

**Tutorial Series** 

# Shaft Calculation - Starter Basics Simple Shaft

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## 1. Software Version

This tutorial was created with MESYS Shaft Calculation version 12-2024, dated 07/12/2024.

## 2. MESYS Shaft Calculation Package – Strengths & Capabilities



Figure 1

The basic version of this software essentially consists of the MESYS shaft calculation tool with the integration of MESYS Rolling Bearing Calculation, according to example figure 1.

To realize and consider the capabilities of MESYS Shaft Calculation, we strongly invite you to visit the MESYS website on the dedicated page for Shaft Calculation.

Please also take a look at the corresponding articles for shafts under Home/Downloads/Categories/Shafts according to figure 2:



Figure 2

## 3. Software Manual 3.1 Manual online & under F1

In addition to the Online address via the MESYS download page, the software manual can also be accessed via the user interface by selecting the 'Help' menu under 'Manual F1':

At any point – you can open the Software Manual locally with specific content directly via your keyboard F1.





### 3.2 Manual as PDF

The Software Manual can also be found in all current languages as a pdf in the MESYS installation directory (fig. 4).

📕   🛃 🖬 🖛   MESYS 1	2-2024			F	igure 4
File Home Share	e View				•
← → * ↑ _ > Π	nis PC > Lo	cal Disk (C:) > MESYS 12-2024			
	^	Name	Date modified	Туре	Size
📌 Quick access		MesysHertz64.exe	02/12/2024 11:43	Application	41,715 KB
Cesktop	1	MesysInterface3D64.dll	26/11/2024 14:12	Application exten	359 KB
🕹 Downloads	1	MesysManual.exe	14/07/2024 17:52	Application	23,589 KB
Documents	1	🔡 MESYS-Manual.pdf	11/07/2024 09:00	PDF Document	12,352 KB
E Pictures		🚰 MesysManual-DE.exe	14/07/2024 17:52	Application	23,666 KB
Aktuelle Datendatei		🛃 MESYS-Manual-DE.pdf	13/07/2024 12:13	PDF Document	12,362 KB
Pasianas		MesysManual-JA.exe	14/07/2024 17:52	Application	23,868 KB
beginner		Te MESYS-Manual-JA.pdf	13/07/2024 10:09	PDF Document	9,958 KB
Drafts		MesysManual-KO.exe	14/07/2024 17:52	Application	23,848 KB
Import Geometry		😼 MESYS-Manual-KO.pdf	13/07/2024 10:22	PDF Document	9,706 KB
This PC		MesysRBC64.exe	02/12/2024 11:41	Application	45,955 KB

## 4. Shaft

### 4.1 Description of a shaft

#### 4.1.1 Beam Model

The Shaft Calculation uses the Timoshenko beam model, which improves upon the classical Euler-Bernoulli theory by accounting for shear deformations and rotational inertia effects.

#### 4.1.2 Limits and Assumptions

While the Timoshenko model is more realistic, it still simplifies the actual behaviour of a shaft. For instance, it does not consider 3D effects like local stress concentrations or nonlinear material properties, which would require more complex FEM analysis.

#### 4.1.3 Options

A nonlinear shaft model can be taken into account. The nonlinear model calculates equilibrium of loads in the deformed state. Further information can be found in the <u>Manual</u>.

### 4.2 Shaft Project

#### 4.2.1 Basic data of the shaft

A shaft in the MESYS Shaft Calculation requires a minimum description for corresponding running of the simulation. Let's go through this process sequentially.



Start MESYS Shaft Calculation or open a new file using the 'New' icon or the File menu item and choose 'New':



MESYS provides a placeholder for a Shaft in the 'System'-Tree. under 'Shafts' as standard. This Shaft can now be further defined in the main window.

The project for Shaft Calculation can be given a name and a description under 'System'.



Assign an example name to the project.



For the moment, we can leave the contents of 'System', chosen by 'System'-tree, i.e. the 'Settings', 'Lubrication' and 'Display settings' tabs untouched.



#### 4.2.2 Shaft input values

The following input data define a shaft:

- Length of the outer segment
- Length of the segment on the hollow shaft
- Diameter of the segment
- Diameter of the segment on the hollow shaft
- Material of the shaft

Optional:

- Temperature across the outer segments

For the purposes of this document, let us illustrate an example horizontal spindle shaft, as shown in figure 7:



Please proceed as described below.

- Select 'Shaft' in the 'System'-Tree left-hand to display the input fields for the shaft in the main window. Start with the 'General'-tab.
  - Choose a name for your shaft, e.g. "Simple Shaft 01".
  - Confirm that your shaft is to be exposed to a speed by ticking the 'rpm' box.
  - Furthermore, please enter the intended speed, which shall be 1000 rpm here.



Select 'Shaft' in the 'System'-tree to display the input fields for the shaft in the main window. Continue with the 'Geometry'-tab.



File Calculation Report Graphics Extras Help	
System B System Shafts Simple Shaft 01	AY +g
Here the shaft geometry can be as- signed for outside and inside lengths and diameters of the segments. Total resulting length (L) of the shaft or hol- low shaft is given at the top right of the tables.	A 3 3 3 A 3 3 A 3 3 3 A 3 3 A 3 3 3 A 3 3 3 A 3 A
General Geometry Loading Supports Sect	tions Settings
Figure 9	m] Length [mm] Diameter 2 [mm] 2 70 25
Result overview	8

The blue control keys on the right side can be used to add, sort or delete rows, whereby ' i deletes the entire table.

#### The example wave geometry should look as described in <u>Figure 7</u> and as follows:

Outer Geometry					Inner Geometry					
	Length [mm]	Diameter 1 [mm]	Diameter 2 [mm]		Length [mm]	Diameter 1 [mm]	Diameter 2 [mm]			
1	100	40		1	20	30				
2	50	50		2	70	25				
3	10	50	55	3	5	25	20			
4	30	55		4	50	20				
5	10	55	45	5	70	22				
6	55	45		6	10	22	18			
7	60	40		7	100	18				
8	10	45					Figure 10			

#### These inputs should result in a shaft geometry as shown in Figure 7 and now shown correctly in Figure 11:



There are 'magnifying glasses' on the right-hand side of the graphical window that can be used to adjust the display of the shaft. Other buttons allow the user to add components such as couplings, gears, supports or rolling bearings to this graphical environment.



