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Tutorial Series — Shaft Calculation - Starter Scope: Sets of Spindle Bearings

Content

This tutorial demonstrates three methods for modelling angular contact ball bearing sets on a shaft. The main differences, as well as the advantages and disadvantages of each method, will be explained. To follow along, the relevant calculation file is required, which can be downloaded from the MESYS download section. The MESYS version used is 12-2025.

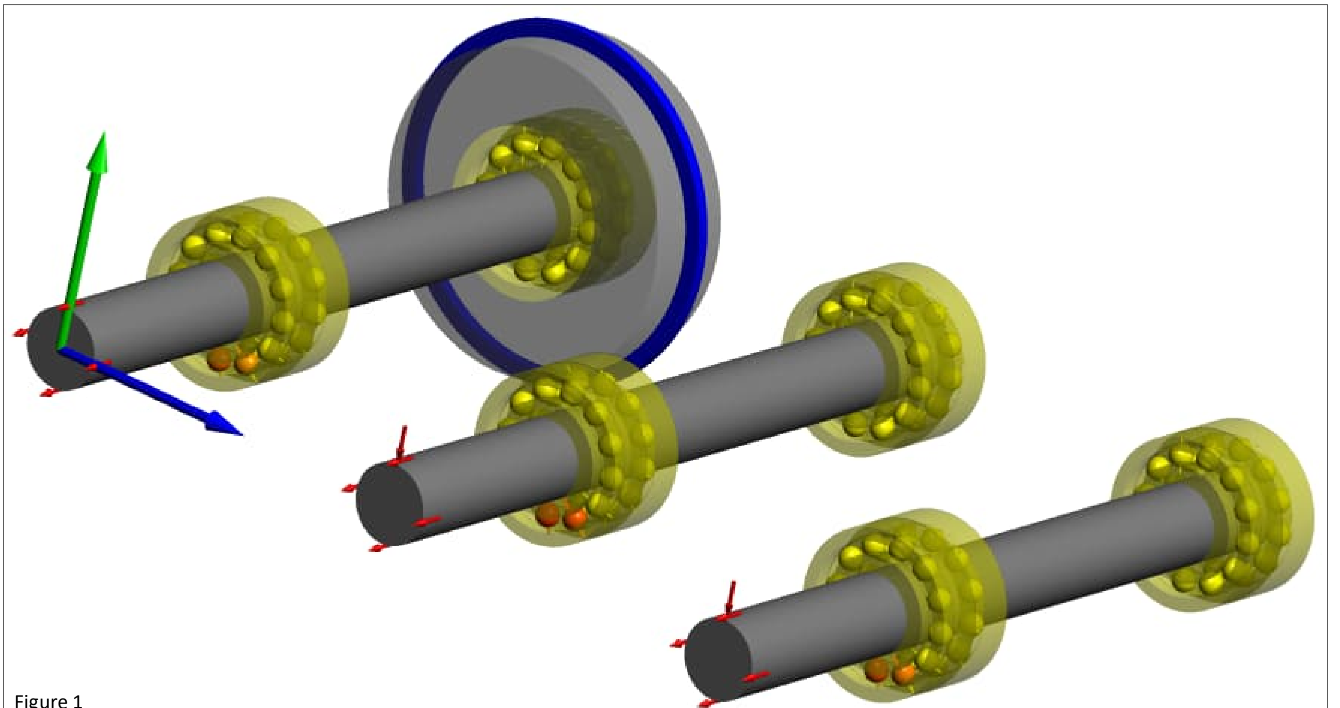

Figure 1

As shown in Figure 1, three independent shaft models have been created to compare the same pairing types with different implementations (concepts) within the same calculation file. Each spindle shaft, supported by two angular contact ball bearings sets arranged in a back-to-back configuration, has a force element with components Fx and Fy acting at its spindle nose.

The bearing set at the working side is assumed to be fully fixed, while the bearing set positioned at the other end only supports the shaft radially. The boundary conditions resulting from the implementation of these three bearing arrangements are initially considered equivalent.

The individual concepts are explained in more detail below.

Concept 1 (Floating Sleeve)

In this variant, four single-row angular contact ball bearings are used and positioned along the shaft in such a way that the bearings of each bearing set are placed directly next to each other in a back-to-back configuration.

