Engineering Consulting Software AG

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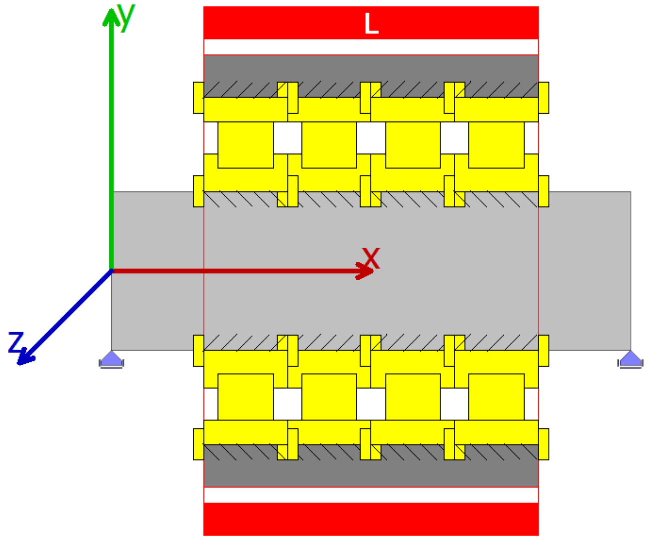
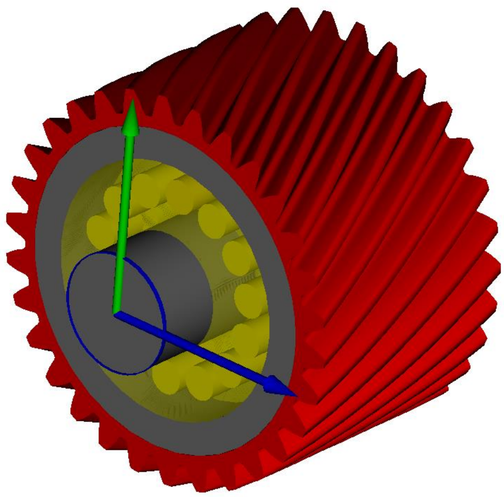
Tutorial: Calculation of a planet support with cylindrical roller bearings

A helical planet is supported by four cylindrical roller bearings. Because of the helical gear a radial load and a moment load has to be supported by the bearings.



