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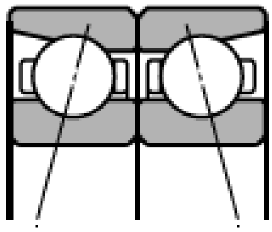
Tutorial: Calculation of paired angular contact bearings

A pair of angular contact ball bearings mounted back-to-back should be calculated for a load case radial load only, and a second load case tilting moment only. The bearings have a build in pretension which is further increased by mounting and temperature.



Bearing geometry

The bearing geometry for an angular contact bearing 7010C is provided as given in following table:

	Parameter	Value	Unit
Inner diameter	d	50	mm
Outer diameter	D	80	mm
Width	B	16	mm
Nominal contact angle	α	15	°
Dynamic load capacity	Cr	28.2	kN
Static load capacity	C0r	20.2	kN
Fatigue limit	Cu	1.1	kN
Pretension	Fpre	4.2	kN
Tolerance		P4	
Tolerance shaft		k5	
Tolerance housing		H6	
Cage frequency at 60rpm	fc	0.435	Hz
Damage frequency inner ring at 60rpm	fip	10.733	Hz
Damage frequency outer ring at 60 rpm	fep	8.267	Hz
Damage frequency rolling element at 60 rpm	frp	7.319	Hz

This data is usually available for bearings and can be easily extracted from some manufacturers. To calculate the life of the bearing you should ask the manufacturer for additional data of inner geometry.

By selecting the tab corresponding to the page "Bearing geometry", a first geometrical input will be set. Now click on the drop-down list on the left in order to choose the desired type of bearing, for this case "Axial angular contact ball bearing". To proceed with the required input data, "Enter inner geometry" must be selected from the drop-down list on the upper right side of the page.

After introducing d, D und B, the user can automatically obtain the Pitch diameter, Dpw (Dpw = (50+80)/2 = 65mm), when clicking the button .

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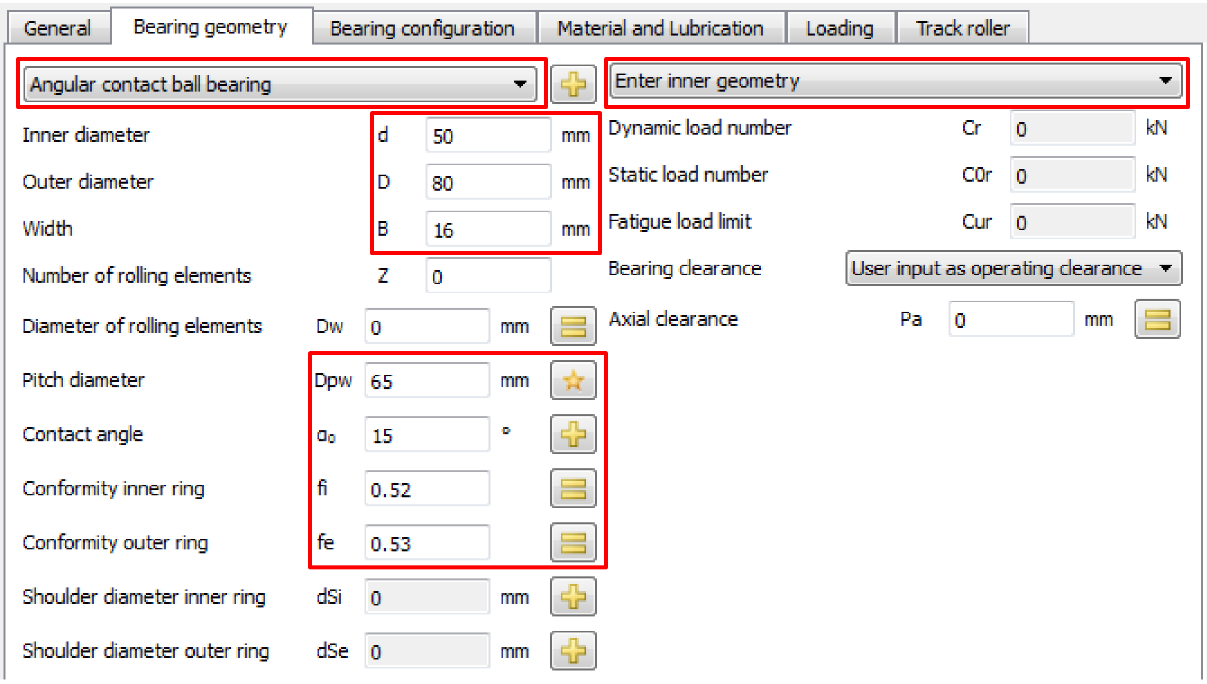
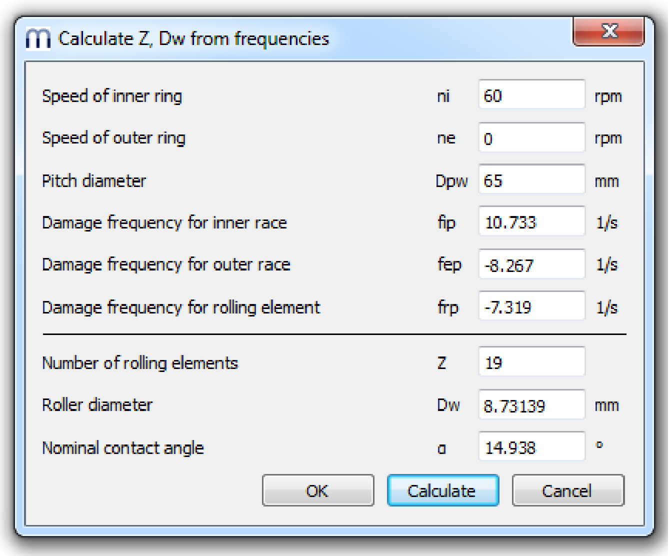


Since the conformity is not provided we use the values according to ISO/TS 16281 with fi = 0.52 and fe = 0.53

Now, the number of rolling elements Z = 19 and the ball diameter Dw = 8.731 will be figured out as the result of a backwards calculation by using the damage frequencies, which must be given to the software. To do so, a pop-up window is opened when pressing the button located next to the "Dw" input, and then "Calculate" once the input data is filled out, and also OK to close the window.



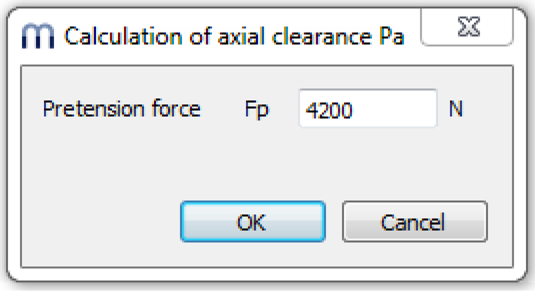
Note that Dw and α must be manually rounded off on the page "Bearing geometry" so that they match standard values (The calculated Dw is practically equal to an usual one with 11/32 inch = 8.731mm, and the contact angle to 15°).

After finishing the tutorial such a data can be checked at the report:

Damage Frequencies

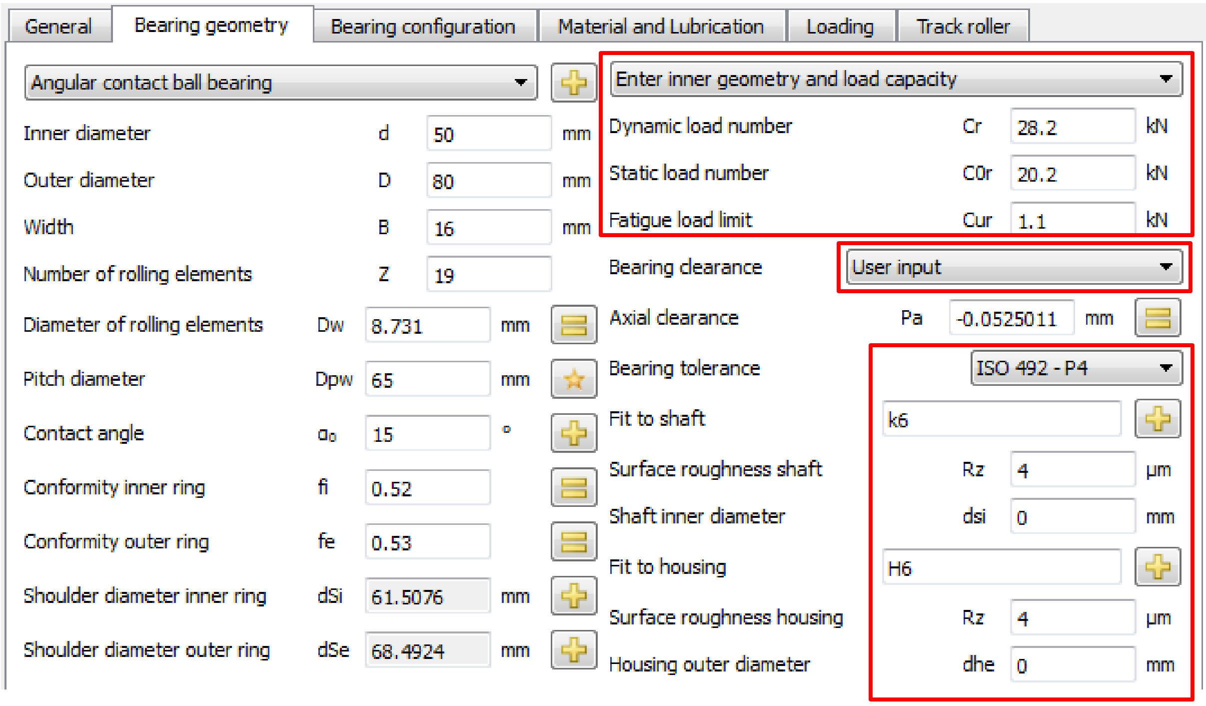
Speed of inner ring	ni	1.000 1/s
Speed of outer ring	ne	0.0000 1/s
Rotation speed of cage	fc	0.4351 1/s
Damage frequency for inner race	fip	10.73 1/s
Damage frequency for outer race	fep	-8.2674 1/s
Damage frequency for rolling element	frp	-7.3194 1/s

A further unknown is the axial clearance of the bearing, since a pretension is given as a force. To calculate the axial clearance click on the conversion button located by its side and calculate the axial clearance:



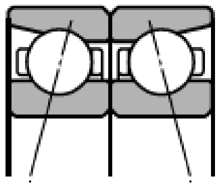
To get a pretension of 4.2kN we need an axial clearance Pa = -0.0525mm.

Now all the geometry of the bearing is given and both the tolerances and load capacities can be entered, so “Enter inner geometry and load capacity” and “User input” must be selected from the drop-down lists, as well as the desired Bearing tolerance. Both “Shoulder diameter inner ring” and “Shoulder diameter inner ring” will be shown after running the software.

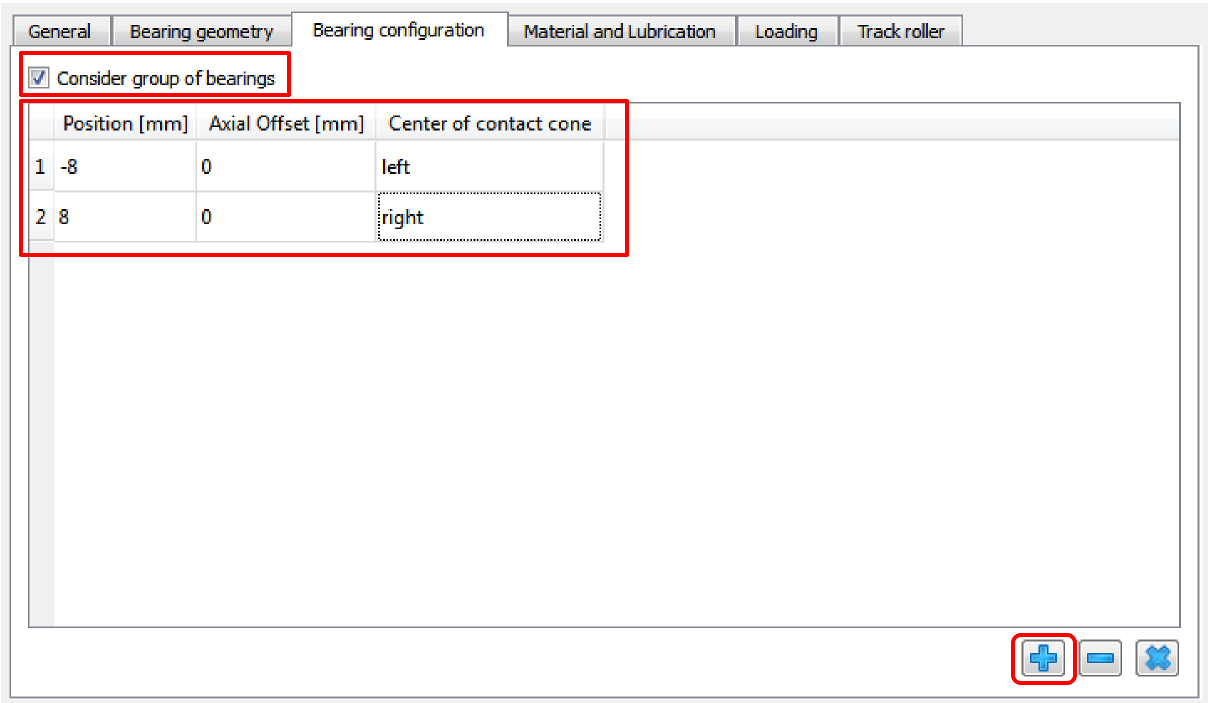


The dynamic load capacity of the bearing given by the manufacturer is slightly larger than according ISO 281. Often manufacturers provide higher values than the standard to consider better material and quality. Therefore it is also possible to enter the values manually in addition to the calculation according to ISO 281.

Bearing configuration



We have two bearings in back-to-back configuration. This can be defined on the page "Bearing configuration". Additional bearings can be added using the + -button on the bottom right corner. The distance of the bearings from the origin is half of the bearing width, i.e. B/2=8mm. For a double row angular contact bearings also the bearing type "Angular contact bearing (double row)" could be used, but the bearing configuration also works for other configurations.