Components	Shaft:	Length = 200 mm;	Ø outside = 20 mm
	Hollow Shaft:	Length = 24 mm;	Ø outside = 80 mm; Ø inside = 42 mm
	Bearing:	Angular Contact Ball Bearing	7004D generic

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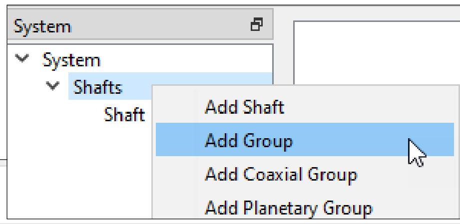
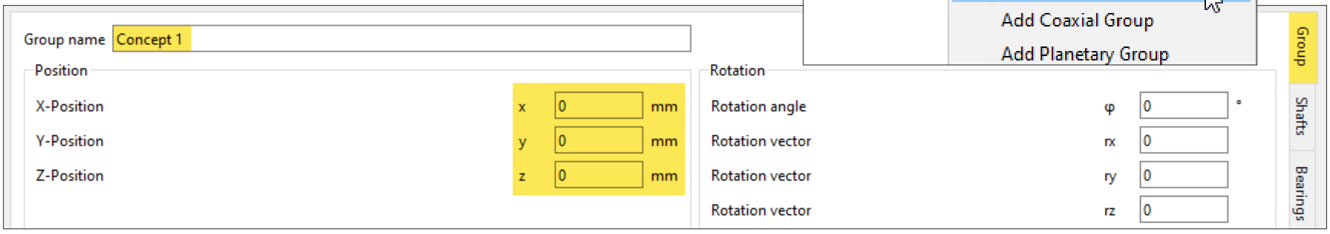
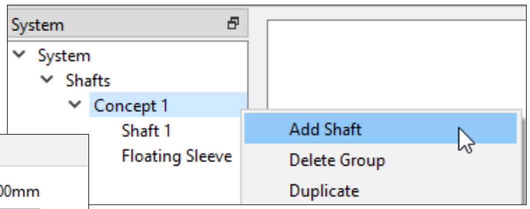
Create a group and name it "Concept 1". Keep this group at the coordinate origin.





Create the two shafts within it as shown in Figure 2 and assign the geometries according to the specifications on page 1.



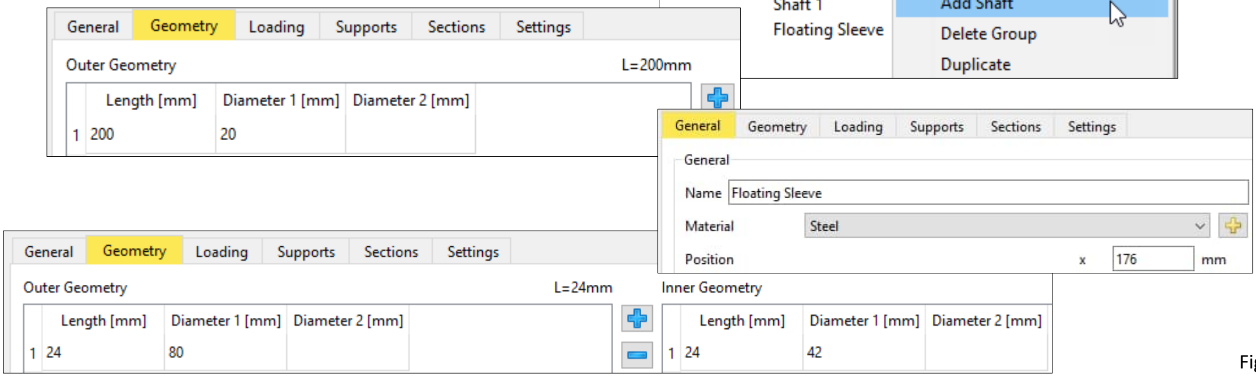
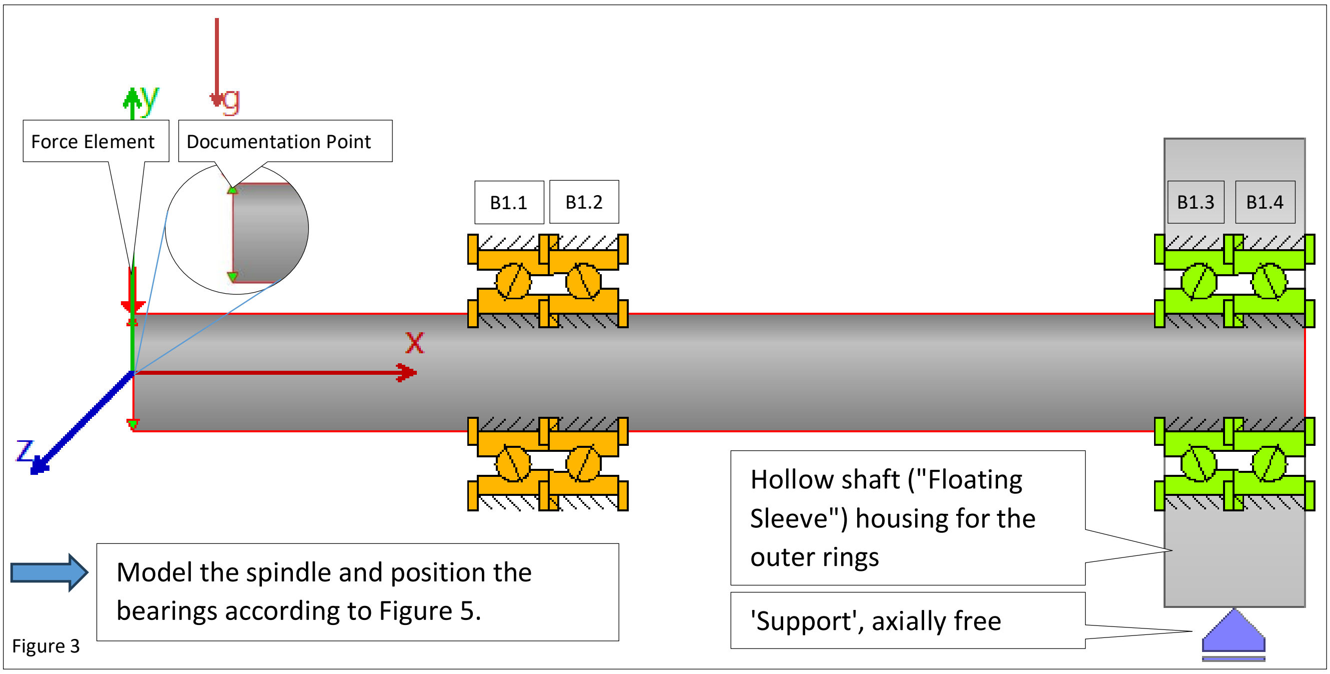
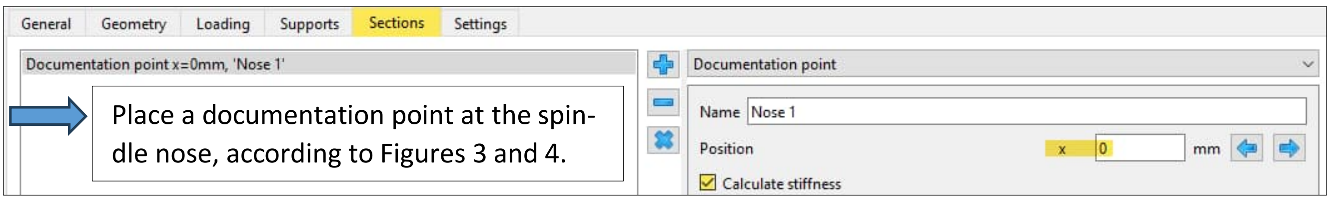


Figure 2



Model the spindle and position the bearings according to Figure 5.

Figure 3



Place a documentation point at the spindle nose, according to Figures 3 and 4.

Figure 4

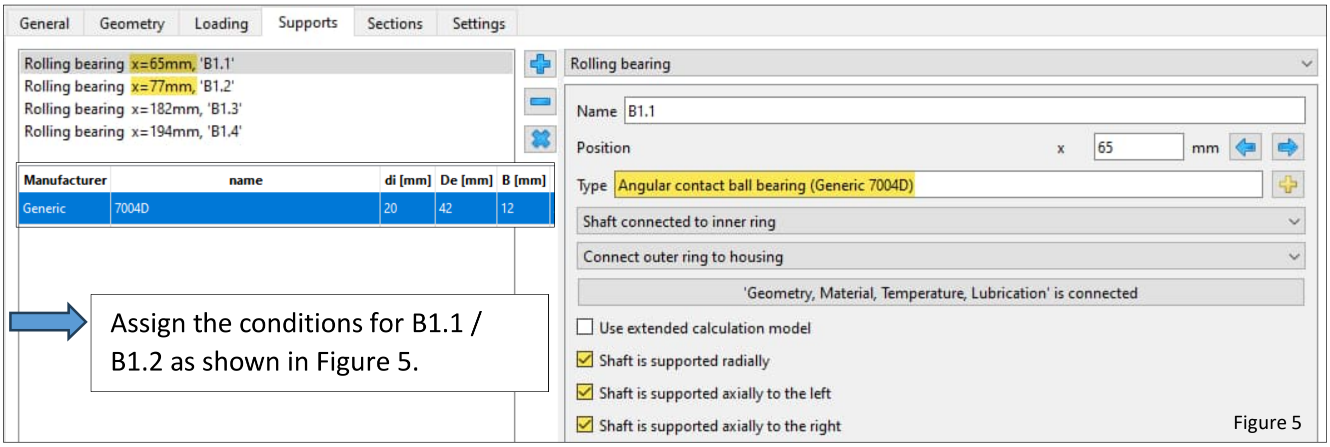


Figure 5

By connecting the outer rings B1.1 / B1.2 to the "housing" (rigid environment) and setting all the associated boundary conditions, the front bearing set behaves like a fixed bearing.

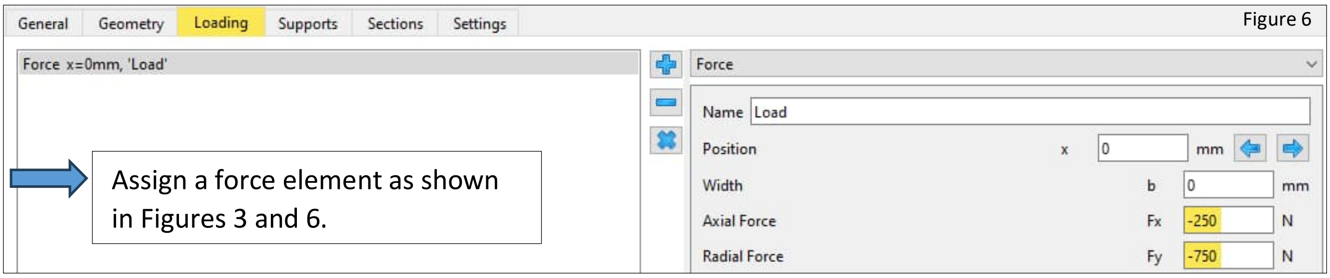


Figure 6

The outer rings for B1.3 / B1.4 are connected to the hollow shaft ("floating sleeve"), which serves as the common housing for the rolling bearings. It limits the axial relative movement of the bearings to each other and simultaneously takes on the force transmission. For this reason, the two axial boundary conditions for the free bearing set B1.3 / B1.4 must be set as 'supported' (Figure 7).

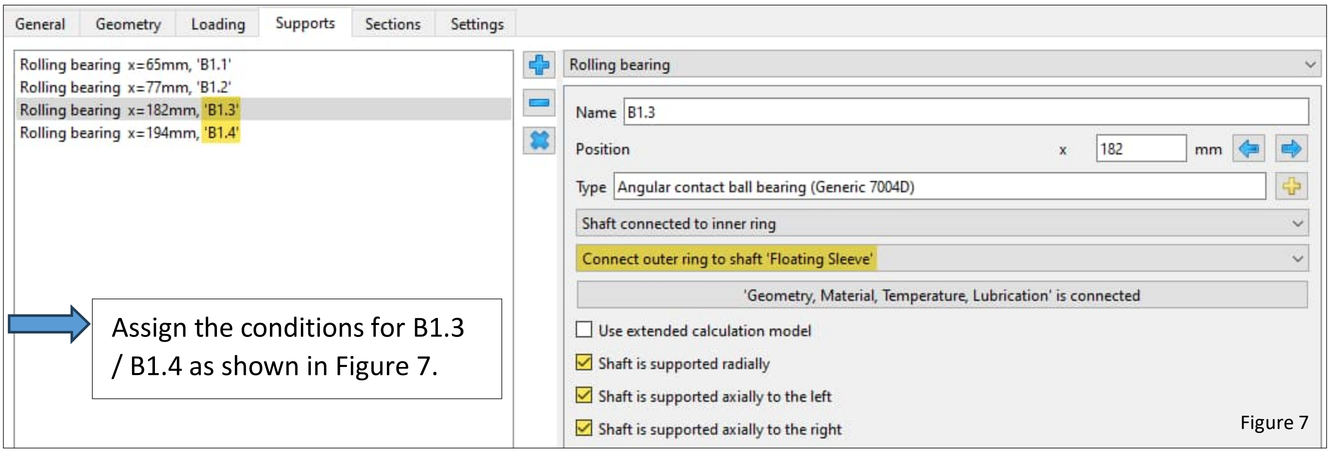


Figure 7

For this specific implementation of the free bearing set B1.3 / B1.4, two additional elements are required: the hollow shaft ("floating sleeve") mentioned above, and a support condition that is applied to its outer diameter, leaving it axially free (not 'supported' axially).

