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.
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 –x-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 it 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 $F_z = -10000$ 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.
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 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.
**Shaft sections**

For a more appropriate 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 1 diagram]

**Shaft 2**

![Shaft 2 diagrams]

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:

![2D View of System Geometry]

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.

![3D View of System Geometry]

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 is 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.
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):
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’.

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.

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:
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.