

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.

🗋 📂 📕	🦸 🖪 🖨 👘								
rstem ₫ ■ System ■ Shafts Shaft)			Shaft Calc	ulation			
Bearings	Project name								
	Calculation description								
	Settings Lubrication								
	Consider weight				Housing material	Steel		•	÷
	Angle for weight	β»	-90	۰	Housing temperature		Th	20	°C
	Calculate natural frequencies				Required life		н	20000	h
	Consider gyroscopic effect			+	Strength calculation	Infinit	e life a	ccording DIN 7	43 💌
	Maximum frequency	fmax	1000	Hz	Shear deformations	Accord	ing Hut	chinson 💌	
	Number of frequencies	Nree	10		Consider nonlinear s	haft model			
	Consider gears as stiffness				Consider load spect	um			
					Calculate modified b	earing life			
sult overview									

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.

			Shaft Calculation					
Project name	Tutorial							
Calculation description	Two shafts connected b	y a rolling bear	ing					
Settings Lubricat	ion							
🔽 Consider weight				Housing material	Steel			•
Angle for weight	βw	-90	•	Housing temperature		Th	20	°C
Calculate natural	frequencies			Required life		н	20000	h
Consider gyrosco	pic effect		÷	Strength calculation	I	infinite life ad	cording DIN	743 🔻
Maximum frequency	f _{max}	1000	Hz	Shear deformations	A	ccording Hut	chinson 🔹	-
Number of frequencie	s N _{freq}	10]	Consider nonlinear s	shaft mod	el		
Consider gears as	stiffness			Consider load spectr	rum			
				Calculate modified be	earing life	2		



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.

File Calculation	Report Graphics Extras Help	
🗈 n 📂 🔒 🔮	😼 📖 🖨	
System 🗗		
▲ System	f/	•
Shafts		ð
Shaft		*
Bearings	v	÷
		0
	z	
		×
	General Geometry Loading Supports Sections Settings	
	General	
	Name Chaft 1	
	Material Steel	
	Position x 0 mm Overload case Constant stress ratio	•
	Speed n 500 rpm 📝 Diameter at heat treatment d _{eff} 0 mm	
	Temperature T 20 °C Number of load cycles N 1 105	
	Factor for surface work-hardening KV 1	
	Stress ratio, tension Pulsating 0	
	Stress ratio, bending Alternating -1	
	Stress ratio, torsion Pulsating 0	

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 🍣-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:



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

		Z,		*					尊るからる。 「中子。 、 、 、 、
Genera	al Geometry	Loading Sup	ports Sections	Setting	gs				
Outer (Geometry			1	Inn	ner geometry			_
	Length	Diameter 1	Diameter 2			Length	Diameter 1	Diameter 2	-
1 20		40			1	90	0		
2 30		48	80		2	20	25	62	
3 90		80			3	30	62		
•	m		4	₽	•		III	4	♣

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 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

Roller bearing 🗸								
Name Fixed bearing								
Position	x	12.5	mm	(
Type Deep groove ball bearing (6008)								
Shaft connected to in	Shaft connected to inner ring							
🔽 transfer data to b	✓ transfer data to bearing calculation							
Connect outer ring to	housing				-			
Shaft is supported	radially							
Shaft is supported	axially to	the left						
Shaft is supported	axially to	o the right						
Bearing offset		δ_{x}	0		mm			
Bearing offset	Bearing offset δ_{ν} 0 mm							
Bearing offset		δz	0		mm			

bearing types. We choose a 'Deep groove ball bearing (6008) for the left bearing, and a 'Cylindrical roller bearing (NU1016)' for the right one.



€ Select bearing type from database							
Deep groove ball bear	ring				•		
Bearing inner diameter				d 40	mm 🔽		
Bearing outer diameter D 68 mm							
Manufacturer	name	di [mm]	De [mm]	B [mm]	C [k] ^		
Generic	61808	40	52	7	5.07815		
Generic	6308	40	90	23	35.888		
Generic	6208	40	80	18	25.735		
Generic	16008	40	68	9	14.4472		
Generic	6008	40	68	15	16.775 💂		
•		III			F.		
				ОК	Cancel		

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 Fz = -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 \mathcal{G} - 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:

General	Geometry	Loading	Supports	Sections	Settings
General					
Name S	haft 2				
Material		Stee	al		▼ 🕂
Position			x	110	mm
Speed			n	1000	rpm 🔽
Tempera	ture		т	20	°C



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:

Ger	neral	Geometry	Loading	Supports		Sections	
Out	ter Geo	metry					
	l	.ength	Diamete	r 1	Diameter 2		
1	30		25				
2	175		35				
3	50		25				



Loading

We will load the second shaft with a 'Cylindrical gear', fill the out the data as the figure below:

General Geometry Loading Supports Sec	tions	Settings			
Cylindrical gear x=85, 'Gear'		Cylindrical gear			•
		Name Gear			
		Position	x	85	mm
		Width	ь	40	mm
		Torque	т	300	Nm
		Direction of torque	Own Inp	ut	•
		Angle to contact	ζ	0	•
		Number of teeth	z	20	
		Normal module	mn	5	mm
		Profile shift coefficient	x	0	
		Normal pressure angle	0 _n	20	•
		Helix angle	βn	30	•
		Helix direction	Helix left	hand	
		Number of teeth of mating gear	z2	0	
		Center distance	а	0	mm
	1				

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.

General Geometry Loading Supports Section	s Sett	tings
Rolling bearing x=15, 'Pilot bearing ' Rolling bearing x=217, 'Fixed bearing 2' Coupling reaction moment x=245, 'Reaction coupling		Roller bearing • Name Pilot bearing Position x 15 mm • Type Four point ball bearing (radial) (QJ305) • • Shaft connected to inner ring • • Image: Transfer data to bearing calculation • • Connect outer ring to shaft 'Shaft 1' • • Image: Shaft is supported radially • • Shaft is supported axially to the left • •



Shaft sections

For a more appropiate 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

General	Geometry	Loading	Supports	Sections	Sett	ings					
Shoulde	r x=20, 'Shoul	der'			+	Shoulder					•
						Name Should	er				-
						Position	x 20		mm		
						Radius		r	0.3	mm	
						Surface rough	ness	Rz	8	μm	
								 `r	 		4

Shaft 2

Shoulder		▼ Shoulder
Name Shoulder		Name Shoulder
Position x	30 mm 🦛	Position x 205 mm 🧔 🚅
Radius	r 0.5	mm Radius r 1 m
Surface roughness	Rz 8	μm Surface roughness Rz 8 μr

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:

General			
Name Shaft 1			
Material	42CrMo4		•
Position	x	0	mm
Speed	n	500	rpm 🔽
Temperature	т	20	°C



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 ³- button, the software will just run a bearing calculation.

Now, the overview of the system geometry should look as shown:

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.



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 in 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.



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



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'.

Result overview											8
Minimal bearing reference life	minL 10rh	3006.81	h	Minimal bearing modified reference life	minLnmrh	2730.33	h	Minimal static safety for bearings	minSF	3.56542	
Minimal dynamic shaft safety factor	minSD	2.741		Minimal static shaft safety factor	minSS	5.809		Maximal equivalent stress	maxSigV	179.574	MPa
Maximal displacement in radial direction	n maxUr	0.05186	mm	Maximal displacement in x	maxUx	0.117212	mm				

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.

Result overview									8
Basic reference rating life L10r	90.2042	Basic reference rating life	L 10rh	3006.81	h	Modified reference rating life	Lnmr	81.91	
Modified reference rating life Lnmrh	2730.33 h	Maximal pressure	pmax	2749.24	MPa	Static safety factor	SF	3.56542	
Ellipsis length ratio inner race eLR_i	204.7 %	Ellipsis length ratio outer race	eLR_e	208.463	%	Extension contact ellipsis inner ring d	Cimax	46.6047	mm
Extension contact ellipsis outer ring dCemin	61.4205 mr	n Viscosity ratio	x	1.47032		Free contact angle	aO	0	•
Distance between rolling elements δRE	6.03873 mr	n Effective diametral clearance	Pdeff	0	mm	Effective axial clearance	Paeff	-99.999	mm

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:

Name	L10h [h]	Lnmh [h]	L10rh [h]	Lnmrh [h]	pmax [MPa]	SF	Fx [kN]	Fy [kN]	Fz [kN]	ŝ
▲ Shaft1										5
Fixed bearing	3005	2728	3007	2730	2749.24	3.57	0.000	0.451	3.714	
Floating bearing	79269	478275	225707	775107	1228.37	10.60	0.000	-1.005	-10.251	
A Shaft 2										
Pilot bearing	30864	45064	11758	12582	2510.84	4.68	0.000	-0.519	3.463	Ľ
Fixed bearing 2	3203	5669	3941	7287	2371.51	5.55	3.000	-1.680	1.733	5
Reaction coupling)						0.000	0.000	0.000	
										ġ
										ī
										400
										100
										•
•									P	

Na	me	Туре	x [mm]	SD	SS	Fx [kN]	Fy [kN]	Fz [kN]	Mx [Nm]	My [Nm]	Mz [Nm]	ux [mm	onar
4	Shaft 1	Chaulder	20	25.85	225.72	0.000	0.452	2 714	0.00	20.00	2.42	0.0120	S
4	Shoulder Shaft 2	Shoulder	20	25.85	5.81	0.000	0.452	5./14	0.00	28.08	-5.45	-0.0129	and c
	Shoulder	Shoulder	30	14.14	91.18	-0.000	-0.518	3.463	0.00	18.21	-0.51	0.1172	1012
	Shoulder	Shoulder	205	2.74	5.81	-3.000	1.678	-1.733	-300.00	0.67	0.20	0.1154	-
													bearings
													Frequencies
•					111							•	



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.