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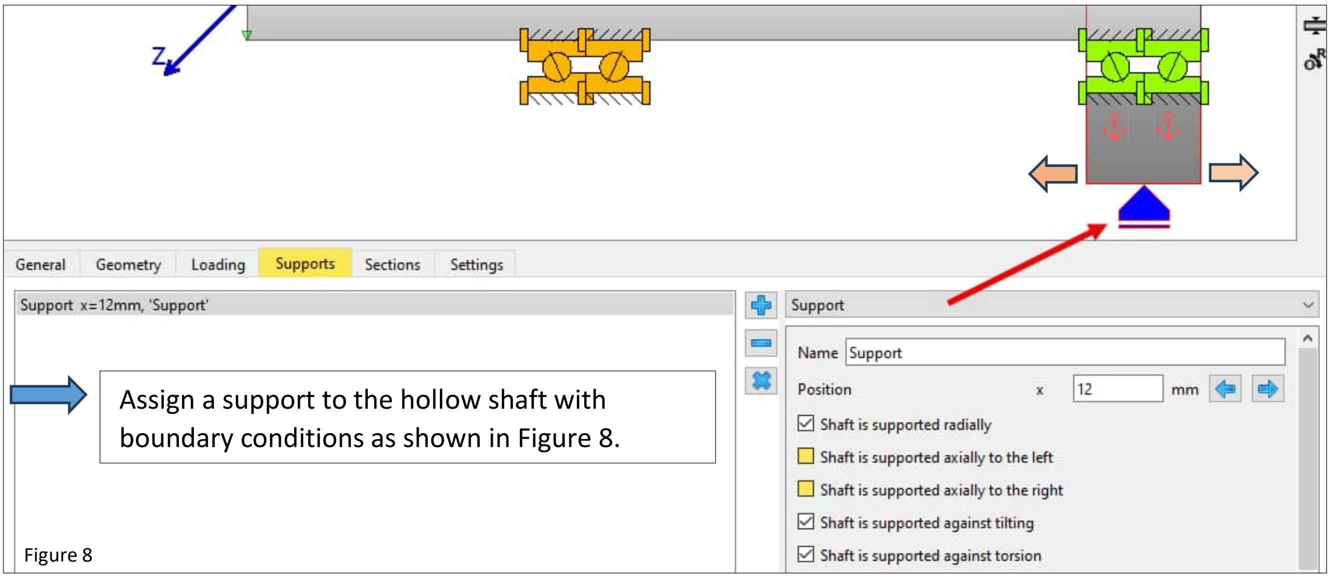


Assign a support to the hollow shaft with boundary conditions as shown in Figure 8.

Figure 8

Concept 2 (Set of Bearings)

In this type of bearing pairing implementation, only two single-row angular contact ball bearings need to be defined initially. Then, a bearing set is generated for each configuration using the software option "Bearing configuration".

- Please add a group and name it "Concept 2." Assign a Z position of 100 mm to this group.
- Copy only "Shaft 1" and move it to the "Concept 2" group.
- Adjust the labels of all elements accordingly.

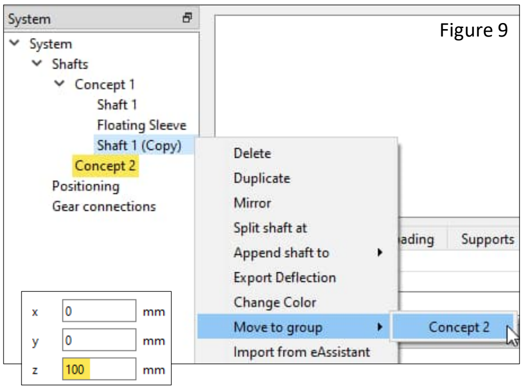


Figure 9

For the implementation of this concept, which involves the use of 2 bearing sets, we only need to start with 2 angular contact ball bearings.

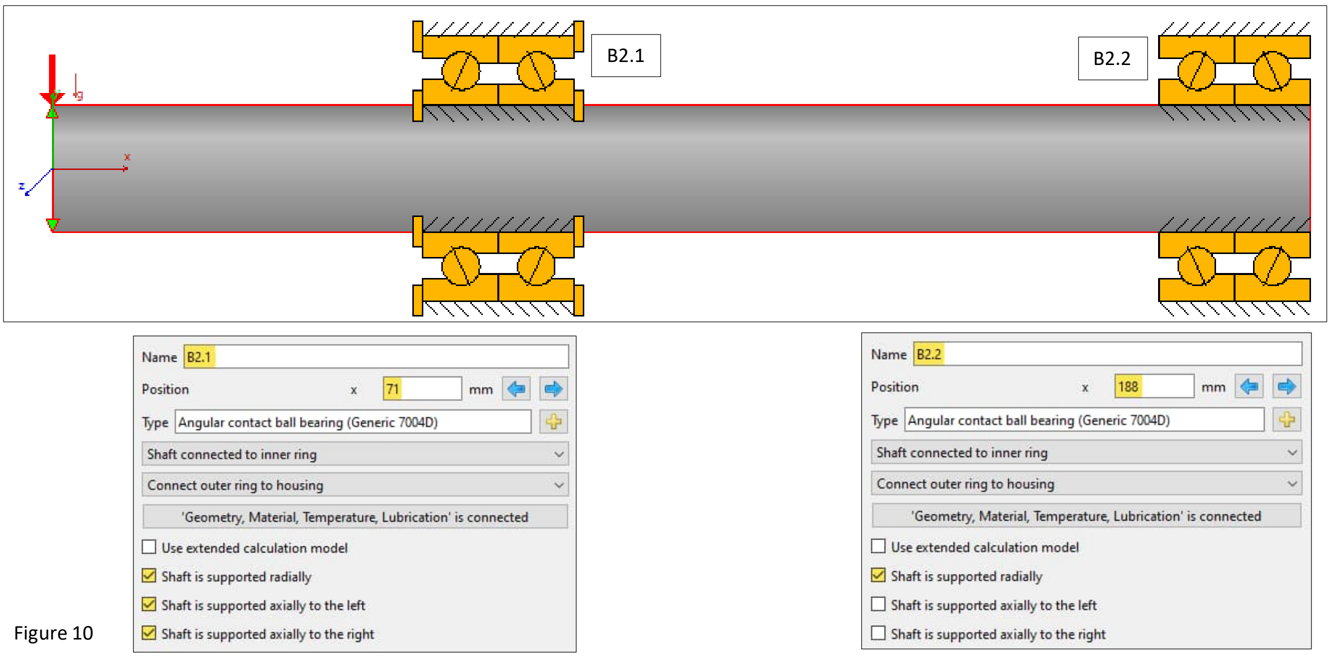
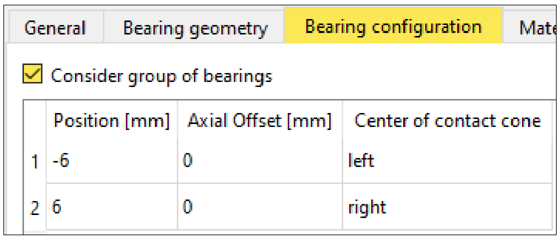
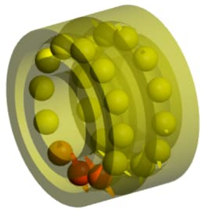


Figure 10

Figure 11



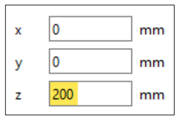
- Activate the 'Consider group of bearings' option for both bearing sets and name the bearings as shown in Figure 10.
- Due to this configuration, the bearing arrangements behave like a double-row angular contact ball bearing.
- The main advantage lies in the simple implementation. However, under certain load conditions, it is not possible to obtain detailed numerical results when one of the rows is not loaded. This can only be observed through the various graphics for load distribution.



Concept 3 (Extended Calculation Model)

In this type of bearing pairing implementation, the "Extended calculation model" option should be activated. This more complex approach allows for the definition of the respective state of rolling bearing surrounding parts for the axial and radial contact with the bearing rings. To ensure comparability with the previous concepts, the setting "Additional shaft for the outer ring with axial contact and no radial play" should be selected for the free bearing.

- Please add a group and name it "Concept 3." Assign a Z position of 200 mm to this group.



- Copy only "Shaft 1" and move it to the "Concept 3" group.
- Adjust the labels of all elements accordingly.

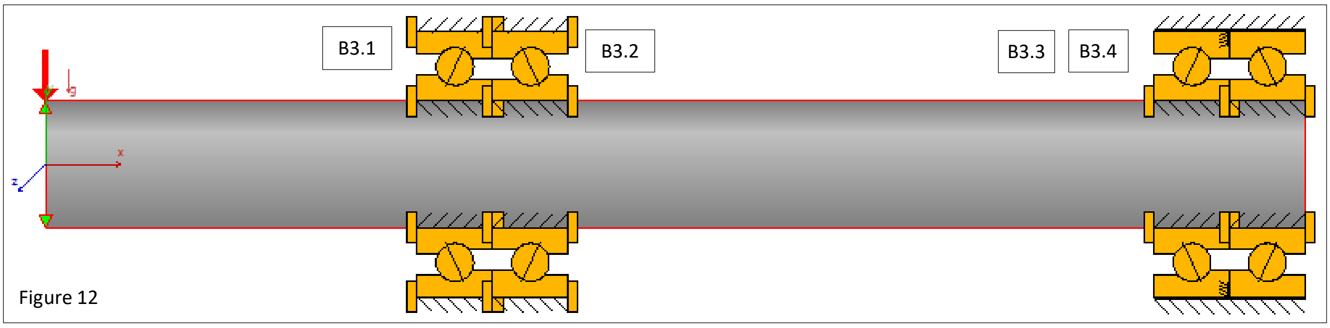


Figure 12

- Keep the axial positions of all rolling bearings and the boundary conditions for the fixed bearing exactly as they are for "Shaft 1".
- Activate the "Extended calculation model" for the rolling bearings of the free bearing set B3.3 & B3.4 using the corresponding checkbox (Figure 13).

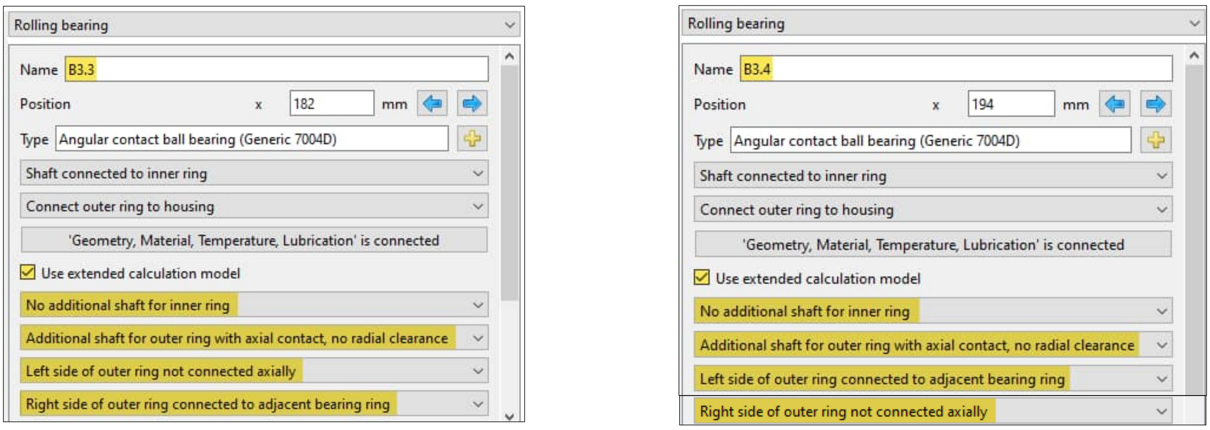


Figure 13

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With this setting, the inner rings are connected to the shaft via a single central node. Axial and radial forces are transmitted, and no play (between the bearing ring and the shaft or housing) is supported.

With this setting on the outer rings, an additional inner shaft for the ring is created, and for the present case, the adjacent bearing defines the axial contact.

Comparison of Results

The alternatives presented will lead to very similar results in practice. In this way, the bearing set 'B2.1' is the equivalent model of bearing set B1.1 / B1.2, respectively B3.1 / B3.2, and 'B2.2' is the equivalent of B1.3 / B1.4, respectively B3.3 / B3.4.

Modelling a bearing set using Concept 1 or 3 provides more detailed information. For example, it is possible to know the tilting angle 'rz' (see blue-bordered cells in Table 1) for both rows of the corresponding bearing set, while the 'rz' of the bearing set modelled with Alternative 2 provides an approximate value:

Shaft	Support	Fx [N]	Fy [N]	Mz [Nm]	ux [mm]	uy [mm]	rz [mrad]	L10h [h]
Floating sleeve	Support	0.0	301.7	-1.5	-0.011	0.000	0.000	
Shaft 1	B1.1	607.6	-1,213.3	8.2	-0.015	-0.017	1.116	4,109
Shaft 1	B1.2	-857.6	150.0	2.2	-0.015	-0.006	0.837	13,933
Shaft 1	B1.3	111.3	212.9	-1.5	-0.004	0.006	-0.235	759,979
Shaft 1	B1.4	-111.3	95.5	0.7	-0.004	0.003	-0.245	2,915,684
Shaft 2	B2.1	-250.0	-1,056.6	19.1	-0.015	-0.012	0.962	3,219
Shaft 2	B2.2	0.0	301.8	-1.2	-0.015	0.004	-0.224	752,878
Shaft 3	B3.1	607.6	-1,213.3	8.2	-0.015	-0.017	1.116	4,108
Shaft 3	B3.2	-857.6	150.2	2.2	-0.015	-0.006	0.837	13,928
Shaft 3	B3.3	111.0	212.4	-1.5	-0.004	0.006	-0.233	765,857
Shaft 3	B3.4	-111.0	95.9	0.7	-0.004	0.003	-0.243	2,923,451

Table 1: Excerpt from Report Result Tables

It is important to note the radial forces 'Fy' of B1.3 / B1.4 and the support of the shaft "floating sleeve" (see green framing in Table 1). The sum of the radial forces 'Fy' from B1.3 and B1.4 should be equal to the resulting radial force in the bearing, but in the computational consideration, it turns out to be slightly higher:

$$\boxed{308{,}4\ \mathrm{N}} = Fy_{B1.3} + Fy_{B1.4} \neq Fy_{FloatingSleeve} = \boxed{301{,}7\ \mathrm{N}}$$

The reason why this equation is not satisfied is that the weight of the outer ring has been taken into account, and its corresponding force opposes the bearing forces, so the correct equation is as follows:

$$Fy_{B1.3} + Fy_{B1.4} - F_{Weight} = Fy_{FloatingSleeve}$$

In the modeling, taking the weight into account could cause the system from Concept 1 to exhibit an additional unwanted modal shape in the axial direction due to the "floating sleeve." To avoid this effect, we can set the density of this component to $\rho = 0\ kg/m^3$:

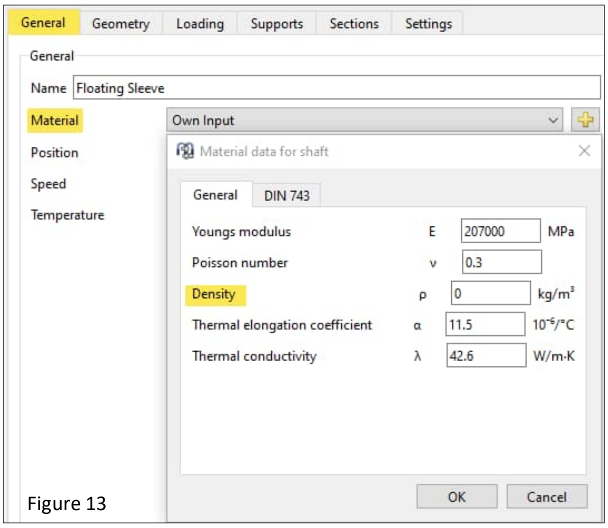

Figure 13

For comparison with the service lives determined in Concept 2 (B2.1 & B2.2), it should be noted that the total service life for combined bearings can be calculated from the service lives of the individual rows (Concepts 1 & 3) as follows:

$$L_{10h} = \left[\sum L_{10h,i}^{-\frac{10}{9}}\right]^{-\frac{9}{10}}$$

This now means for the rows from Concepts 1 & 3, compared to Concept 2 (brown and purple shaded cells from Table 1), as follows:

$$L_{10h,B1.1/B1.2} = \left[L_{10h,B1.1}^{-\frac{10}{9}} + L_{10h,B1.2}^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \left[4'109^{-\frac{10}{9}} + 13'933^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \boxed{3'343\ h}$$

$$L_{10h,B1.3/B1.4} = \left[L_{10h,B1.3}^{-\frac{10}{9}} + L_{10h,B1.4}^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \left[759'979^{-\frac{10}{9}} + 2'915'684^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \boxed{633'351\ h}$$

$$L_{10h,B3.1/B3.2} = \left[L_{10h,B3.1}^{-\frac{10}{9}} + L_{10h,B3.2}^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \left[4'108^{-\frac{10}{9}} + 13'928^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \boxed{3'343\ h}$$

$$L_{10h,B3.3/B3.4} = \left[L_{10h,B3.3}^{-\frac{10}{9}} + L_{10h,B3.4}^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \left[765'857^{-\frac{10}{9}} + 2'923'451^{-\frac{10}{9}}\right]^{-\frac{9}{10}} = \boxed{637'659 h}$$

Finally, we can see through the graphics menu that the contact stresses of Concept 2 will show similar values to those of Alternative 1. The slight differences in the values are mainly due to the different load distribution that results when the tilt angles are considered at different points in the calculation. Nevertheless, as shown here, both alternatives can be used independently without issues for the same purpose:

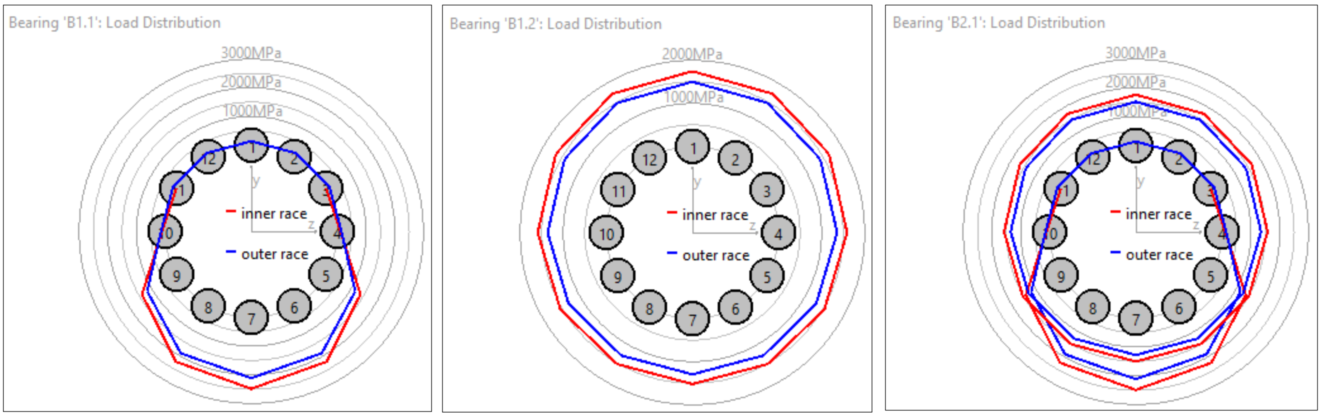

Figure 14: Comparison of Load Distribution for Fixed Bearing Concept 1 vs. Concept 2

For comparison, the results of the stiffnesses (Table 2) from the documentation point at the spindle nose (Figure 4) for the 3 concepts are also provided below:

Table 2

Shaft	Section	cxx [N/mm]	cyy [N/mm]	czz [N/mm]	cry [Nm/rad]	crz [Nm/rad]
Shaft 1	Nose 1	92,809.9	6,700.1	5,738.3	16,965.4	17,917.7
Shaft 2	Nose 2	92,846.5	6,492.5	5,560.6	16,888.4	17,851.2
Shaft 3	Nose 3	92,809.4	6,699.7	5,738.2	16,965.1	17,917.1

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