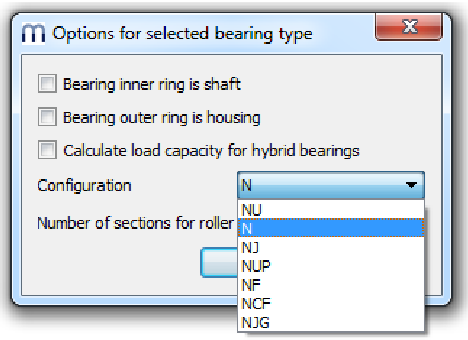


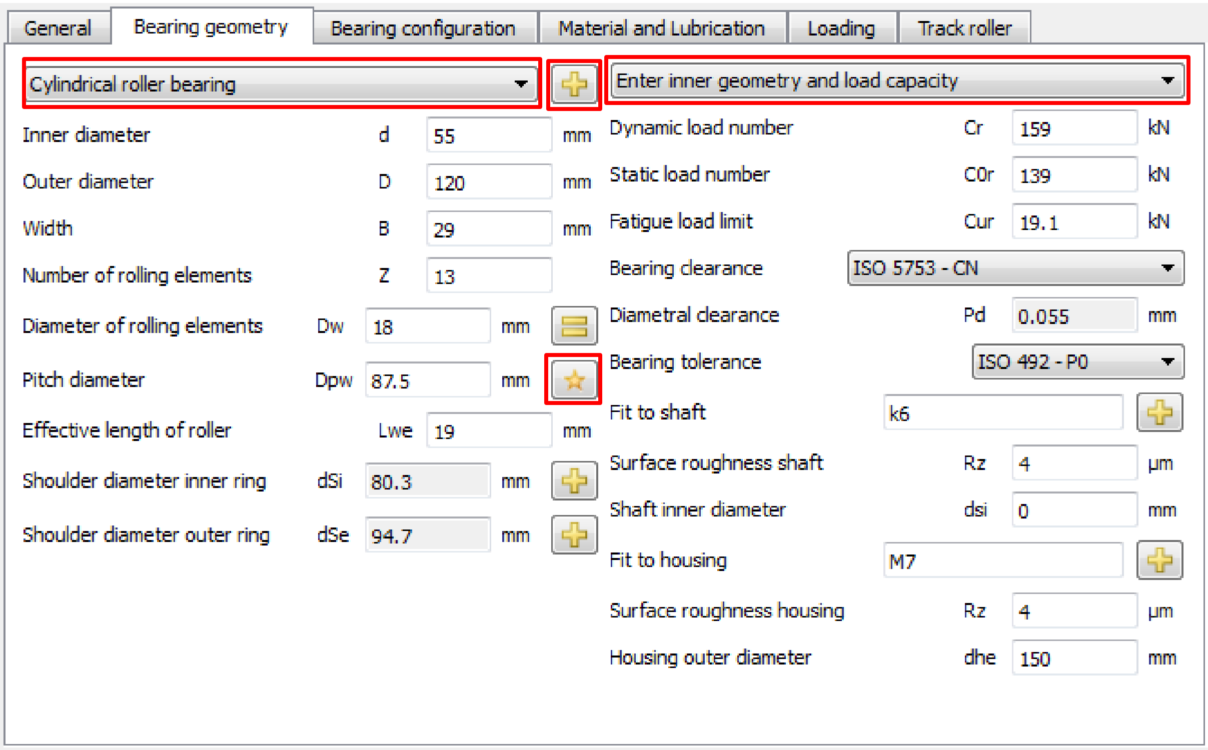
Bearing geometry

The bearing geometry for a cylindrical roller bearing N311 is provided in the following table:

Item	Formula	Value	Unit
Inner diameter	d	55	mm
Outer diameter	D	120	mm
Width	B	29	mm
Number of rollers	Z	13	
Roller diameter	Dw	18	mm
Length of roller	Lwe	19	mm
Pitch diameter	Dpw	87.5	mm
Dynamic load capacity	C	159	kN
Static load capacity	C0	139	kN
Fatigue limit	Cu	19.1	kN
Bearing clearance		CN	
Bearing tolerance		P0	
Shaft tolerance		k6	
Housing tolerance		M7	
Pitch diameter gear	dhe	150	mm

By selecting the tab corresponding to the page "Bearing geometry", the geometrical input will be entered. Now click on the drop-down list on the left in order to choose the desired type of bearing, for this case "Cylindrical roller bearing". Using the -button behind the bearing selection, we can choose the type of "Configuration" from the drop-down list. Click on "N" and press OK. To proceed with the required input data, "Enter inner geometry and load capacity" must be selected from the drop-down list on the upper right side of the page.