An axial offset between the outer races can be defined additionally, if some additional pretension is introduced in the assembly. In this case we have no modification.

Running a calculation with zero load and opening the report, by pressing on the and buttons, we will see the pressure between shaft an inner ring because of the interference fit and an increased pretension of the bearing of 5.79kN (also because of the interference fit. We already get a pressure of 2181MPa in the contact between balls and races:

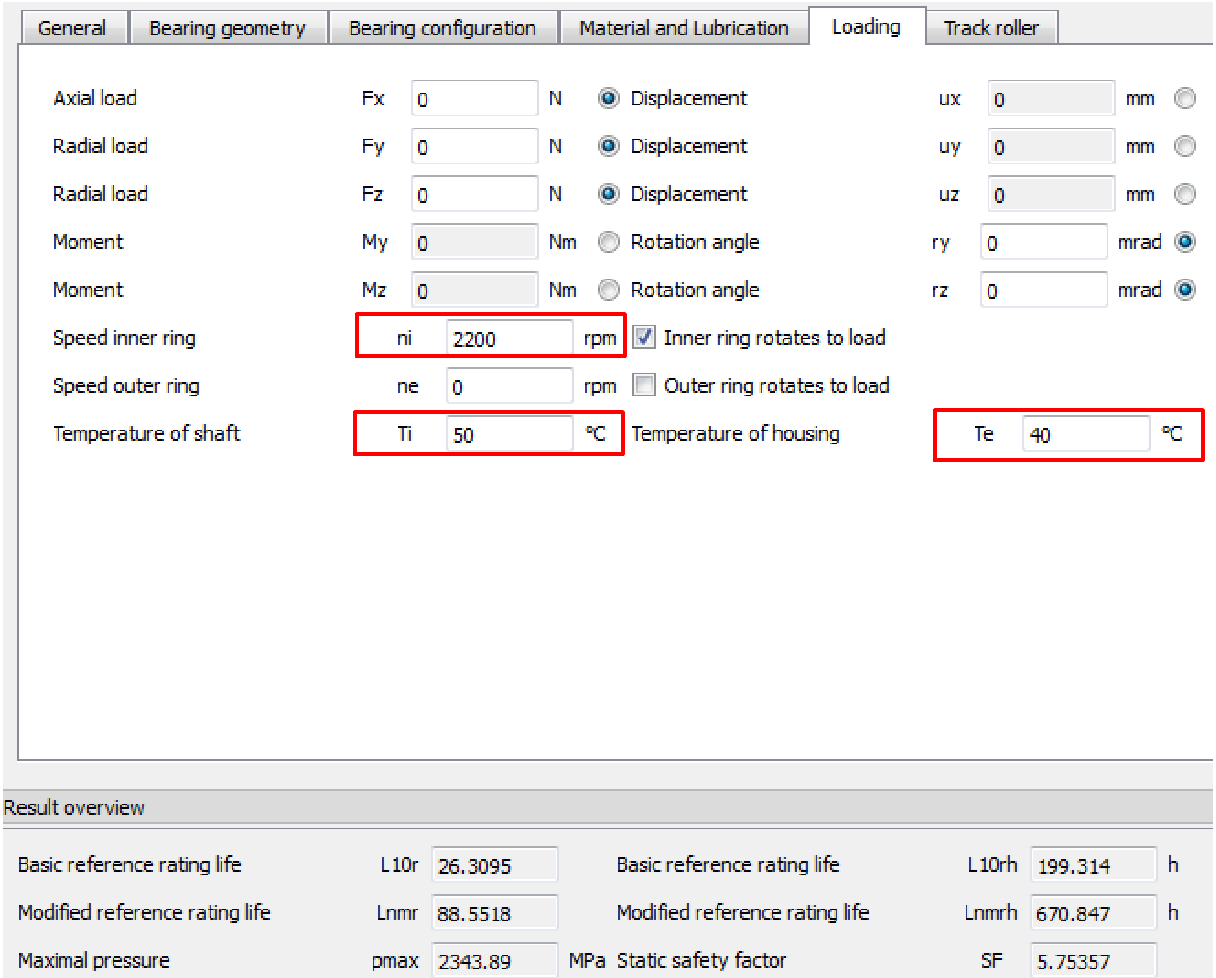
Number	Fx [kN]	ux [mm]	Fy [kN]	uy [mm]	Fz [kN]	uz [mm]	My [Nm]	ry [mrad]	Mz [Nm]	rz [mrad]	pmax [MPa]	SF
1	5.79494	0.0000	0	0.0000	0	0.0000	0.00	0.00	0.00	0.00	2181.52	7.14
2	-5.79494	0.0000	0	0.0000	0	0.0000	0.00	0.00	0.00	0.00	2181.52	7.14

Loading

We want to consider two load cases. The first one is a radial load of Fy = 15kN, the second a moment load of My = 300Nm. The speed of the inner ring should be ni = 2200rpm. The temperature of the shaft should be 50°C, the temperature of the housing 40°C.

Results for no loading

First we have a look at the results for zero loading. So press now on the tab "Loading" and enter just the aforementioned temperatures and inner ring speed.



We already have a pressure of 2343MPa and a life of L10rh = 199h only because of pretension.

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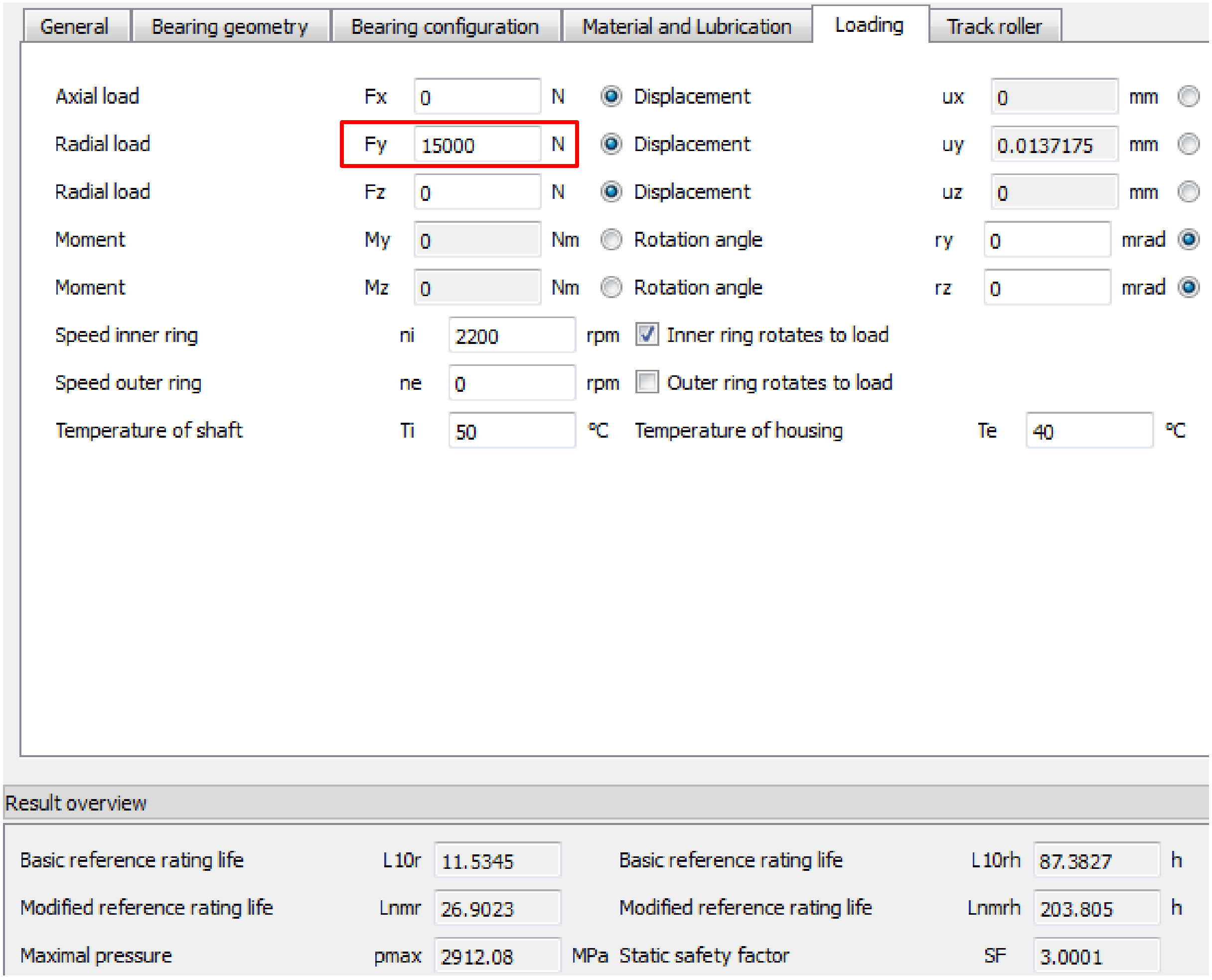
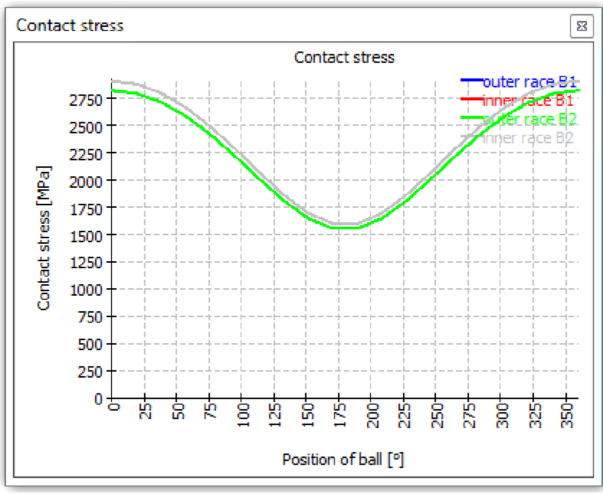
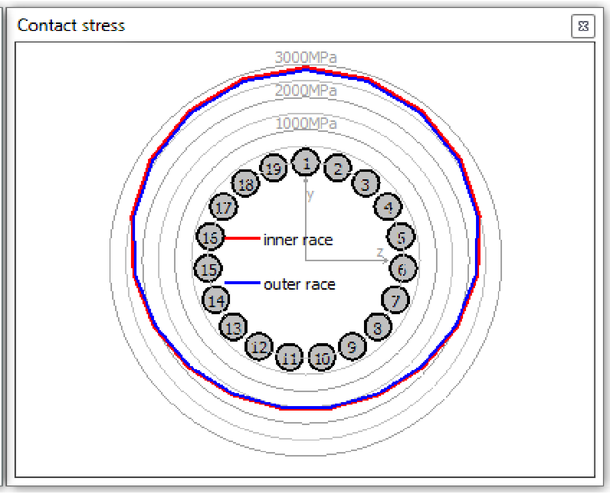
Radial loading

Entering the radial load of Fy = 15kN we get the following results:



The graphic contact stress shows that all balls are still loaded. To plot these charts, click on "Graphics" at the menu bar and select "Contact stress" and "Load distribution".





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When performing the calculation according ISO 281 without pretension, we get a result of L10h = 16666/2200 * (28.2*2^0.7/15)^3 = 215h instead of the L10rh = 87h with pretension by the software.

For the single bearings, we can see in the report that we have an axial (Fx), a radial (Fy) and a moment (Mz) load:

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	7.42436	-0.0009	7.5	0.0137	0	0.0000	0.00	0.00	-89.25	0.00	2912.08	3.00
2	-7.42436	0.0009	7.5	0.0137	0	0.0000	0.00	0.00	89.25	0.00	2912.08	3.00

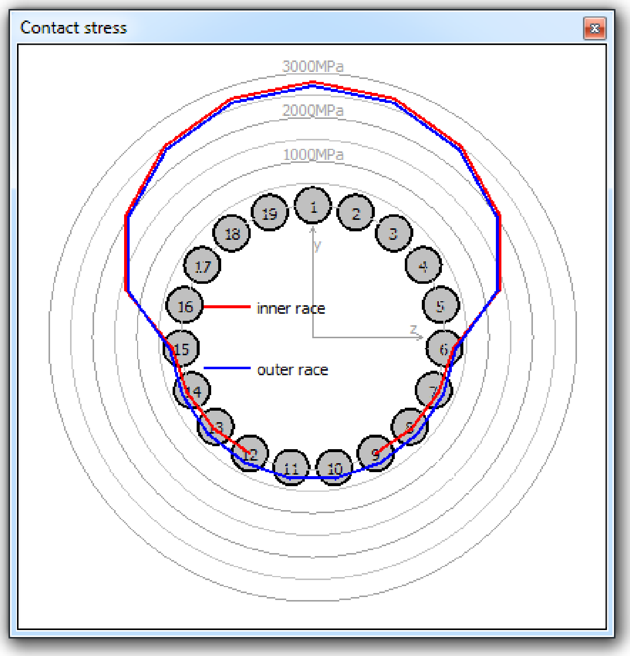
Note that at "Bearing configuration" page, these kind of results can be also shown in additional cells by clicking the right mouse button and selecting them from the context menu:

General | Bearing geometry | Bearing configuration | Material and Lubrication | Loading | Track roller

☑ Consider group of bearings

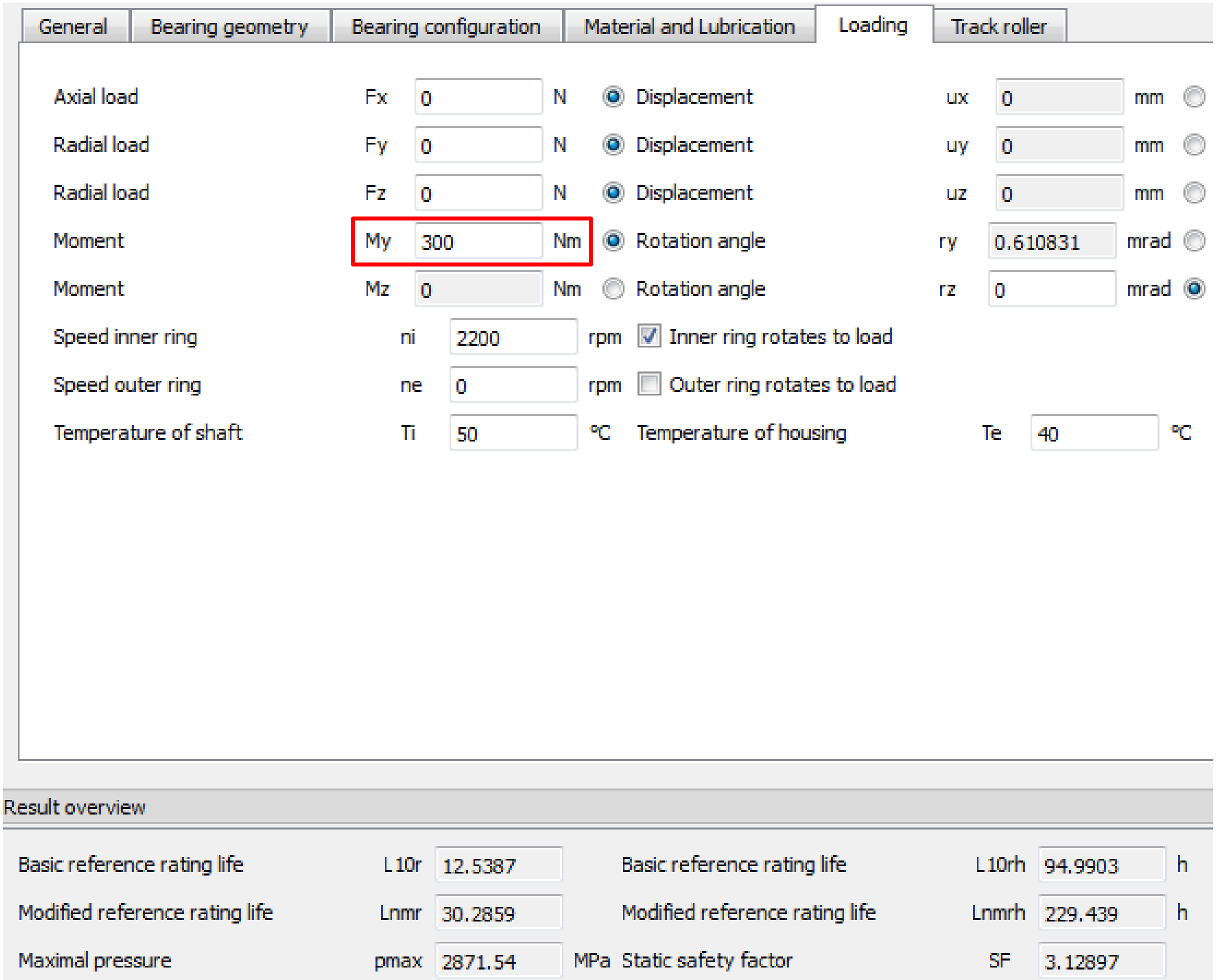
	Position [mm]	Axial Offset [mm]	Center of contact cone	Fx [N]	pmax [MPa]
1	-8	0	left	7424.36	2912.08
2	8	0	right	-7424.36	2912.08

If we do a calculation with operating clearance of zero for comparison (go to the "Bearing geometry" page and proceed as explained before, but now enter Pa =0 mm; Fp =0 N), we get a life of L10rh = 218h, which is close to the ISO 281 result. Now, as we can check in the graph of load distribution, the pretension is missing.

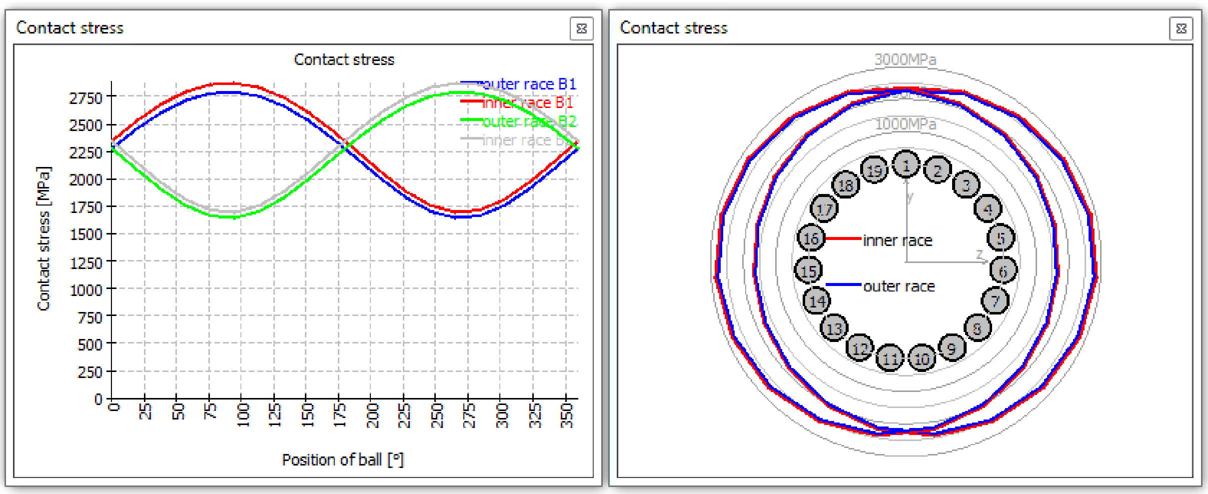


Moment loading

Now we run the same calculation with a moment loading of My = 300Nm.



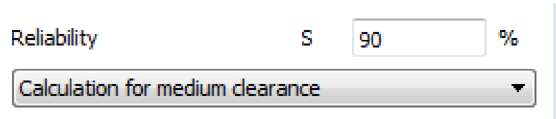
The resulting life and pressure is similar to the calculation before, but now the load distribution is mirrored between the two bearings:



The single bearings have an axial load, a radial load and a moment load:

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	7.72831	-0.0009	0	0.0000	6.68603	0.0049	96.51	0.61	0.00	0.00	2871.54	3.13
2	-7.72831	0.0009	0	0.0000	-6.68603	-0.0049	96.51	0.61	0.00	0.00	2871.54	3.13

All the calculations were done using the medium operating clearance. On the first page “General” this could be changed into minimal or maximal clearance:



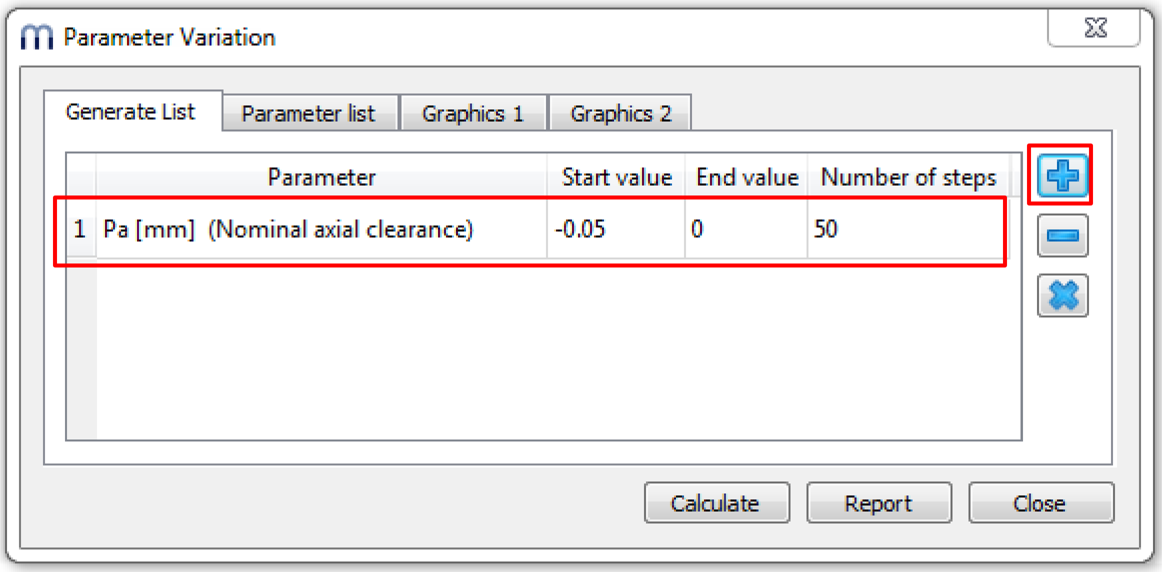
Considering the maximal clearance it could be decided if the pretension could be decreased, to increase the overall life.

Further Analyses

Optimization of life

The maximum bearing life can be found out by identifying and optimizing those parameters with a major influence in it. For this purpose, some features of the software can be easily used, thus enabling the user to reach an optimal configuration of the bearing.

For the case of moment loading (My=300Nm), we will have a look on the nominal axial clearance, since the life has a great dependency on it. This way, we will use the parameter variation, so please select “Calculation”->”Parameter variation”. Now, in the tab page “Generate List“, we add a parameter on the list, so we click on the +-button and a new row is created. Doing a double-click on the first cell, a drop-down list is activated, then select “Pa[mm] (Nominal axial clearance)” from it. Please fill the row as shown:



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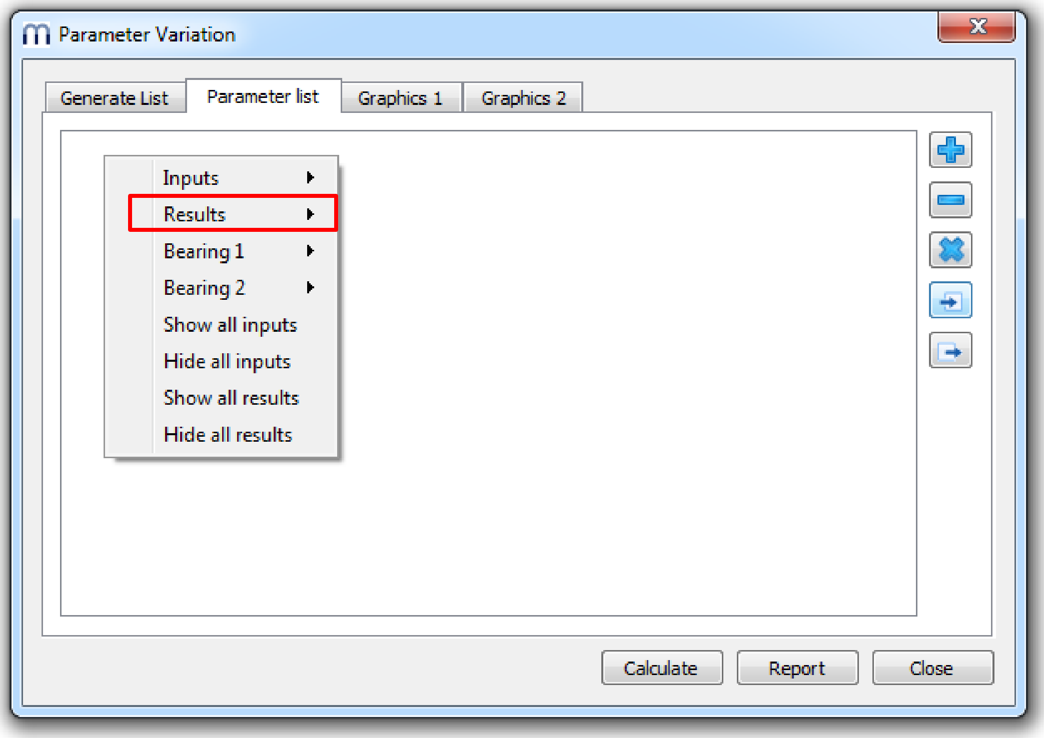
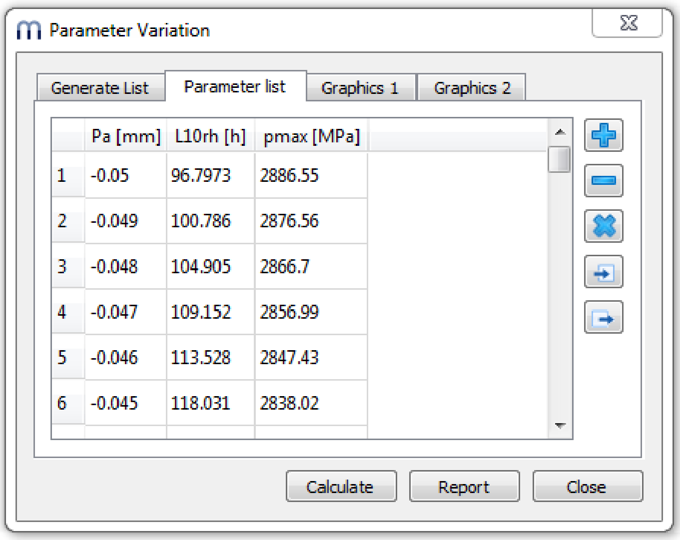
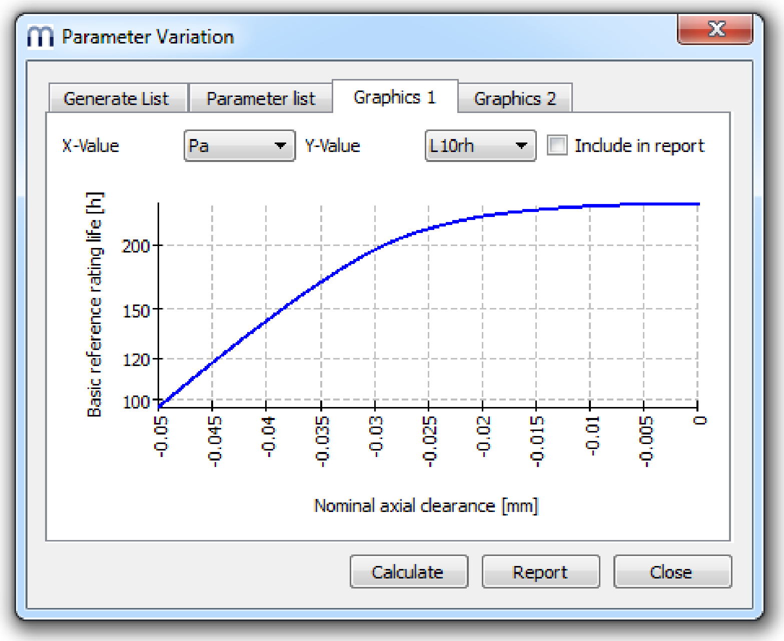
At the tab page "Parameter List", do a right-button click and select "L10rh" and "Pmax" from the context menu "Results".

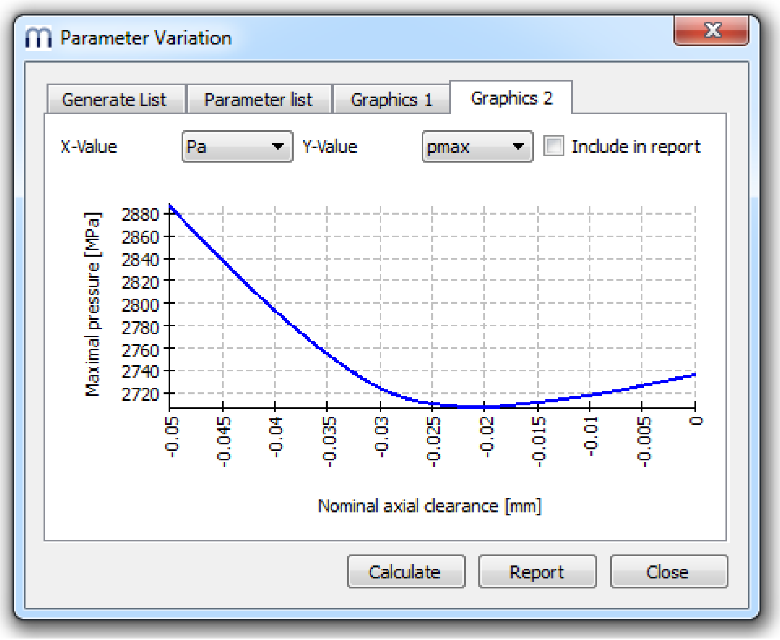


Now, Pressing "Calculate", will generate a list of all parameter combinations and also run the analysis.

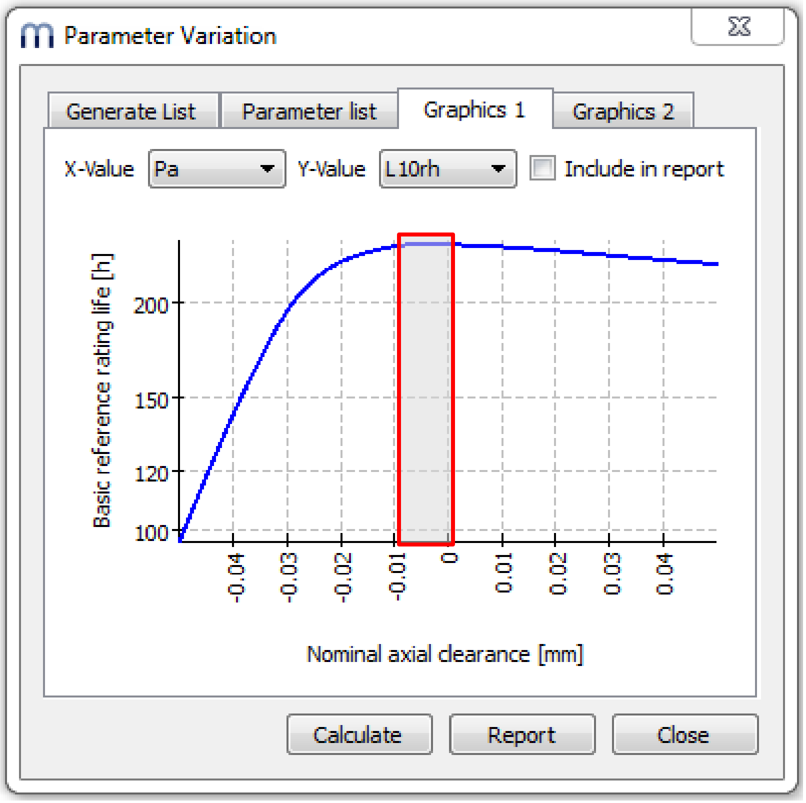


Selecting the tabs "Graphics 1" and "Graphics 2" we can visualize life over clearance or pressure over clearance.



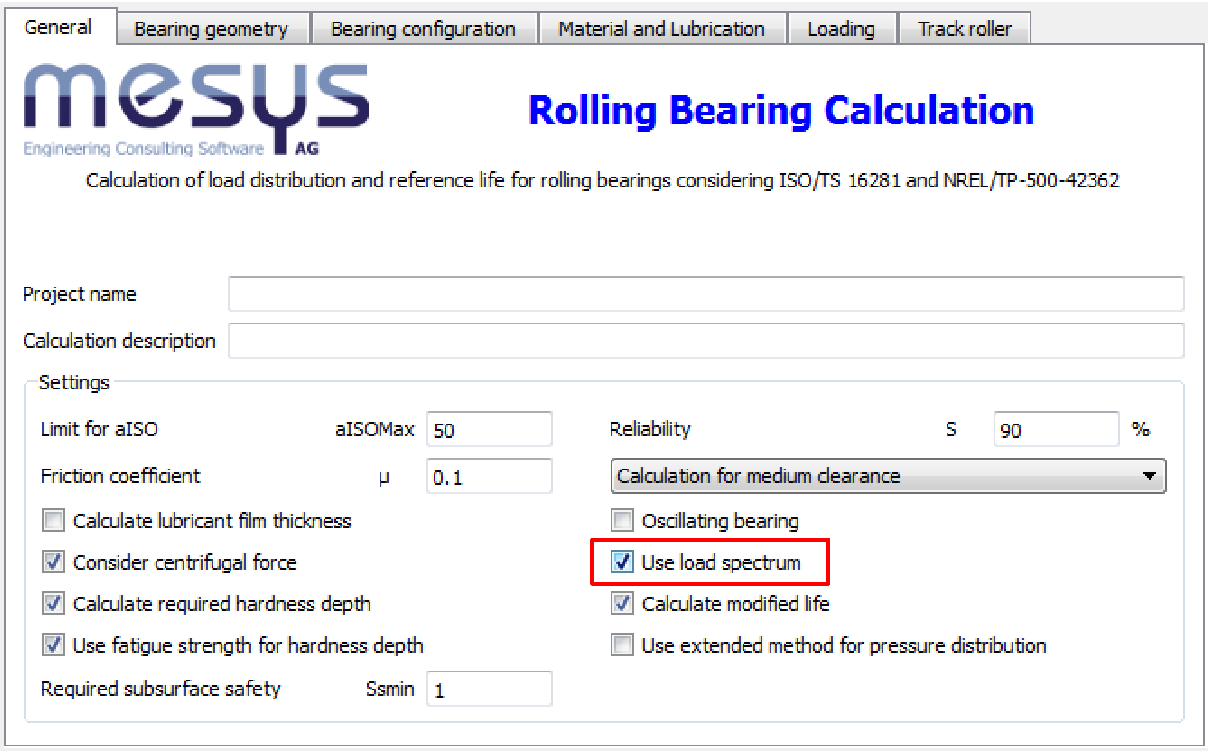


For instance, in case we assume that the bearing must have a certain pretension, the user can deduce from this study, that the higher the pretension is, the shorter life the bearing has. However, if we widen the range of the possible axial clearances to the positive direction of X-Value for the bearing, we can identify a maximum over the range Pa=(-0.01, 0)mm:

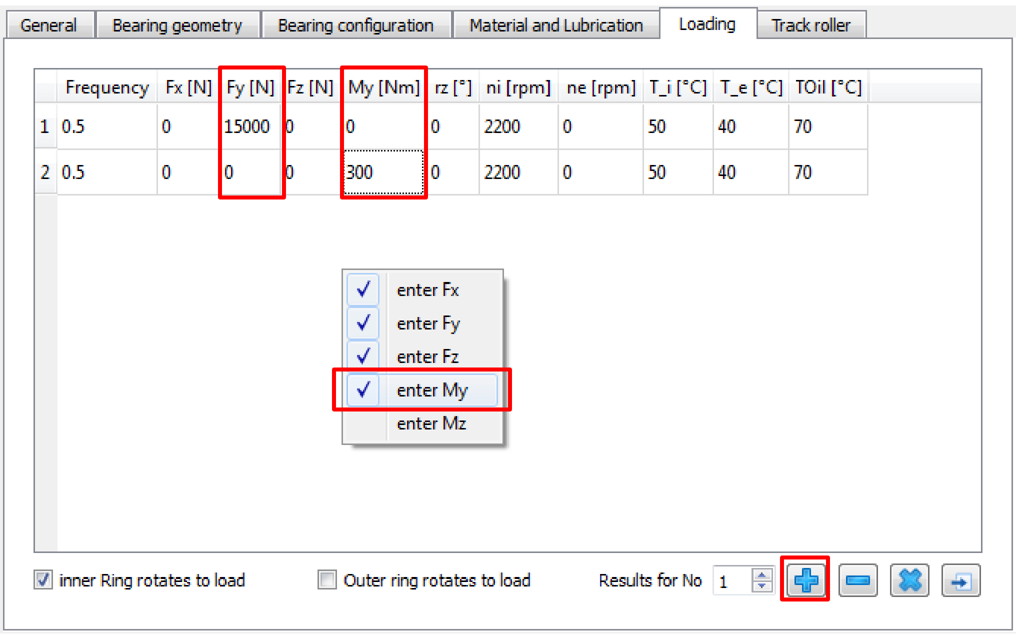

Parameter Variation
Generate List
Parameter list
Graphics 1
Graphics 2
X-Value
Pa
Y-Value
L10rh
Include in report
Basic reference rating life [h]
200
150
120
100
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
Nominal axial clearance [mm]
Calculate
Report
Close

Load spectrum

A load spectrum can be used instead of a single load case. In order to activate this option in the software, go to the tab page “General” and activate the flag for “Use load spectrum”.



Now go to the tab page “Loading”, click twice on the -button in order to add two rows. By default, the column corresponding to “My [Nm]” is not activated, so do a right button click on the window and activate the flag for “enter My”; as a result of it, “ry[°]” will be hidden and “My [Nm]” will be shown in its stead. Now fill out the table as shown:



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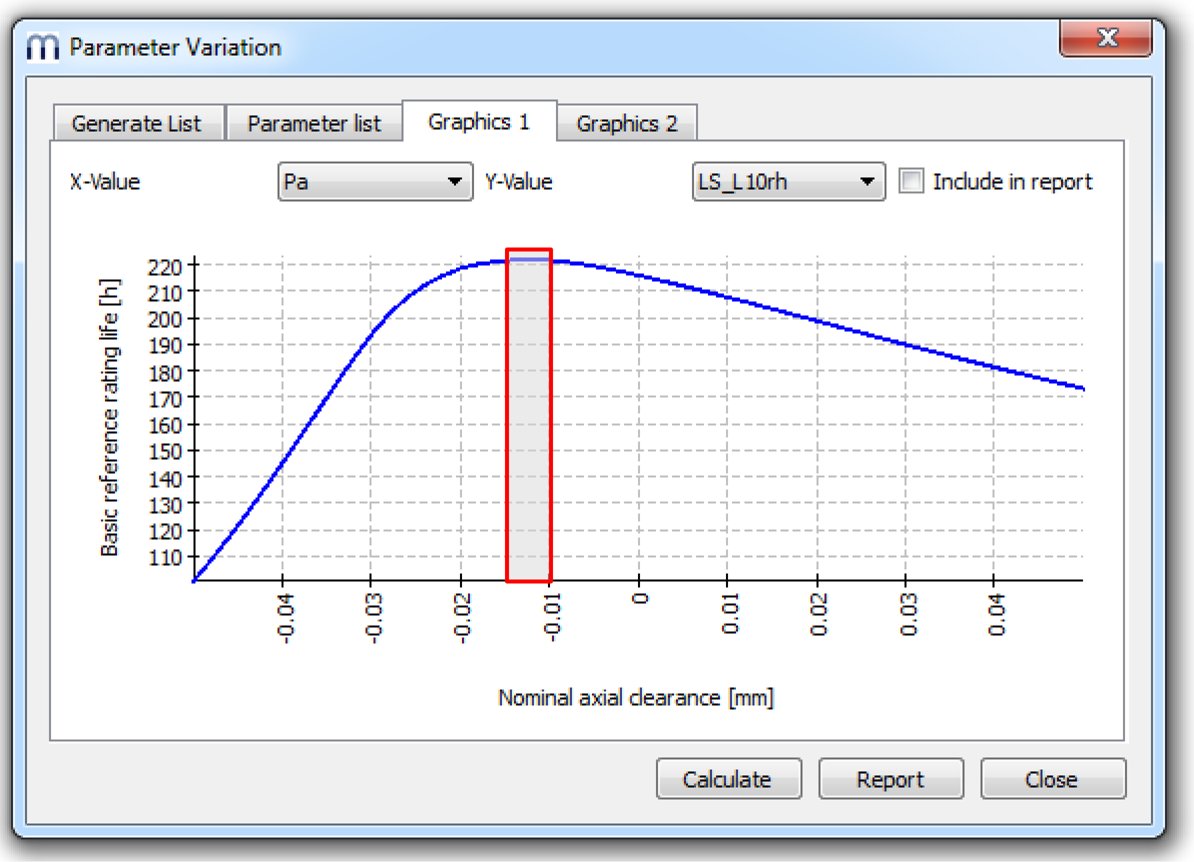
We have set an equal distribution of load frequency for the current example, by entering "0.5" in each of the corresponding case cells.

Running the software calculation and carrying out a parameter variation study as we did before for the moment loading, it can be observed how the optimal axial clearance is now found over the range Pa=(-0.015,-0.01)mm:



Please note that for each load case, a full calculation using all factors is made. The resulting life is calculated using the life of each element.