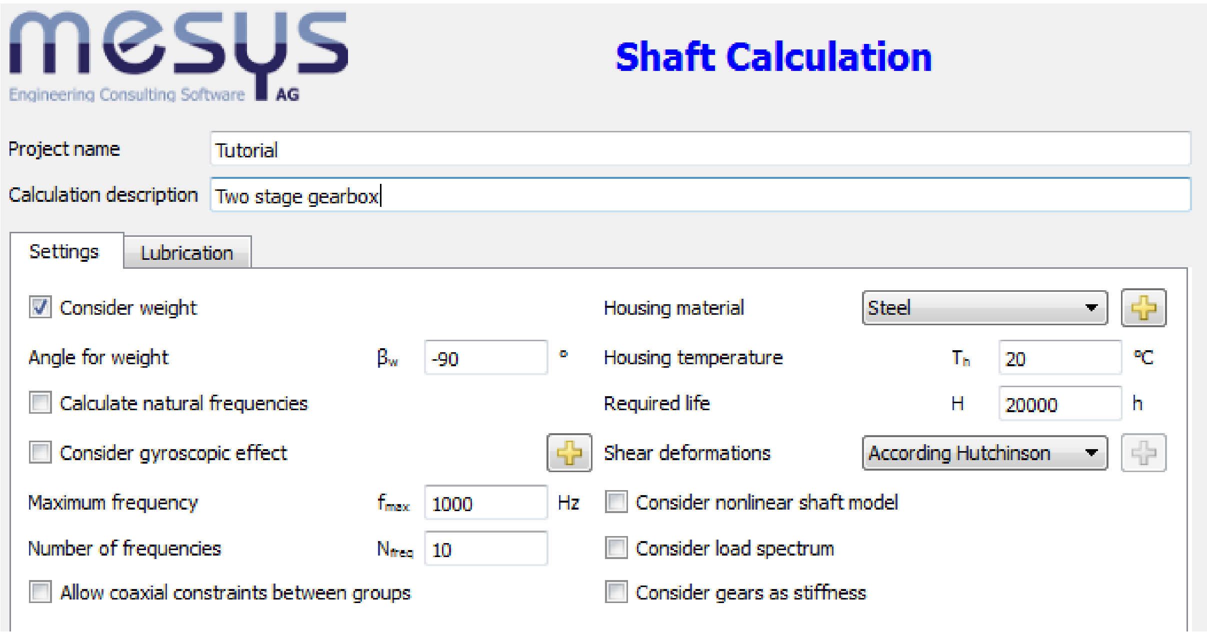
MESYS AG
Technoparkstrasse 1
CH–8005 Zürich
info@mesys.ch
T: +41 44 455 68 00

Tutorial: Calculation of a two stage gearbox

This tutorial shows the usage of MESYS shaft calculation with systems of parallel shafts. A two stage gearbox is defined using the program. Please start with the tutorial for shaft calculation to see how to introduce geometry and supports for single shafts.

System Data



We don't need to change anything on the first page for system data.