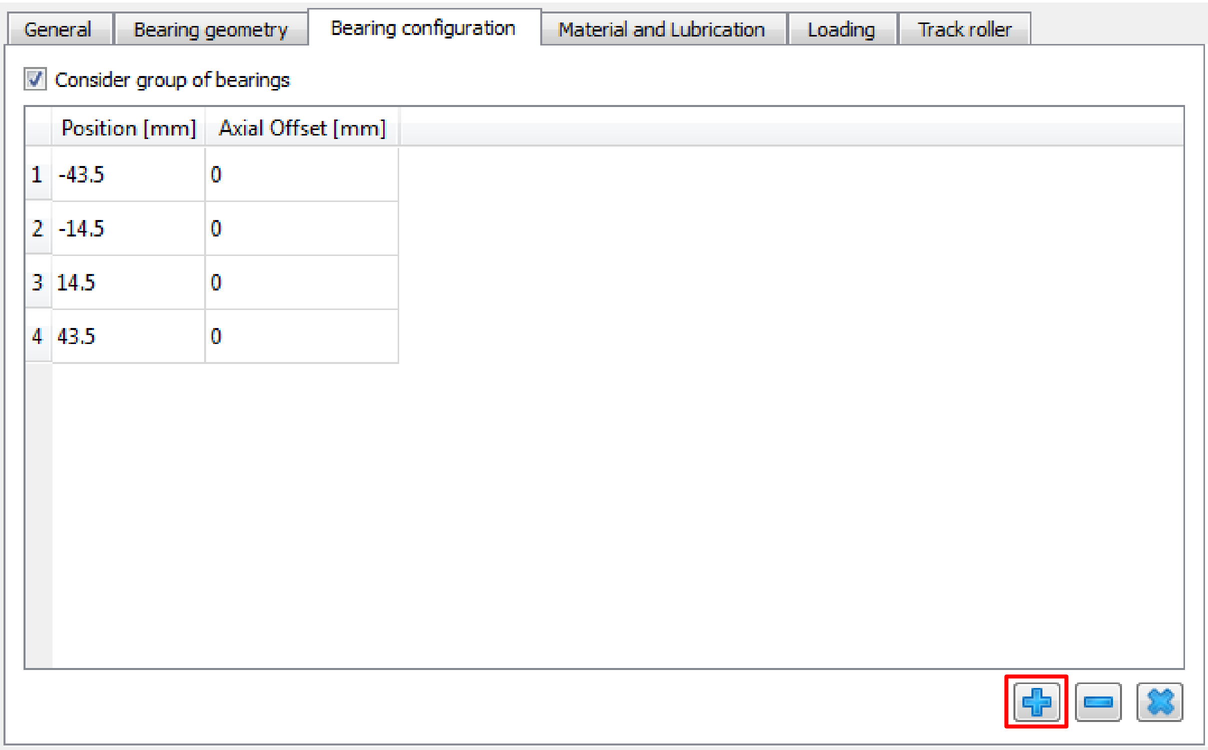


The user can either automatically obtain the Pitch diameter, Dpw (Dpw = (50+80)/2 = 65mm), when clicking the button , or enter it manually.

The pitch diameter of the gear is used for the outer diameter of the housing. Now all the geometry of the bearing is given and both the "Shoulder diameter inner ring dSi" and "Shoulder diameter inner ring dSe", as well as the "Diametral clearance Pd" will be shown after running the software.

Bearing Configuration

As we have four bearings, we enter their positions on the tab page "Bearing configuration". The amount of bearings can be added using the -button on the bottom right corner. We want to set the configuration's origin in the middle of the four bearings, so the distance of the two first bearings from the origin is half of the bearing width, i.e. B/2=±14.5mm, and the one of the outer bearings, B+B/2=±43.5mm.



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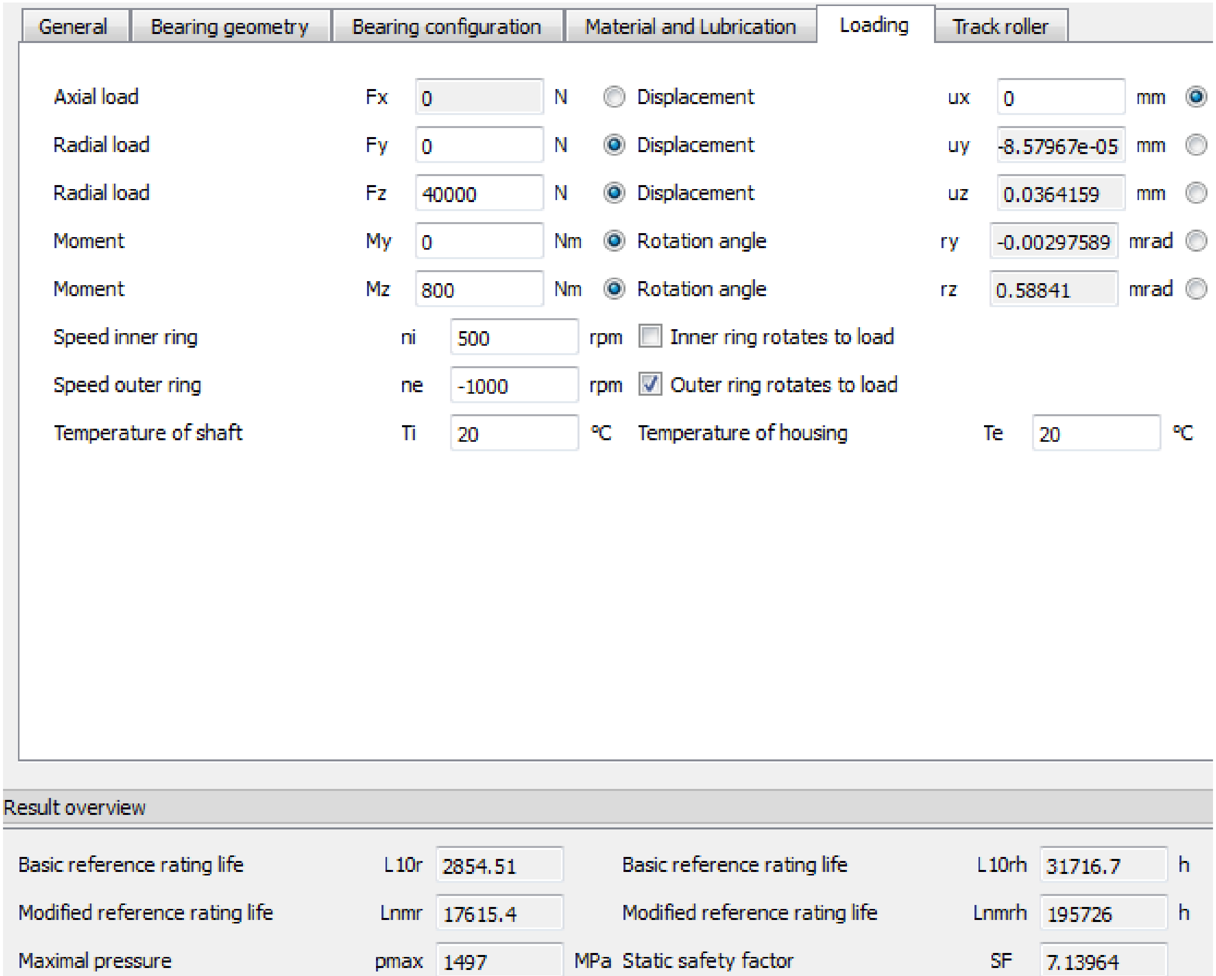
Loading

The loading is imposed by the gear. We have a radial force of Fz= 40kN and a bending moment of Mz =800 Nm. Note that a pair of forces in axial direction are responsible for the moment, not the given radial force. The speed of the inner race is the speed of the planet carrier. This speed should be ni = 500rpm. The outer race rotates with the planet. So ne =-1000rpm which results in a relative speed of 1500rpm. So press now on the tab "Loading" and enter the data as shown:



Entering these values and running the calculation we will get a resulting life L10rh = 31716h.

After running the software (press on the -button), we will realize that the bearings on the left and the right will take a larger load than the center bearings, as can be seen either in the chart at "Graphics"->"Contact stress on roller" or in the report, by pressing on the -button.

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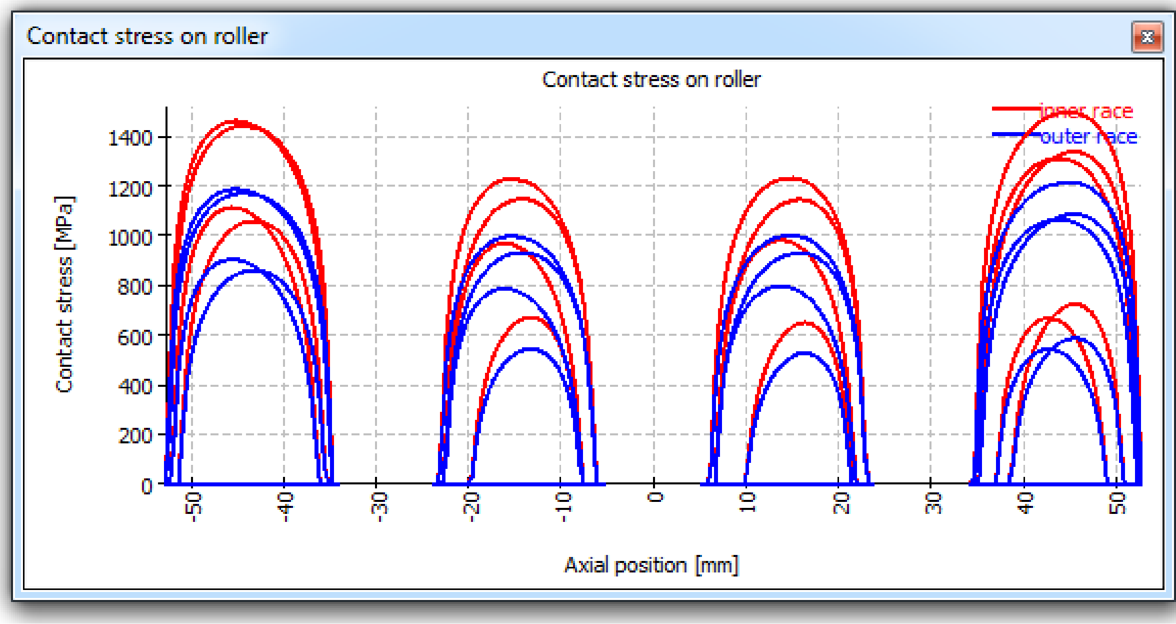

Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	0	0.0000	-8.37163	-0.0257	11.8121	0.0363	4.13	-0.00	6.07	0.59	1459.64	7.51
2	0	0.0000	-1.92951	-0.0086	8.18601	0.0364	1.47	-0.00	2.22	0.59	1228.60	10.60
3	0	0.0000	1.96474	0.0084	8.19436	0.0365	-1.59	-0.00	2.22	0.59	1231.08	10.56
4	0	0.0000	8.33641	0.0255	11.8076	0.0365	-4.08	-0.00	6.23	0.59	1497.00	7.14

Note that this calculation assumes a rigid shaft and housing, so the real loading on the outside bearings should be a little different.

In the report we also find the pressure between shaft, bearing and housing:

Pressure between inner ring and shaft	pFitShaft	11.114 MPa
Pressure between outer ring and housing	pFitHousing	0.9324 MPa

Since the outer ring is rotating to the load it should have a stronger fit than the inner ring. The interference of the outer ring should be increased; the interference of the inner ring should be decreased.

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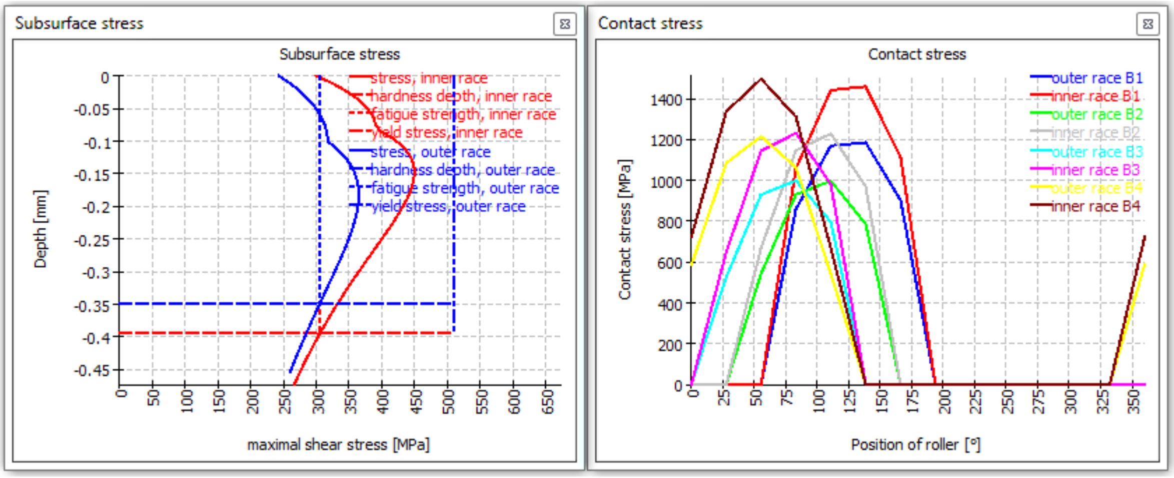
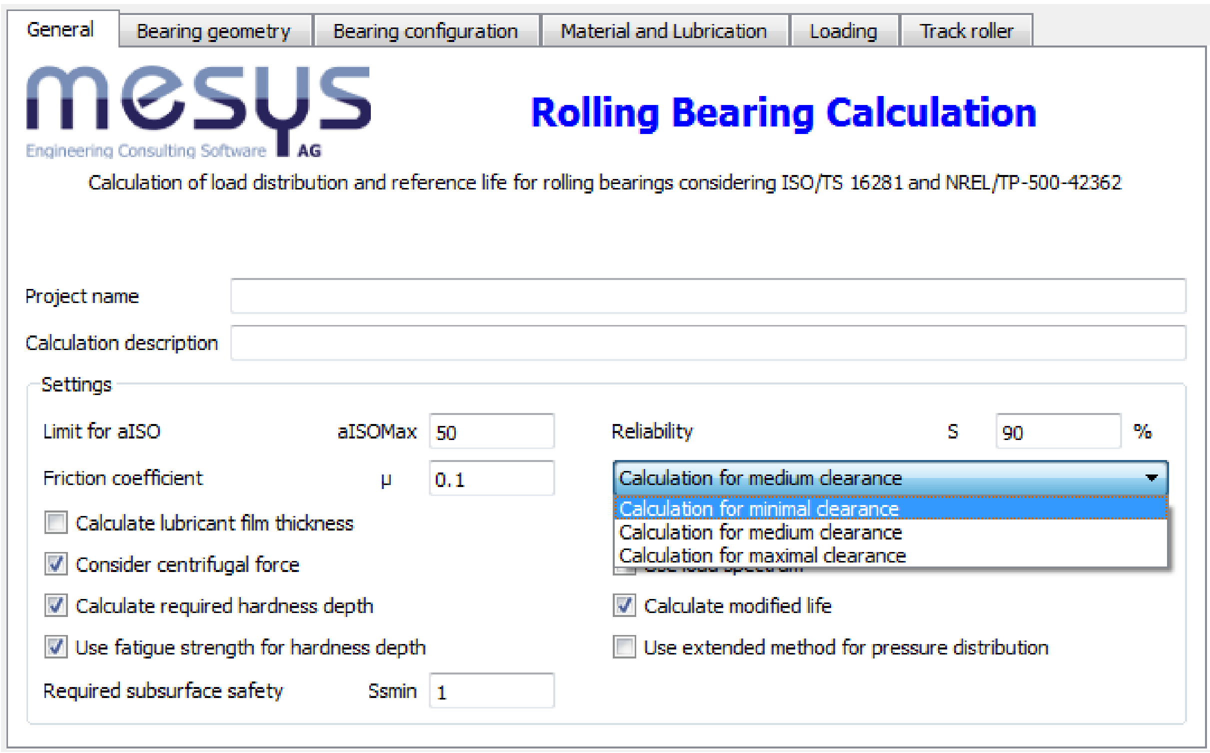
Since the loading is quite small, the subsurface stresses should be no problem. We can see in the graphics that a hardness depth of 0.4mm would be enough for the highest loaded contact.



The load zone for the bearings is relatively small. It is only about 140°.

Selecting "minimal clearance" on the tab page "General" and running the software, the load zone increases to 200° and the life L10rh to 64000h.



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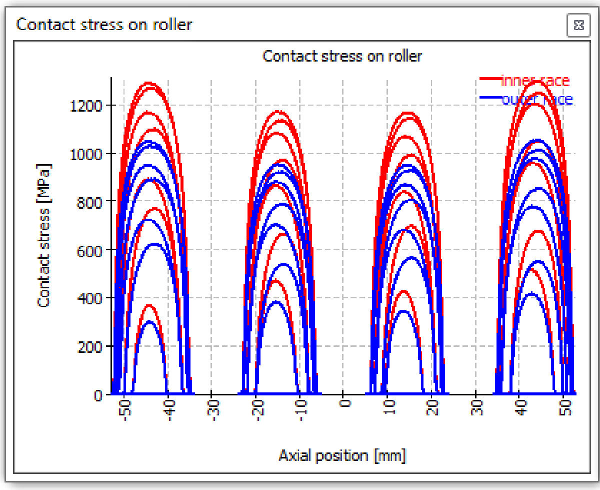

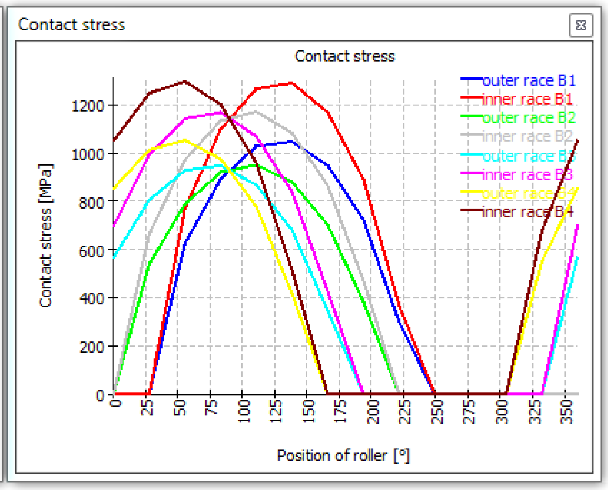

Therefore further reducing the clearance could improve the life, but this has to be done under consideration of temperatures which also influence the clearance.

The change from medium clearance to minimum clearance reduces the angle rz fom 0.59mrad to 0.24mrad. This can affect the contact pattern between the gears and therefore is important for the lead modifications of the gear.

For maximal clearance life reduces to 21901h and the angle increases to rz = 0.8mrad. So just the position in the tolerance field influences both the life and the tilting angle by a factor of three or more.

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Comparison with MESYS Shaft Calculation

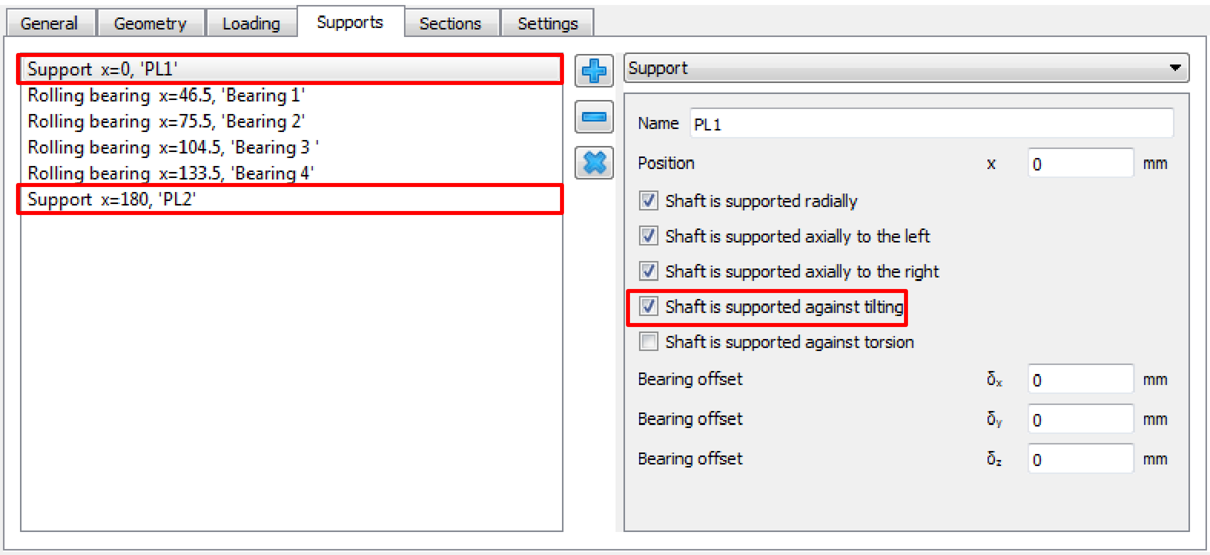
It is noteworthy to compare this example with the output from the *MESYS Shaft calculation* in order to take into account non-rigid conditions for both the pin and the bearing's inner ring.

Here is the output for the bearing calculation:

Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	0	0.0000	-8.37163	-0.0257	11.8121	0.0363	4.13	-0.00	6.07	0.59	1459.64	7.51
2	0	0.0000	-1.92951	-0.0086	8.18601	0.0364	1.47	-0.00	2.22	0.59	1228.60	10.60
3	0	0.0000	1.96474	0.0084	8.19436	0.0365	-1.59	-0.00	2.22	0.59	1231.08	10.56
4	0	0.0000	8.33641	0.0255	11.8076	0.0365	-4.08	-0.00	6.23	0.59	1497.00	7.14

Number	χ	eC	aISO	Pref [kN]	L10r	Lnmr	L10rh [h]	Lnmrh [h]
1	4.17	0.55	5.74	11.66	6061.62	34821.7	67351.3	386908
2	4.17	0.55	14.16	7.05	32386.2	458693	359846	5.09659e+006
3	4.17	0.55	14.05	7.08	31978.7	449386	355318	4.99318e+006
4	4.17	0.55	5.68	11.74	5917.88	33592.4	65754.3	373248

We will compare it in turn with two posible conditions in the *MESYS Shaft Calculation*, on one hand we suppose that the shaft is supported against tilting:



Name	L10rh [h]	pmax [MPa]	SF	Fx [kN]	Fy [kN]	Fz [kN]	Mx [Nm]	My [Nm]	Mz [Nm]
Pin									
PL1				0.000	5.806	19.999	0.00	-744.40	125.56
Bearing 1	37114	1581.62	6.40	0.000	-8.397	-13.695	0.00	-8.35	8.85
Bearing 2	571426	1178.20	11.53	0.000	-1.463	-6.234	0.00	-2.57	1.90
Bearing 3	547807	1192.66	11.25	0.000	1.332	-6.443	0.00	2.27	1.76
Bearing 4	34766	1634.91	5.99	0.000	8.585	-13.627	0.00	8.56	8.27
PL2				0.000	-5.896	20.001	0.00	744.61	127.59
Planet Shaft (Planet Gear)									

Shafts | Bearings | Frequencies

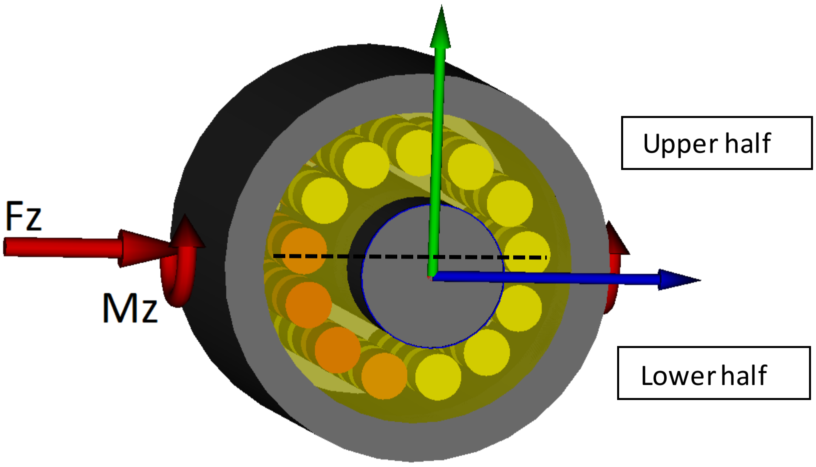
And on the other hand, we suppose that it is not:

Name	L10rh [h]	pmax [MPa]	SF	Fx [kN]	Fy [kN]	Fz [kN]	Mx [Nm]	My [Nm]	Mz [Nm]
Pin									
PL1				0.000	4.400	20.000	0.00	0.00	0.00
Bearing 1	26445	1667.63	5.75	0.000	-8.540	-15.435	0.00	-14.14	10.70
Bearing 2	1435689	1067.88	14.03	0.000	-1.033	-4.527	0.00	-2.91	1.46
Bearing 3	1405976	1077.68	13.78	0.000	1.014	-4.638	0.00	2.85	1.49
Bearing 4	25761	1691.76	5.59	0.000	8.616	-15.400	0.00	14.11	10.39
PL2				0.000	-4.489	20.000	0.00	0.00	0.00
Planet Shaft (Planet Gear)									

Having a glance at these highlighted results, the user quickly realizes how important this fact is for the bearing's dimensioning.

It is also worth mentioning that the asymmetric "pmax [MPa]" distribution between the four bearings has to do with the roller's position in the different bearings. Since we have bearings with an odd number of rollers, i.e. z=13, suject to a Mz loading, the resultant force distribution on the rollers at the first bearing will be a bit smaller than at the fourth bearing. As we can see the at the figures, the rollers with more pressure of the fourth bearing are located at the upper half, which is coincident with the part with less number of rollers, so this way, the maximum pressure reached in the roller is a little bit higher. At the first bearing, the situation is just the opposite.

View from the first bearing location:



View from the fourth bearing location: