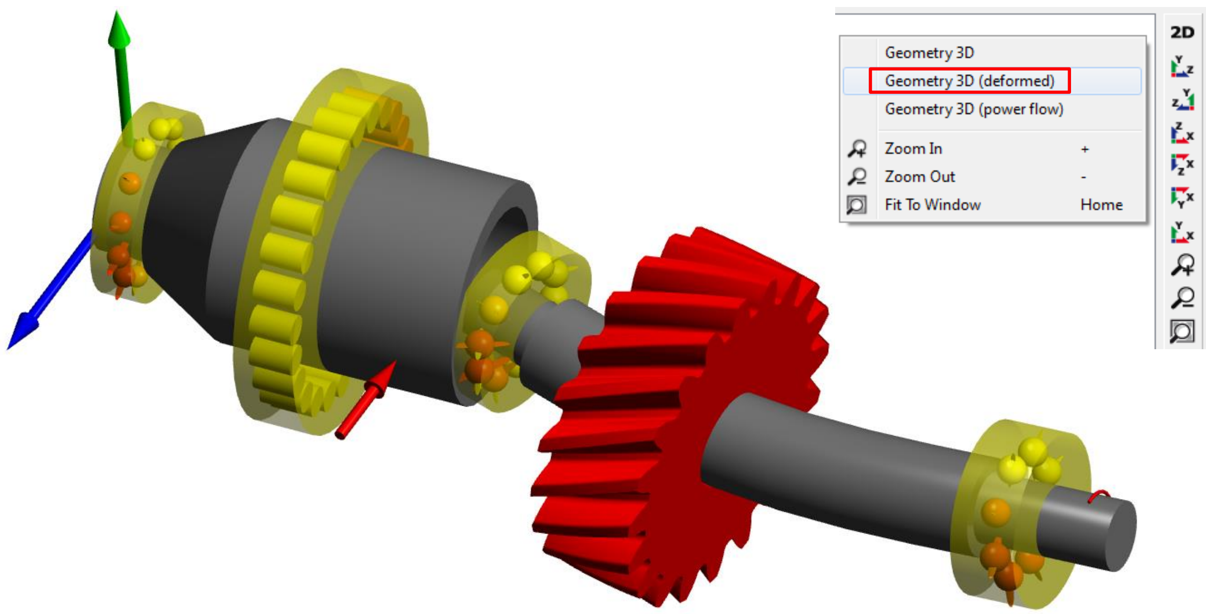


In the same way, it is possible to visualize the deformed shape of the shafts (go to the 3D-view of the geometry overview, do a right-click and select 'Geometry 3D (deformed)' from the context menu):



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At the window 'Result overview', which is located at the bottom of the software, some general results like safety factors, displacements or minimal bearing life are shown when clicking on the header 'Shafts'.

Result overview

Minimal bearing reference life	minL10rh	3006.81	h	Minimal bearing modified reference life	minLnmrh	2730.33	h	Minimal static safety for bearings	minSF	3.56542	
Minimal dynamic shaft safety factor	minSD	2.741		Minimal static shaft safety factor	minSS	5.809		Maximal equivalent stress	maxSigV	179.574	MPa
Maximal displacement in radial direction	maxUr	0.05186	mm	Maximal displacement in x	maxUx	0.117212	mm				

Also if you click on any of the existing bearings at the system tree, specific results for the selected bearing like 'Maximal pressure' are available.

Result overview

Basic reference rating life	L10r	90.2042		Basic reference rating life	L10rh	3006.81	h	Modified reference rating life	Lnmr	81.91	
Modified reference rating life	Lnmrh	2730.33	h	Maximal pressure	pmax	2749.24	MPa	Static safety factor	SF	3.56542	
Ellipsis length ratio inner race	eLR_i	204.7	%	Ellipsis length ratio outer race	eLR_e	208.463	%	Extension contact ellipsis inner ring	dCimax	46.6047	mm
Extension contact ellipsis outer ring	dCemin	61.4205	mm	Viscosity ratio	χ	1.47032		Free contact angle	α0	0	°
Distance between rolling elements	δRE	6.03873	mm	Effective diametral clearance	Pdeff	0	mm	Effective axial clearance	Paeff	-99.999	mm

Moreover, when selecting the system tree headers "Shafts" or "Bearings", additional results will be shown at the central window of the software. Click on the different tabs at the side to take a look at them:

Name	L10h [h]	Lnmh [h]	L10rh [h]	Lnmrh [h]	pmax [MPa]	SF	Fx [kN]	Fy [kN]	Fz [kN]
Shaft 1									
Fixed bearing	3005	2728	3007	2730	2749.24	3.57	0.000	0.451	3.714
Floating bearing	79269	478275	225707	775107	1228.37	10.60	0.000	-1.005	-10.251
Shaft 2									
Pilot bearing	30864	45064	11758	12582	2510.84	4.68	0.000	-0.519	3.463
Fixed bearing 2	3203	5669	3941	7287	2371.51	5.55	3.000	-1.680	1.733
Reaction coupling							0.000	0.000	0.000

Shafts | Sections | Bearings | Frequencies

Name	Type	x [mm]	SD	SS	Fx [kN]	Fy [kN]	Fz [kN]	Mx [Nm]	My [Nm]	Mz [Nm]	ux [mm
Shaft 1			25.85	225.72							
Shoulder	Shoulder	20	25.85	225.72	0.000	0.452	3.714	0.00	28.08	-3.43	-0.0129
Shaft 2			2.74	5.81							
Shoulder	Shoulder	30	14.14	91.18	-0.000	-0.518	3.463	0.00	18.21	-0.51	0.1172
Shoulder	Shoulder	205	2.74	5.81	-3.000	1.678	-1.733	-300.00	0.67	0.20	0.1154

Shafts | Sections | Bearings | Frequencies

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In this results output, life and bearing forces are shown for all bearings. Furthermore, since we created shoulders to analyze the effect of notches, both the minimal dynamic and static shaft safety factors, i.e. 'SD' and 'SS', are shown at the tab page 'Sections'.

Report results

The main report, which is shown by pressing on the -button, does not show details for the bearings, only an overview of results.

By Selecting 'Report'>'Full report' at the menu bar, a full report is available, which includes the detailed reports for each bearing calculation. In this example the full report has 40 pages and includes several charts regarding rolling element loads for each rolling bearing.