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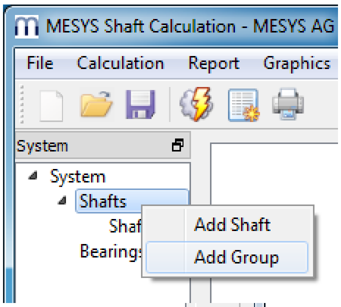
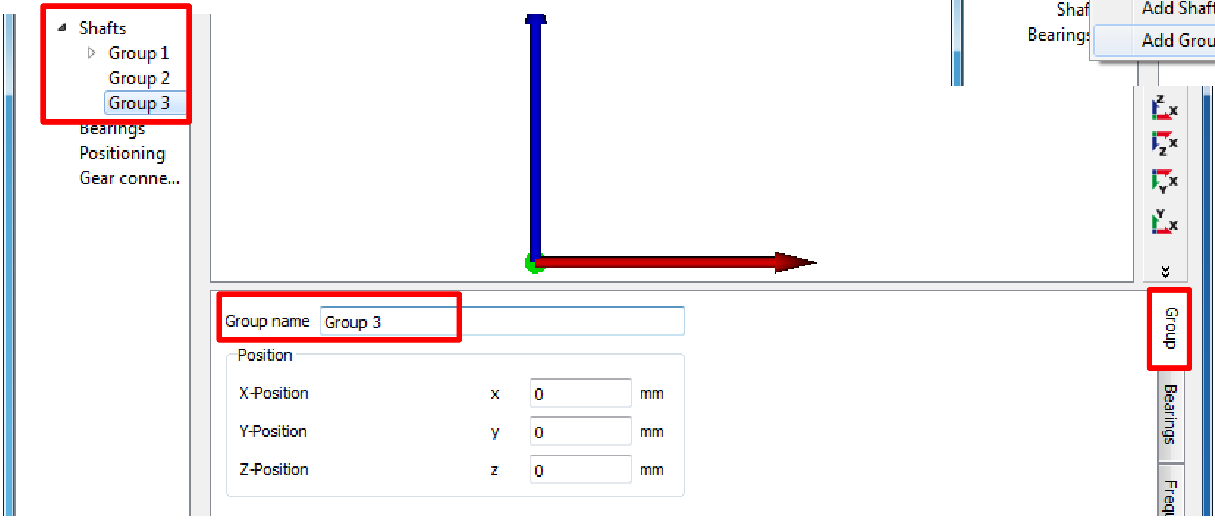
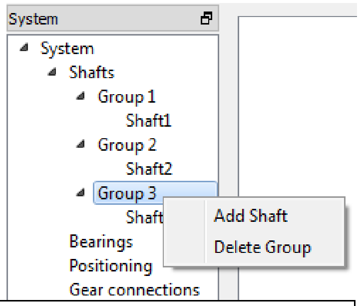
Defining Shafts



For systems of parallel shafts groups have to be used. With a right mouse click on 'Shafts' in the system tree three groups can be added.

The groups can be given a name on the page for the group:





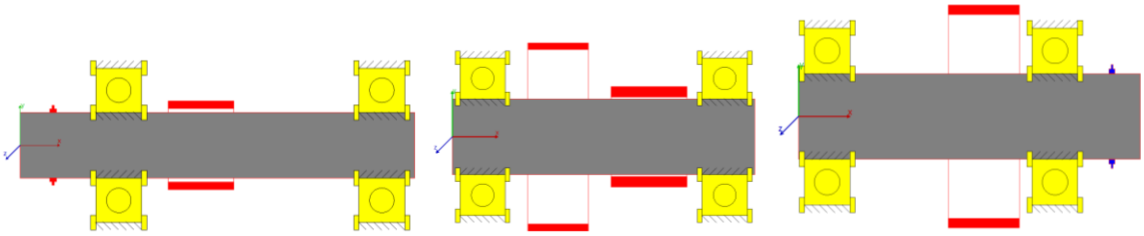
Now for each group we add a shaft and name them 'shaft 1' to 'shaft 3'.

For each shaft we add a geometry as a cylinder with length 120 and diameters 20 for 'Shaft 1', with length 100 and diameter 25 for 'Shaft2' and length 120 and diameter 30 for 'Shaft3'.

For the shafts we add the following elements:

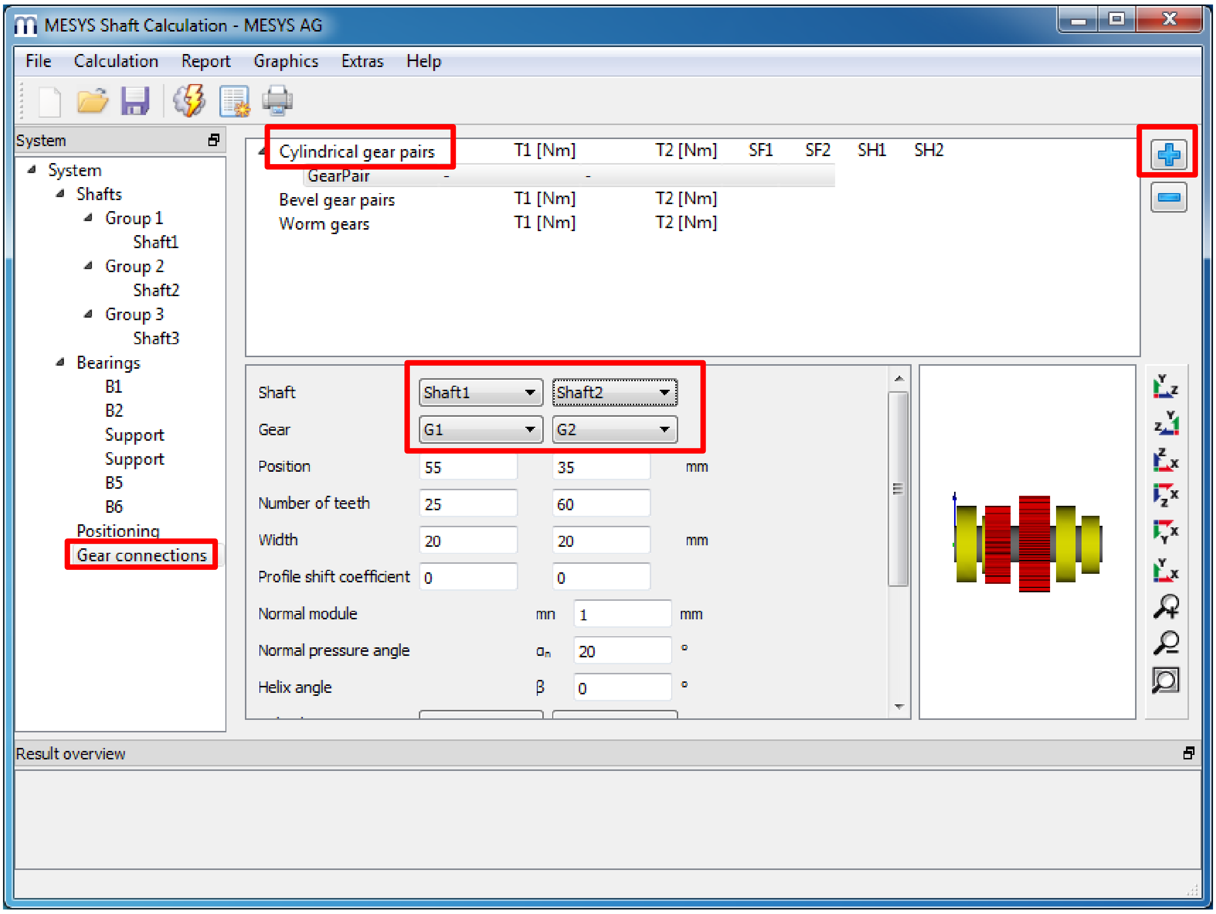
Shaft	Element	Name	Position	Parameters
Shaft1	Coupling	Input	10	Mx = 20Nm
	Gear	G1	55	mn=1, α=20, b=20, z=25
	Rolling bearing	B1	30	Deep groove ball bearing 6204
	Rolling bearing	B2	110	Deep groove ball bearing 6204
Shaft2	Gear	G2	35	mn=1, α=20, b=20, z=60
	Gear	G3	65	mn=1.5, α=20, b=25, z=20
	Rolling bearing	B3	10	Deep groove ball bearing 6205
	Rolling Bearing	B4	90	Deep groove ball bearing 6205
Shaft3	Gear	G4	65	mn=1.5, α=20, b=25, z=50
	Rolling bearing	B5	10	Deep groove ball bearing 6206
	Rolling bearing	B6	90	Deep groove ball bearing 6206
	Reaction coupling	Output	110	

Now the shaft should look like the following images:



Defining gear connections

As the next step connections are defined between the gears. For this select ‘Gear connections’ in the system tree, click on ‘Cylindrical gear pairs’ and add a connection using the -button on the right.



Now select the shafts and gears which should be connected. Connect G1-G2 for the first pair, then add a second pair and connect G3-G4. Circumferential backlash and gear mesh stiffness can be changed here. It is not needed to enter the center distance as it will be calculated later. The calculation program for the gear strength calculation can be selected if available.

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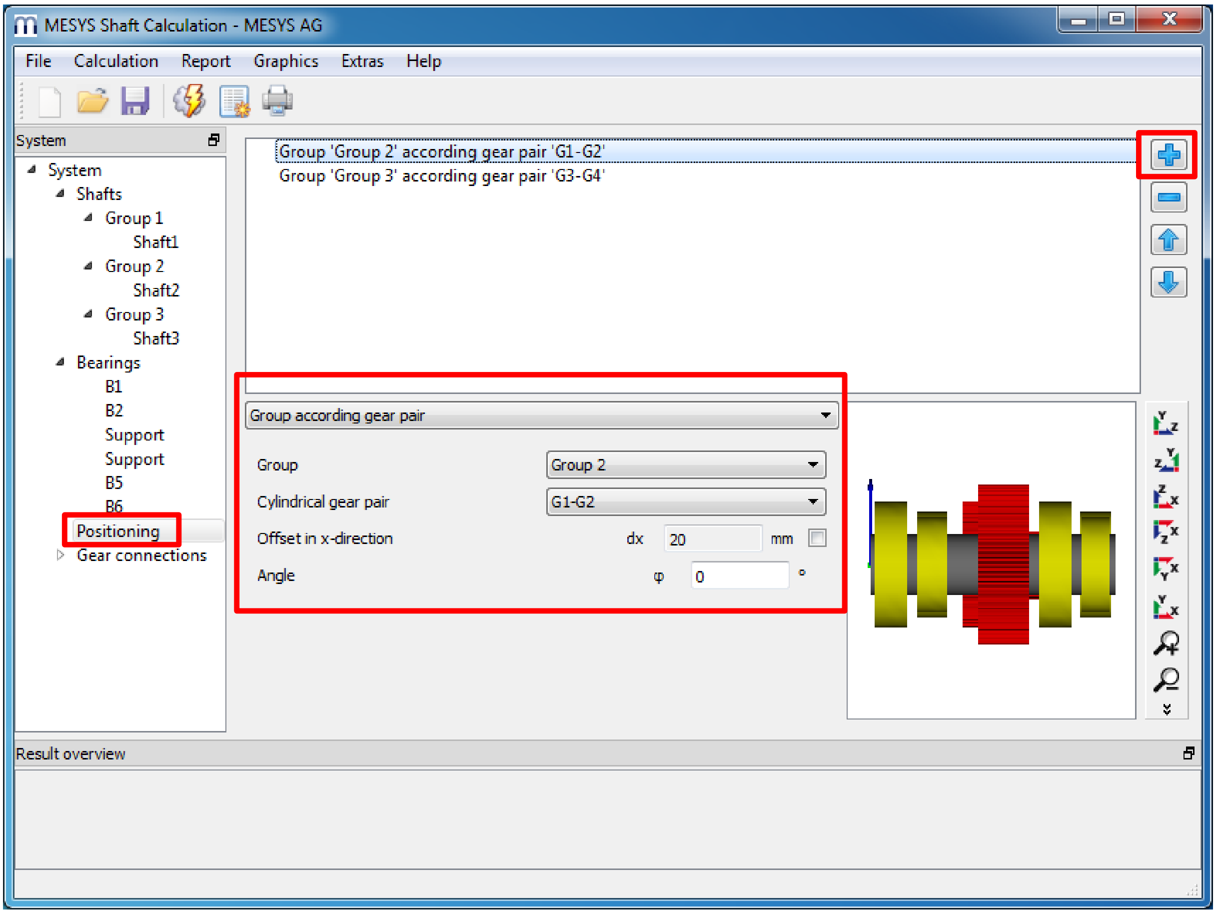
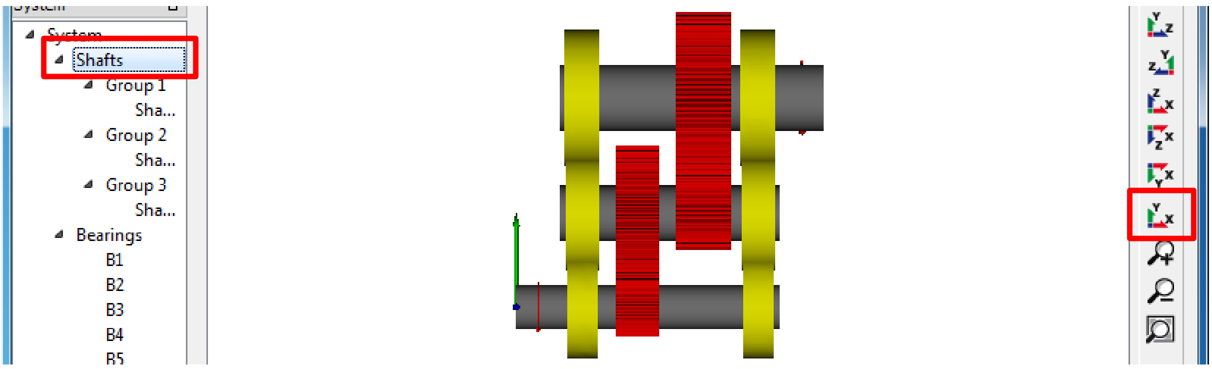
Define positioning