#### 4.2.3 Position in space

Angle 0

Before continuing with the entries, the position in space must be defined. This exposes the configuration also to the corresponding weight forces.

Select 'System' in the left-hand tree to display the input fields in the 'Settings'-tab. Assign the position in space to your shaft here, ticking the consideration of a weight force and define its direction ( $\beta_w$ ).

File Calculation Repo	ort Graphics Extras Help		
🗋 🗁 💾 🚳			
System	mesi	JS	Shaft Calculation
<ul> <li>Shafts</li> <li>Simple Shaft 0</li> </ul>	Engineering Consulting Software	AG	Shart Calculation
<ul> <li>Bearings</li> <li>Bearing</li> </ul>	Project name	starter Tutorial	
	Calculation description	Simple Shaft 01	
	Settings Lubrication	n Display settings	
	Consider weight		+ Housing material Steel
Figure 12	Angle for weight		β <sub>w</sub> -90 ° Housing temperature
→g	Ļ	g	The angle is defined trough x-y-plane, a rotation around z-axis. A value of zero results in a weight in the direction

z-axis. A value of zero results in a weight in the direction of shaft axis. The weight direction is also shown as an arrow in the shaft graphics and it can be varied within the load spectrum.

After entering -90° for  $\beta_w$ , we should get the following arrow direction for weight force in the graphic window:

Angle 180°

Angle -90°

File Calculation Report G	Graphics Extras Hel	р								
🗋 🦢 💾 🥰 属										
System B V System Shafts Simple Shaft 01			After directi	entering -90° for βν ion for the weight fo	v, v rce	ve in	e should the grap	obtain th hics winc	ie following low:	g arrow
	Outer Geometry			L=325mn	1	Inn	er Geometry			
	Length [mm] 1 100	Diameter 1 [mm] 40	Diameter 2 [mm]	^	4	1	Length [mm] 20	Diameter 1 [mm] 30	Diameter 2 [mm]	
	2 50	50	55		*	2	70	25	20	
	4 30	55	22		1 L	4	50	20	20	
Figure 14				v						

Figure 13



## 5. Loading 5.1 General



## **5.2 Force Vectors**

To assign a common force, proceed as follows:

Assign a load with '
+ and select the type in the drop-down on the right, which we define with 'Force'.





		유 오 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇 〇
General       Geometry       Loading       Supports       Sections       Settings         Force x=175mm, 'Radial 1'       The force vectors can be defined on the bottom right-hand side of the main window. Let us load the shaft with a radial and an axial component as follows.       Image: Component as follows.         Image: Component as follows.       Image: Component as follows.       Image: Component as follows.         Image: Figure 17       Image: Component as follows.       Image: Component as follows.	Force Name Radial 1 Position Width Axial Force Radial Force Radial Force Torque Bending moment Bending moment	x 175 mm (= ) b 0 mm Fx 0 N Fy -2000 N Fz 0 N Mx 0 Nm My 0 Nm Mz 0 Nm
General     Geometry     Loading     Supports     Sections     Settings       Force x=175mm, 'Radial 1'     Force x=220mm, 'Radial 2'     Force x=220mm, 'Radial 2'     Force x=220mm, 'Radial 2'	Force Name Radial 2 Position Width Axial Force Radial Force Radial Force Torque Bending moment Bending moment	x 220 mm (* * * * * * * * * * * * * * * * * *
General     Geometry     Loading     Supports     Sections     Settings       Force x=0mm, 'Axial'     Force x=175mm, 'Radial 1'       Force x=220mm, 'Radial 2'	Force Name Axial Position Width Axial Force Radial Force Radial Force Torque Bending moment Bending moment	x 0 mm (m) (m) (m) (m) (m) (m) (m) (m) (m)

### The shaft should now appear to us as shown in the following Figure 19:



Figure 19

By selecting 'Shafts' in the system tree, the display of the force vectors can also be switched to 3D:



## 6. Supports 6.1 General



## 6.2 Rolling bearings

#### 6.2.1 Mounting a Rolling Bearing

After assigning the support type, in this case rolling bearings, MESYS will place a deep groove ball bearing by default.





#### 6.2.2 Bearing type and denomination

This insertion of a rolling bearing has following effects on the content of the simulation:

- Creation of a group 'Bearings' in the 'System'-tree
- Entry 'Bearings' under the 'Supports'-tab
- Placement of a rolling bearing at the axial position x = 0

The interface to MESYS Rolling Bearing Calculation is 'activated' when a rolling bearing is assigned. To select a rolling bearing or to define one in all its characteristics, please select 'Bearing' in the system tree.





Go to 'System'/'Bearing' and open tag 'Bearing geometry'. From the large selection of bearing types via the left dropdown, we select 'Deep groove ball bearing'.

File Calculation Report	Graphics E	xtras Help					
🗋 🗁 💾 🚳 📑							
System ₽	General	Bearing geometry	Bearing configuration	Material and Lubrication	Loading		
V Shafts	Deep groove ball bearing						
✓ Bearings	Deep groove ball bearing Deep groove ball bearing (double row)						
Bearing			4				
Figure 24 Angular contact ball bearing (double row) Axial angular contact ball bearing							

The design of the rolling bearing ('inner geometry') showed in figure 25 below the left bearing type selection dropdown, can be entered manually.

At this point however, we select an already defined rolling bearing from the database.



Choose 'Select bearing from database' on the right dropdown and filter inner & outer diameters d = 40 and D = 80 mm on the left side, to find the 'Generic' 6208 Deep groove ball bearing, as shown in figure 26.

File Calculation Report G	raphics Extras	Help						
🗋 늘 💾 🥵 😱 (								
System &	General Bea	ring geometry Bearing confi	iguration	Material	and Lubri	cation	Loading	Track roller
✓ Shafts	Deep groove ba	all bearing					~ 🕂	Select bearing from database 🗸 🗸
Simple Shaft 01 Searings Bearing	Inner diameter				d 40 mm			Enter outside geometry only Enter outside geometry and load capacity Enter inger geometry
	Outer diameter			D	80	m	m 😯 🗹	Enter inner geometry and load capacity
	Manufacturer	name	di [mm]	De [mm]	B [mm]	C [kN]	C0 [kN] ^	Select bearing from database
	SKF	*6208 N	40	80	18	32.5	19	Bearing clearance User input as operating clearance ~
	SKF	6208 ETN9	40	80	18	35.8	20.8	Diametral clearance Pd 0 mm 🚍
	SKF	*6208	40	80	18	32.5	19	
	SKF	*6208-ZNR	40	80	18	32.5	19	Select Select bearing from database' in
	SKF	*6208-Z	40	80	18	32.5	19	the right-hand drop-down menu and fil-
	SKF	*6208-RS1	40	80	18	32.5	19	ter the inner and outer diameters d = 40
	SKF	*6208-2ZNR	40	80	18	32.5	19	and $D = 80$ mm on the left-hand side to
	SKF	*6208-2Z	40	80	18	32.5	19	find the door groove ball bearing (go
	SKF	*6208-2RS1	40	80	18	32.5	19	find the deep groove ball bearing 'ge-
	Generic	6208	40	80	18	25.735	15.9028	neric' 6208, as shown in Figure 26.
Figure 26	<						>	

#### 6.2.3 Positioning of Bearings

The positioning of the rolling bearing can be done by numerically entering the axial position on X. This can be done by turning back to 'System'/Simple Shaft 01/'Supports' in the lower right window or by combining Shift+left mouse button by sliding on the graphical representation of the bearing itself.





Add a second bearing by pressing the blue ' 💠 '-button shown in figure 26, which will cause a copy of the above bearing. We want to name the rolling bearing to be designed as a floating bearing 'B2 - floating'.



Figure 28

#### 6.2.4 Conditions of Rolling Bearing

Let's now assign the operating conditions for the rolling bearing. Roughly assessed and within the scope of this tutorial, these could be the desired degrees of freedom, the fits, the properties of the bearing seats and, for example, the accuracy class.

So let's go back to 'System'/'Bearings', in the 'Bearing geometry' tab (fig. 29) and enter this basic information for the rolling bearings. For the time being, let's first deal with bearing clearance (CN) only conditionally.



File Calculation Report Graphics	Extras Help	
System #	General Bearing geometry Bearing configuration Material and Lubrication Loading Track roller	
✓ Shafts	Deep groove ball bearing V 🔂 Select bearing from database	~
Simple Shaft 01	Inner diameter d 40 mm 🔂 🗹 Dynamic load number	Cr 25.735 kN
B1 - fixed 'Generic 6208'	Outer diameter D 80 mm 🔂 Static load number	C0r 15.9028 kN
B2 - floating 'Generic 6208'	Manufacturer name di Immi De Immi B Immi C IkNi CO IkN A Fatigue load limit	Cur 0.828755 kN
	Bearing clearance	ISO 5753 - CN 🗸
	B1 clearance shall be CN and the pre-	Pd 0 mm
	cision class PO while k6 & H7 are fur-	ISO 492 - PO 🗸
	Fit to shaft	k6 🖧
	ther assumptions at a roughness Rz of Surface roughness shaft	Rz 4 µm
	4. Furthermore, we assume a housing Shaft inner diameter	dsi 25 mm
	diameter 'dhe' of Ø 90 mm	H7 47
	Surface roughness housing	Rz 4 µm
	Housing outer diameter	dhe <mark>90</mark> mm
	Generic 6208 40 80 18 25.735 15.9028	
Figure 29	SKF         6208 - SKF         40         80         18         32.5         19         v           <             >         >	





Enter the same settings for B2 as for B1 or alternatively chose to adopt settings from already configured B1, as shown in figure 32.

For B2, in the end a different setting is still required with regard to the support directions though. The nonlocating bearing must not absorb axial forces and should be released axially. To do this, we go back to 'System/'Simple Shaft 01' in the 'Supports' tab for B2 – as shown in <u>figure 28</u>.





Figure 32

## 7. Shaft sections

### 7.1 General

For a proper calculation of shafts, stress concentrations, load types and sizes or necessary safety factors must be taken into account. For this purpose, the software offers the option of defining different notch cases for each shaft on the 'Sections' tab.

### 7.2 Shaft Strength

#### Note: This analysis needs the extension for DIN 743.

The method for shaft strength calculation can be selected under System, in 'Settings'-tab on right side. Currently, DIN 743 (2012) is available. It can be selected if the calculation should be done considering infinite or finite life. For finite life the number of cycles is calculated using the input for 'Required life' H.

For more information about sections please refer to <u>Software Manual</u> specific content.

Housing material	Steel					~	\$
Housing temperature	2			Th	20		⁼C
Required life				н	20000		h
Bearing reliability			s	9(	)	%	
Strength calculation		Infinite life accordin	ig D	IN 7	43		~
Bearing position		Definition for each I	bear	ing			~
Shear deformations		According Hutchinson				$\sim$	÷
Consider nonline	ar shaft model						
Consider load spe	ctrum						
Calculate modifie	d bearing life						

Figure 33

In our example, we focus the analysis on a point at which the diameter changes significantly. We therefore set a 'Section' at 'Simple Shaft 01' on a defined point, i.e. on the right shoulder of the 6<sup>th</sup> outer segment, as shown on the right.



Figure 34





As the strength calculation requires a clear material definition, we will select one from the database (fig. 36).

 Therefore, go to 'System/Shafts/Simple Shaft 01' and assign under the 'General' tab the material 42CrMo4 as an assumption to the shaft.



## 8. Lubrication

Let us assume that we are dealing with sealed DGBBs and that they are fitted with a standard lubricant of class ISO VG 46 mineral oil. Furthermore, the application should be carried out under normal contamination.

Select a lubricant class ISO VG 46 mineral oil as lubricating grease under normal cleanliness.



File Calculation Report	Graphics Extras Help		
🗋 🗁 💾 🥳 📑	9		
System # System Shafts Simple Shaft 01	Engineering Consulting Software Lag	Shaft Calculation	
<ul> <li>Bearings</li> <li>B1 'Generic 6208'</li> <li>B2 'Generic 6208'</li> </ul>	Project name Starter Tutorial Calculation description Beginner Simple Shaft 01 Settings Lubrication Display settings		
	ISO VG 46 mineral oil	✓ Grease lubrication, Normal cleanliness	~ 🕂
	Oil	Temperature	TOil 70 °C
	Viscosity at 40°C	nu40 46 mm²/s Oil density	ρ 870 kg/m³
	Viscosity at 100°C	nu100 7 mm <sup>2</sup> /s Pressure viscosity coefficient	α 0.0147418 1/MPa
Figure 37	contains effective EP additives	FZG load stage	FZG 12

A lubricating grease selection that deviates from the series for mass-produced products such as deep groove ball bearings is usually not practicable in terms of cost. A comparison of reference viscosity and operating viscosity using the ISO VG value is recommended. However, in addition to the usual viscosity references, a lubricant used in mass production should also be evaluated with regard to its suitability in terms of lubricant quantity, lubricant displacement space, effective contact stresses or friction and thus potentially effective temperatures in contact.

## 9. Interfaces

### 9.1 Bearing to Shaft

If we consider the Rolling Bearing Calculation as a plug-in for Shaft Calculation, we can assume that the relative main interfaces are to be defined. We find the standard connection of the parameters under 'System'/'Shafts'/...B1 or B2, as displayed in following figure 38:



Let us then find and compare these interfaces on the programme interface. This step is not necessary if all 4 checkboxes in fig. 38 above are ticked (default)!



## 9.2 Geometry

System 🗗	General B	earing geometry Rea	ring configuratio	n Mater	ial and L	ubrication	Loadin	a Track roller			
<ul> <li>✓ System</li> <li>✓ Shafts</li> </ul>	Deep groove	ball bearing	ing coningulatio	iii iiiiiiiiii		abrication	~ 4	Select bearing from data	base		~
Simple Shaft 01	Inner diamete	r		d	40	n	m 🕂	] Dynamic load number		Cr 25.735	kN
B1 'Generic 6208'	Outer diamete	er		D	80	п	in 🔂 🗆	Static load number		C0r 15.9028	kN
DE GENERE GEOG	Manufacture	er name	di [mm]	De [mm]	B [mm]	C [kN]	CO [kN	Fatigue load limit		Cur 0.828755	kN
	Generic	6208	40	80	18	25.735	15.9028	b og clearance		ISO 5753 - C3	~
	Generic	6207	35	72	17	22.5206	13.5357	Diameth		Pd 0.024	mm
	Generic	62/32	32	65	17	17.6079	10.4249	Bearing toleran	eometry is	ISO 492 - P0	~
	Generic	6206	30	62	16	17.6031	10.2484	Fit to shaft	connected	kő	÷
	Generic	62/28	28	58	16	14.6793	8.09764	Surface roughness shaft			μm
Figure 39	Generic	6205	25	52	15	12.6793	7.12723	Shaft inner diameter		dsi 25	mm

### 9.3 Material



### 9.4 Temperature

System 🗗	General Rearing geometry Rearing configuration	Material and Lubrication Loading Track roller	
<ul> <li>✓ System</li> <li>✓ Shafts</li> <li>Simple Shaft 01</li> </ul>	Axial load	Fx 75 N O Displacement	ux 0.0409269 mm 🔘
✓ Bearings	Radial load	Fy -780.906 N O Displacement	uy -0.0149256 mm 🖲
B2 'Generic 6208'	Radial load	Fz 28,5454 N O Displacement Temperature	uz 0.000490082 mm 🖲
	Moment	My 0.0683181 Nm O Rotation and is connected	ry -0.0106767 mrad 🖲
	Moment	Mz 1.9241	rz -0.152308 mrad 🖲
	Speed inner ring	rpm 🗹 Inner ring rotates to load	
	Speed outer ring	ne 0 rpm 🗌 Outer ring rotates to load	
Figure 41	Temperature inner ring	Ti 25 °C Temperature outer ring	Te 20 °C

## 9.5 Lubrication



# 10. Calculation step

## **10.1** Activation

After entering and setting all the points and passages mentioned above, the resulting shaft model is ready to start the 1<sup>st</sup> calculation step.



By selecting System/Shafts, we find ourselves in the results overview, which can be viewed by topic using the vertical tabs at the lower right edge:



Figure 43

### 10.2 Results

Results are available in different outputs. There is the default result overview on the bottom of the user interface (figure 43), an overview of bearing forces and natural frequencies, several graphics and the editable report.







bearing B2 with Fx = 0 is completely axially unloaded (fig. 45).

Have a look also at the other results and the additional tabs as shown in figure 46:

Name Welle	n [rpm] ∑T [Nm] 1000 -	∑P [kW] minL10rh [ - 198794	h] minLnmrh [h] 713143	pmax [MPa] 1641.58	minS0eff 16.74	maxSigV [I 8.49	ИРа] SD 69.44	SS maxU 99.99 0.02	lr [mm]	mass [kg] 3.09	centerMass 172.97	; [mm] J (	lxx [kg m²] ).0010	Jyy [kg m²] 0.0212	Jzz [kg m²] 0.0212	Wellen
Name Y Simple Sh	e Shaft 01 oulder with relief gr	Type bove Shoulder with re	x [mn	1] SD SS 69.44 99.99 69.44 99.99	Fx [kN] 9 9 0.000	Fy [kN] Fz [ 1.102 -0.1	(N] Mx [N	m] My [Nm] 1.051	Mz [Nn 9.761	n] ux [mm	1] uy [mm] -0.0155	uz [mm 0.0016	] rx [mrad] 0.0000	ry [mrad] 0.0002	rz ['] 0.2585	Sections
Number 1	f [Hz] 20.0296	f [1/min] 1201.77	D [-] 0.0419399	Type Torsional 'Si	mple Shaft	01'										Shafts
2 3 4 5	143.163 1047.83 1264.28 1309.46	8589.79 62869.6 75856.7 78567.7	0.218533 0.0666211 0.0856523 0.0578778	Axial 'Simpl Radial 'Simp Radial 'Simp Radial 'Simp	e Shaft 01' Ile Shaft 01' Ile Shaft 01' Ile Shaft 01'	Note	Conten	ts are visi	ible he	ere if exa	aminatic	on of fr	equenci	es is sele	ected.	Sections
6 7 8 9	1591.64 2473.5 2517.23 5110.1	95498.3 148410 151034 306606	0.0782232 0.059286 0.0644119 0.0978351	Radial 'Simp Radial 'Simp Radial 'Simp Radial 'Simp	le Shaft 01' le Shaft 01' le Shaft 01' le Shaft 01'											Frequenci
10	5153.55	309213	0.100553	Radial 'Simp	le Shaft 01'											<u>R</u>

Figure 46

### 10.3 Report

#### 10.3.1 Main Report

Using the toolbar button or menu 'Report'/'Show Report', a report for the shaft calculation is generated which only gives an overview for the bearing results. There is also 'Report'/'Full report' which is generating a full report with results of the shaft calculation and the full reports of the bearing calculations.



Figure 47



#### 10.3.2 Report options

In the menu 'Report'/'Options' the contents of the report can be configured. The graphics to be included can be selected and some sections of the report could be discarded if not of interest. The legend for all the table parameters can be shown in the report.

R Report	options		×
Shafts	Bearings	Ball screws	
Please se	elect the cont	ents for the report:	
Grap	hic: Displacer	nent	Graphic: Forces
Grap	hic: Moments		Graphic: Stresses
Grap	hic: Campbel	l diagram	Graphic: Mode shapes
Grap	hic: Gear line	loads	Graphic: Gear gap width
Grap	hic: Gear relat	ive displacement	Graphic: Gear flank modifications
🗹 Inclu	de load spect	rum details	Include support displacements
🗹 Inclu	de details for	strength calculation	☑ Include mass properties
✓ Inclu	de legend for	tables	Include measurements in shaft graphics
Show	standard be	aring results table	Show custom bearing results table
🗹 Inclu	de bearing re	ports in full report	
Inclu	de ball screw:	s reports in full report	
✓ Inclu	de gear repor	ts in full report	

#### 10.3.3 Report format The report can be saved in .docx format, for instance, allowing further processing.



Figure 48

The logo in the report can be configured in 'mesys.ini'. See Configuration with INI-File. Further information on this can be found at appropriate page in the <u>Manual</u>.



#### 10.3.4 Report Tables

The second secon														
Dat	Start	Einfügen	Seitenlayout	Formeln	Daten Übe	rprüfen An	sicht	Entwickler	tools Acrol	pat PDF-XC	hange 💡 🛛	Vas mõchten Si	e tun?	
Einfü Zwisch		alibri F K <u>U</u> -	• 11 • A		∎ ≫ • E	Standard Standard * % + % Zahl	000	Bedingte	Formatierung * e formatieren * natvorlagen *	Einfügen	<ul> <li>∑ - <sup>A</sup><sub>Z</sub>▼</li> <li>↓ - </li> <li>∞ -</li> <li>Bearbeite</li> </ul>	PDF Er erstellen u	stellen von PDF-D nd Freigeben von dobe Acrobat	
A3 $\bullet$ : $\times \checkmark f_{e}$														
	A	В	С	D	E	F	G	н	I	J	К	L	м	
1	Bearing st	iffness ma	trices											
2	B1 - fest (0	Seneric 620	)8)											
3	-	ux [µm]	uy [µm]	uz [µm]	ry [mrad]	rz [mrad]			Fx [N]	Fy [N]	Fz [N]	My [Nm]	Mz [Nm]	
4	Fx [N]	3.32011	-9.36438	0.13058	2.37464	79.1575		ux [µm]	4.99918	0.0244	0.00815	-5.45274	-191.114	
5	Fy [N]	-9.36498	116.4	-1.45514	-2.04036	-226.458		uy [µm]	0.02488	0.01113	0.0004	-0.112	0.27242	
6	Fz [N]	0.1306	-1.45514	71.6892	145.094	2.04036		uz [µm]	0.00812	0.0004	0.0204	-3.13602	-0.22788	
7	My [Nm]	0.00241	-0.00208	0.14736	0.94654	0.04104		ry [mrad]	-0.00554	-0.00011	-0.00319	1.55081	0.17424	
8	Mz [Nm]	0.08036	-0.23009	0.00208	0.04104	2.04061		rz [mrad]	-0.19395	0.0003	-0.00023	0.17411	8.0433	
9	B2 - lose (	Generic 620	08)											
10		ux [µm]	uy [µm]	uz [µm]	ry [mrad]	rz [mrad]			Fx [N]	Fy [N]	Fz [N]	My [Nm]	Mz [Nm]	
11	Fx [N]	2.94889	0.00433	-0.00935	7.57775	72.356		ux [µm]	6.87217	-0.00184	-0.00058	-23.4483	-259.894	
12	Fv [N]	0.00433	123.931	-4.60453	0.12204	-0.99832		uv [um]	-0.00236	0.00809	0.0005	0.00774	0.09363	
4	>   1	Rolling bearing	s Bearing	stiffness mat	rices Section	ons Shaft g	geon	netry Shaft	1 +	•				
Bereit												Ħ	II	

Figure 52

In the menu 'Report'/'Result tables', it is possible to output the result data by means of matrices (figure 52).

File		Calculation	Rep	ort	Graphics	Extras	Help
	٦	😂 💾		Sho	ow report		F6
Syst	em	1	٩	Pri	nt report		
× :	Sys	tem		Sav	e report as		
	Ý	Shafts	-	Rep	port options	5	
	~	Simple S Bearings		Rep	port templa	tes	•
		B1 'Gene		Sav	e special re	port as	
		B2 'Gene		Ful	l report		
				Cri	tical freque	ncies	
				Res	ult tables		
			_				Fig



Result tables by means of matrices with detail results for bearings can also be opened (fig. 54) via context with a right click on the bearing in the system tree.

R1		-	x v	$f_x$											File C	alculatio	n Report	Graphics Extras Help	
A	A	в	с	D	E	F	G	н	I.	J	к	L	м	N		> 💾	(§)		
1	Results p	er rolling e	element												C		5		
2	LoadCase	Bearing	Row	Ball	ψ [°]	Qi [N]	Qe [N]	Fc [N]	Mg [Nm]	pi [MPa]	pe [MPa]	piTrunc [N	peTrunc [	l αi [°]	System		u.	General Bearing geometry	Be
3	1	1	1	1	1 0	0	0.308294	0.308294	0	0	115.7739	0	115.7739	1.158905	✓ Syste	m			
4		1	1	1	2 40	0	0.308203	0.308203	0	0	115.7625	0	115.7625	0.986913	× 5	hafts		mocu	
5		. 1	1	1	3 80	C	0.308023	0.308023	0	0	115.74	0	115.74	0.591525		Simple	e Shaft 01		
6		. 1	1	1	4 120	229.7891	230.097	0.307909	0	1244.395	1050.17	1244.395	1050.17	0.092801	✓ B	earings		Engineering Consulting Software AG	
7		. 1	1	1	5 160	527.5244	527.8323	0.307867	0	1641.582	1385.015	1641.582	1385.015	0.033584		B1 'Ge	neric 6208'		
8		1	1	1	6 200	465.6562	465.9641	0.307875	0	1574.721	1328.638	1574.721	1328.638	0.032549		B2	Show Ren	oort	
9		1	1	1	7 240	119.9481	120.256	0.30793	0	1001.95	845.9113	1001.95	845.9113	0.096278			CI		
10	1	1	1	1	8 280	0	0.308069	0.308069	0	0	115.7458	0	115.7458	0.606552		-	Show lote	erances Report	
11	1	1	1	1	9 320	0	0.308234	0.308234	0	0	115.7664	0	115.7664	1.000856		1	Show Res	ult Tables	
17	12 Global results Bearing stiffness matrix Rolling element results Tolerance report .								🕀	:			<u> </u>		Paramete	r Variation			
Bere	it 🛅																Thermal p	permissible speed	
Fig	ure 54																	Figur	e 55

10.3.5 Tolerances Report



Let us now return to the practical content of this exercise. The question is now mature to understand if our chosen fits are the right ones for the intended speed and temperature.

A special report for tolerances can be created by right-clicking on 'B1' or 'B2' (Fig. 56). If a rolling bearing tolerance, radial or axial clearance is assigned under 'System'/'Shafts'/'Bearings'/B1 or B2 in the 'Bearing geometry' tab (refer to figure 29), pressure and interference of the bearing seats and resulting bearing clearances for Min, Mean, Max, and Probable can be output. If you want to print the 'Full report' (Figure 47), the information mentioned above is already included.

So let's see what the interference looks like at the bearing seats and what residual clearance is left on B1, taking into account the selected fits of ISO tolerance grades 6 / 7 (refer to figure 29), centrifugal force and temperature:

Properties for different clearance		Minimum	Minimum probable	Mean value	Maximum probable	Maximum	Unit
Nominal diametral clearance	Pd	6.00	7.99	13.00	18.01	20.00	μm
Tolerance shaft	∆ds	18.00	15.71	10.00	4.29	2.00	μm
Tolerance bearing inner ring	∆d	-12.00	-10.29	-6.00	-1.71	0.00	μm
Interference inner ring	lw_i	28.40	24.40	14.40	4.40	0.40	μm
Effective interference inner ring	lw_iop	28.39	24.39	14.39	4.39	0.39	μm
Pressure inner ring	pFit_i	20.14	17.30	10.20	3.11	0.28	MPa
Tangential stress inner ring	sigt_i	101.64	87.33	51.55	15.77	1.46	MPa
Mounting force inner ring (µfit=0.1)	Ffit_i	4556.3	3913.7	2308.2	704.3	63.1	Ν
Tolerance bearing outer ring	ΔD	0.00	-1.56	-6.50	-11.44	-13.00	μm
Tolerance housing	∆Dh	0.00	3.59	15.00	26.41	30.00	μm
Interference outer ring	lw_e	-1.60	-6.75	-23.10	-39.45	-44.60	μm
Effective interference outer ring	lw_eop	-1.60	-6.75	-23.10	-39.45	-44.60	μm
Pressure outer ring	pFit_e	0.00	0.00	0.00	0.00	0.00	MPa
Tangential stress outer ring	sigt_e	0.00	0.00	0.00	0.00	0.00	MPa
Mounting force outer ring (µfit=0.1)	Ffit_e	0.0	0.0	0.0	0.0	0.0	Ν
Change of diametral clearance	∆Pd	-19.24	-13.66	-9.76	-5.86	-0.28	μm
Effective diametral clearance	Pdeff	-13.24	-5.67	3.24	12.15	19.72	μm
Effective axial clearance	Paeff	-	-	75.80	146.46	186.23	μm
Effective free contact angle	α0eff	0.00	0.00	4.89	9.48	12.09	0

Print the tolerance report for B1.

Table 1



It can be seen in Table 1, that the interference at the inner ring under 'Effective Interference inner ring' is still positive even in the worst case (Maximum). On the other hand, the residual radial clearance is no longer sufficient even at Minimum probable!

It should also be taken into account that the inner ring rotating under rotary load will probably experience a temperature higher than 20°C.

	Cha 25°	nge te C. nge th	emperatur e radial clo	e of	shaf	to		× sy ×	stem Shafts Simple': Bearings B1 'Gen B2 'Gen	Shaft 01 eric 6208' eric 6208'	General General Name	Geometry Simple Shaft 0	Loading	Support 42CrtMo4	is Sections	; Setting				
,	class C3 for both bearings.										Position							х	0	mm
	Class	class C3 for both bearings.									Speed							n	1000	rpm 🗹
								Fig	ure 57		Tempera	iture						Т	25	°C
System Y System	ð	General Be	earing geometry Bearing	g configurati	on Mat	terial and L	ubricatior	n Loadi	ng Track roll	er										
✓ Shafts Simple S	Shaft 01	Deep groove	ball bearing						~ 4	Select bea	aring from databa	se					~			
✓ Bearings		Inner diameter					d	40	mm 🐈	Dynamic l	oad number				Ci	25.735	kN			
B1 'Gene B2 'Gene	eric 6208'	Outer diamete	r				D	80	mm 🛟	Static load	number				CI	Dr 15.9028	kN			
DE GEN		6208' Manufacturer name di [mm] De [mm] B [mm]						C0 [kN]	nmax_Oil [rp	Fatigue loa	ad limit				C	ur 0.828755	kN			
		Generic	6208	40	80	18	25.735	15.9028	0	Bearing cle	earance				ISO 5753 - CN		~			
	Generic 6207 35 72 17					22.5206	13.5357	0	Diametral	clearance				From database User input as o	perating cleara	ance				
	Generic 62/32 32 65 17					17	17.6079	10,4249	0	Bearing to	lerance				User input					
		Generic	6206	30	62	16	17 6031	10 2484	0	Fit to shaft	t				ISO 5753 - C2	ange				
		Conside	63/30	20	50	16	14 6702	0.00764		Surface ro	ughness shaft				ISO 5753 - CN		_			
Eiguro EO	20 50 10 14.075					14.0795	0.09704	•	Shaft inne	r diameter				ISO 5753 - C3						
Figure 58		Generic 6205 25 52 15 12.6793						7.12723	U	Fit to hous	ing				ISO 5753 - C5					

• Run the Tolerance Report again.

						Та	ble 2
Properties for different clearance		Minimum	Minimum probable	Mean value	Maximum probable	Maximum	Unit
Effective diametral clearance	Pdeff	-8.33	0.34	10.15	19.96	28.64	μm
Effective axial clearance	Paeff	-	24.61	133.94	187.32	223.82	μm

It can be seen in Table 2, that an internal clearance C3 <u>could</u> prevent radial preload. However, it should be noted that the temperature gradient is usually not known exactly and that this clearance design should be checked again in practice!

## **11.** Analysis

### **11.1 Bottom result window**

Result overview		Ð
Minimal bearing reference life minL10rh 174263 h	Minimal bearing modified reference life minLnmth 586842 h Minimal static safety for bearings (ISO 17956) minS0eff 15.7913 Minimal dynamic shaft safety factor minSD [69.4045	
Minimal static shaft safety factor minSS 99.99	Maximal equivalent stress maxSigV 8.49414 MPa Maximal displacement in radial direction maxUr 0.0239788 mm Maximal displacement in x maxUx 0.0486353 n	nm

Above tooltip window shows significant results of the simulation such as minimum modified reference life, structural safety factors, equivalent stress and maximum axial and radial deviation from deformations of the shaft.

#### **11.2 Lower results window**

ſ	Name	L10rh [h]	Lnmrh [h]	pmax [MPa]	S0eff	pmin [MPa]	Pdeff [µm]	Paeff (mm)	Δα [°]	Pref [kN]	Fx [N]	Fy [kN]	Fz [kN]	Fr [kN]	Mx [Nm]	My [Nm]	Mz [Nm]	Mr [Nm]	ux [mm]	uy [mm]	uz [mm]	ur [mm]	rx [mrad]	ry [mrad]	rz [mrad]	m [']
Ŀ	<ul> <li>Simple Shaft 01</li> </ul>																									
	B1 - fixed 'Generic 6208'	306782	1368890	1552.84	19.76	0.00	10.15	0.13	0.01	0.97	75.00	-0.92	0.03	0.92	0.00	0.07	1.93	1.93	0.0340	-0.0167	0.0005	0.0167		-0.0098	-0.0938	0.3244
L	B2 - floating 'Generic 6208'	174263	586842	1673.77	15.79	0.00	9.01	0.13	0.00	1.18	0.00	-1.11	0.12	1.11	0.00	-0.00	0.01	0.01	-0.0019	-0.0188	0.0017	0.0189		-0.0001	0.0764	0.2626
																									Figur	e 60

-> The values for Hertzian pressure (pmax) are at a reasonable level

- -> The effective mean radial clearance (Pdeff) has a positive value
- -> The tilting (rr) is well within the permissible values specified by manufacturers

Figure 59



-> The modified reference service life (Lnmr) is at a particularly comfortable level

### 11.3 Graphics

It is possible to analyse the application in depth using graphical representations of numerous shaft and bearing parameters.



File Calculation Report

phics Extras Help

### 11.4 Load Spectrum

Another method of analysing application behaviour is to consider different conditions or load states. Work with load spectra under such conditions.

If the flag for the calculation with load spectrum is set on the 'System' page, an additional item titled load spectrum is shown in the system tree.

File Calculation Report	Graphics Extras Help						
🗋 🗁 💾 🗳 ,							
System System Load spectrum Shafts Simple Shaft 01 Bearings B1 'Generic 6208'	Project name	Starter Tutorial Beginner Simple Shaft 01					Shaft Calculation
B2 'Generic 6208'	Settings Lubricat	ion Display settings		βw	-90	-	Housing material Ste
	Calculate natural	frequencies pic effect		f <sub>max</sub>	50000	Hz	Required life Bearing reliability Strength calculation Bearing position
Figure 62	Consider gears as stif	 c loads in static equilibrium fness point load stiffness	Gear is load only			~	Shear deformations           Consider nonlinear shaft model           Consider load spectrum           Calculate modified bearing life

Activate the load spectrum mode via the corresponding field.

Under this setting, you have the option of loading the variable parameters into the table via the context menu and then assigning values to them, as demonstrated in following figure 63:



File Calculation Report Graphics	Extras H	lelp								
🗋 🦢 💾 🧳 🔜 🖨										
System &	Shaft	Comment	Frequency	TOil [°C]	THousing [*C]	n [rpm] Simple Shaft 01	T [°C] Simple Shaft 01	Fx [N] Simple Shaft 01	Fy [N] Simple Shaft 01	Fz [N] Simple Shaft 01
✓ Shafts Simple Shaft 01	Element					General	General	Axial	Radial 1	Radial 2
✓ Bearings	1	stop	0	20	20	0	20	0	0	0
B1 - fixed 'Generic 6208' B2 - floating 'Generic 6208'	2	idle cold	0.2	20	20	1000	20	0	0	0
The 'Comment'	3	idle	0.2	60	25	1000	30	0	0	0
fields see he	4	load	0.6	70	25	1000	32	75	-2000	150
fields can be							General	• L		
freely labelled.	Fu	irthermoi	re. the l	load spec	trum ele-	-	Simple Shaf	t01 🕨 Ger	neral +	
			-, L L		1		Show All	Axi	al 🕨	x
	m	ent can a	iso be c	calculated	d sepa-		Hide All	Rac	lial 1 🔹 🖌 🗹	Fx
	l ra	telv if the	e corres	ponding	selection	-		Rac	lial 2 🕨 🕨	Fy
,					<u> </u>			B1 -	fixed +	Fz
	na	is been m	hade at	the botto	om of the			B2 -	floating	Mx
		ad spectr	um win	dow.						My
Figure 63										Mz
					Run	calculation for	result element	only Result el	ement	3

Enter the load spectrum according to the contents in Fig. 63.

- Calculate the shaft using the corresponding button.
- Evaluate the results in the lower results window.
- Deactivate the load spectrum mode.

Consider load s	pectrum

3

## **11.5 Parameter Variations**

Using the menu point 'Calculation'/'Parameter variation' a dialog for parameter variations is shown. It allows the user to do parameter studies with results provided in tables and graphics. Typical applications are for example visualizing life over clearance, displacement over load or as shown here in the following, clearance over temperature. An optional optimization max., min. for parameter is available too. Further general information on parameter variation can be found in the <u>Manual</u>.



One or more parameters can be configured in 'Generate List'. These can be supplemented with 'Additional Rules'.

1       S1.T[*C] (Shaft 1 'Simple Shaft 01' Temperature)       20       30       10         housing_Temperature [(Housing temperature) ax [m/s <sup>2</sup> ] (Global acceleration in x) acz [m/s <sup>2</sup> ] (Global acceleration in z) oilTemp[*C] (Oil temperature) S1.n [pm] (Shaft 1 'Simple Shaft 01' Temperature) S1.n [pm] (Shaft 1 'Simple Shaft 01' Position) B1.frictionCoefficientFit coefficient for fitting) B2.frictionCoefficientFit coefficient for fitting)       Image: CoefficientFit Coefficient for fitting)         R2.frictionCoefficientFit coefficient for fitting)       Image: CoefficientFit Coefficient for fitting)         R2.frictionCoefficientFit coefficient for fitting)       Image: CoefficientFit Coefficient for fitting)         R2.frictionCoefficientFit coefficient for fitting)       Image: CoefficientFit Coefficient for fitting)         R2.frictionCoefficientFit coefficient for fitting)       Image: CoefficientFit Co	Parameter		Start value	End value	Number of steps		with
housing_Temperature [(Housing temperature) ax [m/s <sup>2</sup> ] (Global acceleration in x) ay [m/s <sup>2</sup> ] (Global acceleration in z) az [m/s <sup>3</sup> ] (Global acceleration in z) oilTemp [*C] (Oil temperature) S1.n [rpm] (Shaft 1'Simple Shaft OI' Temperature) S1.n [rpm] (Shaft 1'Simple Shaft OI' Temperature) S1.r [*C] (Chaft 1'Simple Shaft OI' Temperature) S1.r [*C] (Shaft 1'Simple Shaft OI' Temperature) S1.r [*C] (Chaft 1'Simple Shaft OI' Temperature) S1.r [*C] (Chaft 1'Simple Shaft OI' Temperature) S1.r [*C] (Shaft 1'S	S1.T [°C] (Shaft 1 'Simple Shaft 01' Temperat	ire) 🗸	20	30	10	-	
dditional rules Parameter Start value End value Based on	housing_Temperature [(Housing temperature ax [m/s <sup>2</sup> ] (Global acceleration in x) ay [m/s <sup>2</sup> ] (Global acceleration in z) az [m/s <sup>2</sup> ] (Global acceleration in z) oilTemp [*C] (Oil temperature) S1.n [rm] (Shaft 1 "Simple Shaft 01" Speed) S1.x [rm] (Shaft 1 "Simple Shaft 01" Temperature S1.x [rm] (Shaft 1 "Simple Shaft 01" Position B1.frictionCoefficientFit coefficient for fittis B2.frictionCoefficientFit coefficient for fittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictionCoefficientFittis B2.frictis B	re) ^ re) ig) ig) v				88	
	dditional rules Parameter	Start va	lue End val	ue	Based on	<b>•</b>	

R Parameter variation

×



Jei	ierate List	Optimization	Parameter list	Graphics 1	Graphics 2	Settings			
	S1.T [°C]	B1.lweOp [mm]	B1.lwiOp [mm]	B1.Pdeff [mm]	1			4	
1	20	-0.0231	0.0143939	0.0142377		Inputs	*		
2	21	-0.0231	0.0143941	0.0134198		Results			8
3	22	-0.0231	0.0143942	0.0126019		Bearing 2 'B2'	•	-	1
4	23	-0.0231	0.0143944	0.011784		Shaft 1 'Simple Shaft (	)1' →		•
5	24	-0.0231	0.0143946	0.0109661		Inputs Results			
6	25	-0.0231	0.0143947	0.0101482		Show all inputs			
7	26	-0.0231	0.0143949	0.00933026		Hide all inputs			
8	27	-0.0231	0.0143951	0.00851236		Show all results Hide all results			
9	28	-0.0231	0.0143952	0.00769445					
10	29	-0.0231	0.0143954	0.00687655					
11	30	-0.0231	0.0143956	0.00605864					

Under the 'Parameter list' tab, the required parameter results based on the given parametrization can now be chosen via the context menu.

Parameterisation of the shaft temperature (Fig. 67) to analyse the radial clearance and the effective mean interference Shaft / inner ring.



Perform the parameter study shown in figure 67.

MESYS wishes you an instructive and profitable experience with our tutorials. If you have any questions, suggestions or queries, please do not hesitate to contact <u>info@mesys.ch</u>.