The next step is to define the positioning of the shafts. For this select ‘Positioning’ in the system tree.

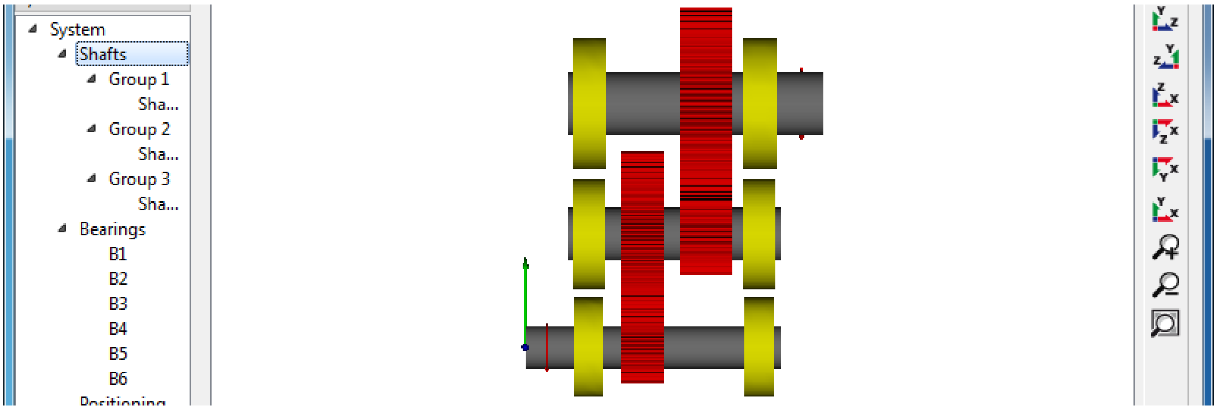


Add two constraints using the -button on the right. Several options for positioning are available. Select ‘Group according gear pair’ and position ‘Group2’ with pair ‘G1-G2’ and ‘Group3’ with pair ‘G3-G4’. The angle could be changed, we just leave it to 0° for this example, getting a vertical orientation of all shafts.

Now click on ‘Shafts’ in the system tree and choose the x-y-plane for the view:



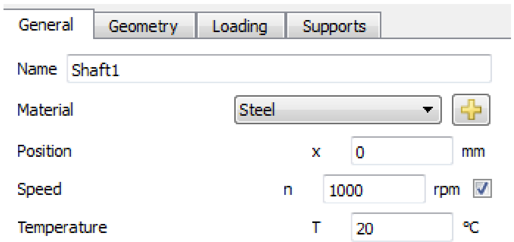
We see that there are collisions between the bearings. We go back to 'Gear connections' and change module for pair 'G1-G2' to 1.25 and to 1.75 for 'G3-G4'. Afterwards the space between the bearings is small, but we don't have any collisions:



Running the calculation

Before running the calculation we have to define the speed for the system. Enter a speed of 1000rpm for 'Shaft1'.

For all other shafts the flag behind the input of speed should not be set as the speed is calculated by the program.



After running the calculation the results overview should look similar to the following:

Result overview

Minimal bearing reference life	minL10rh	5206.8	h	Minimal bearing modified reference life	minLnmrh	2696.97	h
Minimal static safety for bearings	minSF	3.31313		Maximal bearing stress	pmax	2817.32	MPa
Maximal displacement in x	maxUx	0.00125648	mm	Maximal displacement in y	maxUy	0.0105804	mm
Maximal displacement in z	maxUz	0.0391698	mm	Maximal displacement in radial direction	maxUr	0.0395863	mm
Minimal root safety for gears	minGearSF	3.0644		Minimal flank safety for gears	minGearSH	1.1457	
Maximal equivalent stress	maxSigV	45.3345	MPa				

The safety factors for the gears depend on the selected program for gear calculations. We also did not enter any details for the gear calculations. Minimum bearing life is 5200h, static bearing safety is 3.3. Therefore bearings could be ok, dependent on the needs for life. Minimum gear safety is 1.14 for the flank and 3 for the root stresses, so gears should also be ok.

This can now be used to detail the shaft geometry and optimize the gears.

Gear calculations

For gear calculations the 'Required Life' on page 'System' should be defined. Also either 'Consider gears as stiffness' should be set which results in an automatic increase of shaft diameter according to the gears, or you should consider the gear stiffness in the shaft geometry yourself.

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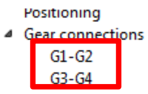
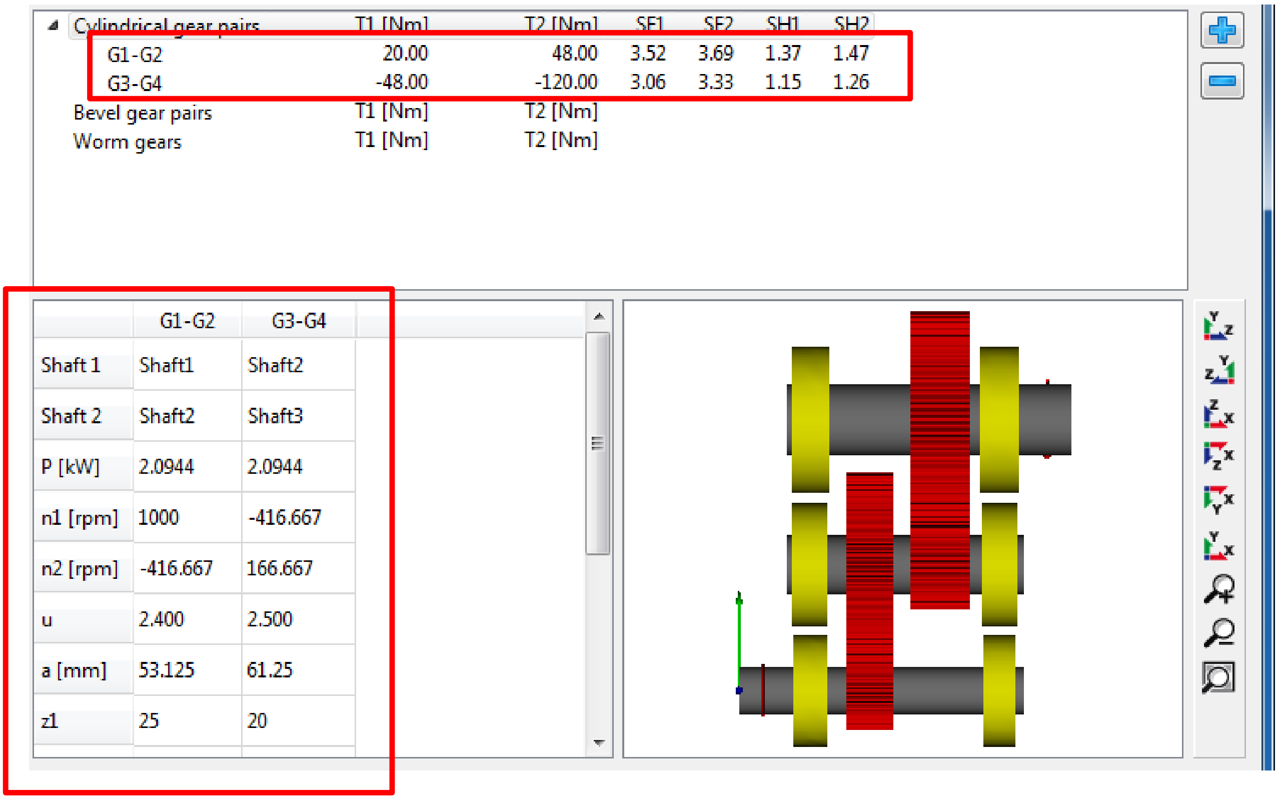
The gear calculation can be opened by selecting the gear pair in the system tree. Dependent on the gear calculation program it is opened within the shaft calculation program or as an extra window. Gear parameters can be changed and are read back on closing the gear calculation.

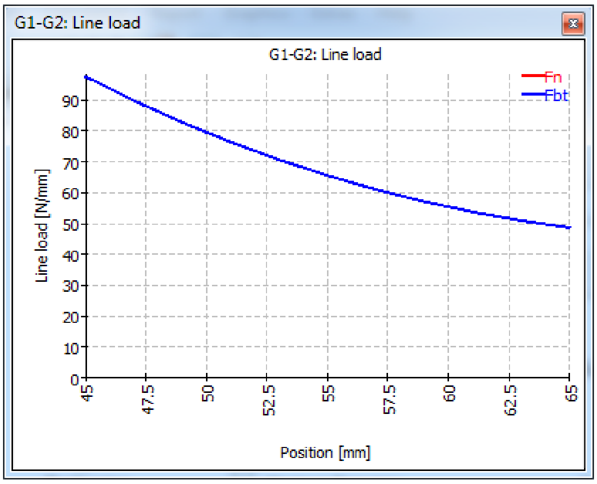


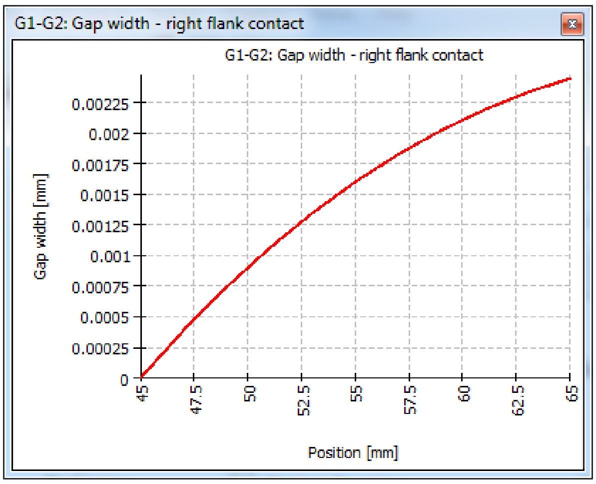
On the page 'Gear connections' the torque for each gear is shown and its safety factors. Selecting 'Cylindrical gear pairs' an overview for gear pair data is shown in a table.



Graphics for gear pairs

Two graphics for gear pairs are available so far. The line load and the gap width.

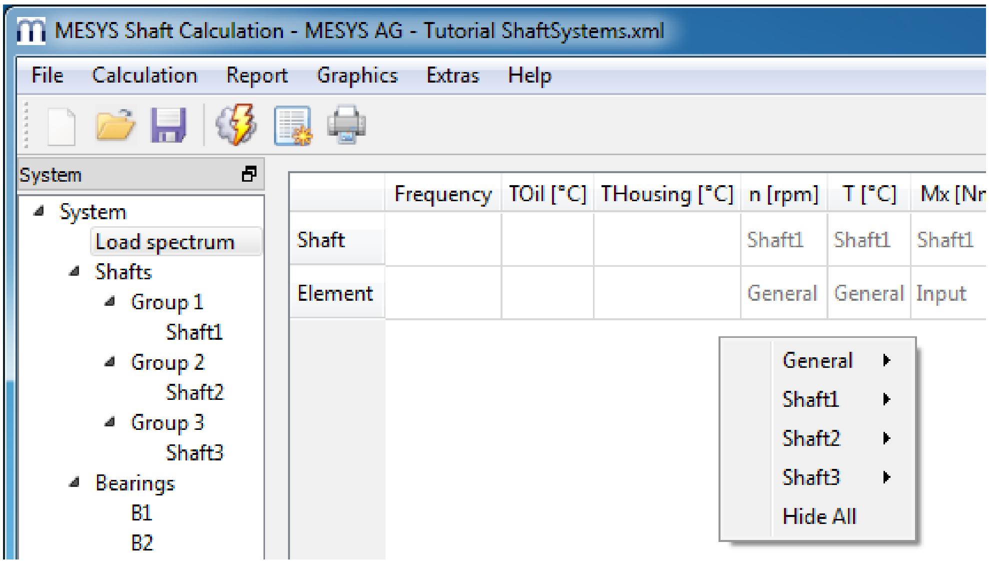




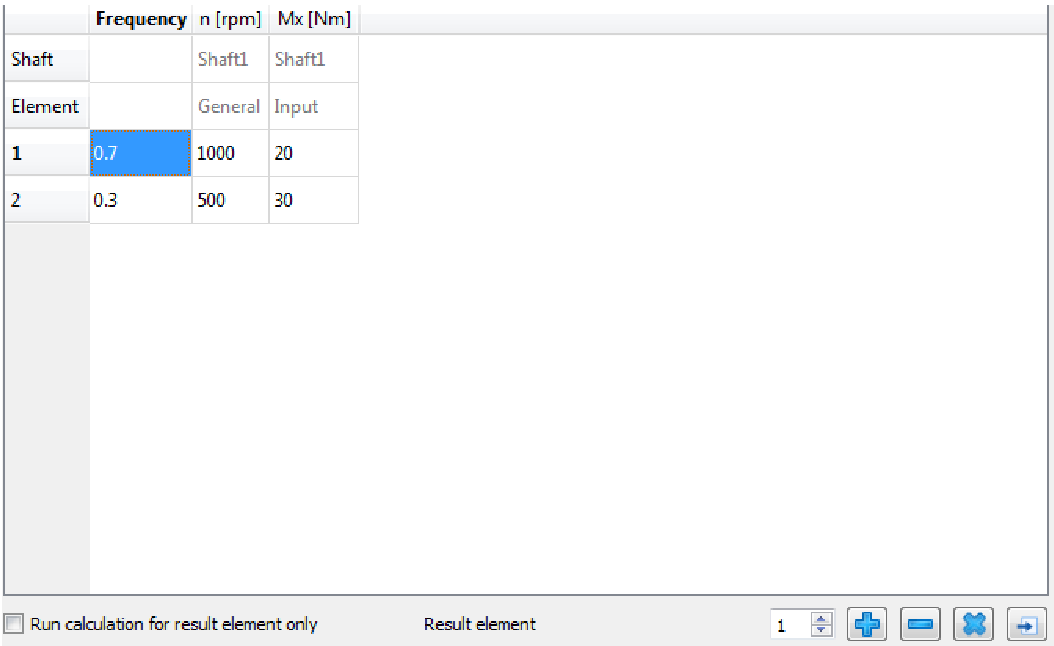
The gap width shows the gap between the flank if the contact would be just on one point. So in this case a flank line correction of 2µm could be made. These diagrams are made with the setting 'Consider gears as stiffness' set. Gear mesh stiffness, shaft and bearing stiffness have an influence to these diagrams. But also manufacturing errors and housing stiffness have an influence on the real gearbox.

Considering load spectra

Load spectra are added easily to the system. Go to the 'System' page, select 'Consider load spectrum' and then go to the new page 'Load spectrum':



Press the right mouse button and select 'Hide All'. Then press the right mouse button again and select 'Shaft1'->'General'->n and 'Shaft1'->"Input'->'Mx'. Then add two lines using the -button on the bottom:



For a simple load spectrum we add a first case with frequency 0.7, speed 1000rpm and torque 20Nm and a second load case with frequency 0.3, speed 500 and torque 30.

Now all gears and bearing are calculated using the load spectrum. On the 'Gear connections' page we see the torques for each load case and the safety factors for the whole spectrum:

Cylindrical gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2
G1-G2	-	-	2.46	2.58	1.18	1.27
1	20.00	48.00				
2	30.00	72.00				
G3-G4	-	-	2.26	2.46	1.02	1.14
1	-48.00	-120.00				
2	-72.00	-180.00				
Bevel gear pairs	T1 [Nm]	T2 [Nm]				
Worm gears	T1 [Nm]	T2 [Nm]				

An additional graphics for the gear connections show the line load for all load cases: