

Tutorial

Shaft Systems - Starter Single-Stage Planetary Gearbox

Table of contents

1.1 Aim of the tutorial 2 1.2 Software version 2 1.3 Notes 2 2 MESYS Shaft Systems 2 2.1 General 2 2.2 Description 3 3. Software Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4 2 Unitial situation 4
1.2 Software version 2 1.3 Notes 2 1.3 Notes 2 2 MESYS Shaft Systems 2 2 I General 2 2.1 General 2 2.2 Description 3 3. Software Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4 2 Unitial situation 4
1.3 Notes 2 2 MESYS Shaft Systems 2 2.1 General 2 2.2 Description 3 3. Software Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4 2 Unitial situation 4
2 MESYS Shaft Systems 2 2.1 General 2 2.2 Description 3 3. Software Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4.2 Unitial situation 4
2.1 General 2 2.2 Description 3 3. Software Manual 3 3. I Online Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4.2 Initial situation 4
2.2 Description 3 3. Software Manual 3 3. 1 Online Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4 2 Initial situation 4
3. Software Manual 3 3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4.2 Initial situation 4
3.1 Online Manual 3 3.2 Manual as PDF. 3 4. Project of a Shaft system 4 4.1 Content of the tutorial. 4 4 2 Initial situation 4
3.2 Manual as PDF
4. Project of a Shaft system
4.1 Content of the tutorial
4.2 Initial situation 4
4.2.1 Requirements
4.2.2 Definition of components
4.3 Illustration
4.3.1 Creating the file
4.3.2 Groups
4.3.3 Components
4.3.4 Gears
4.3.5 Supports
4.3.6 Loads
4.3.7 Lubricant
5. Calculation
5.1 Settings
5.2 Calculation step
6 Results
6.1 Overview of results
6.2 Overview of gear connections
6.2.1 Gear calculation
6.2.2 Results of gear connections
6.3 Load spectra
6.4 Graphical representation of results17
6.4.1 Overview
6.4.2 Graphics menu
6.4.3 Export

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1. Foreword 1.1 Aim of the tutorial

This starter tutorial for the Shaft Calculation extension <u>MESYS Shaft Systems</u> aims to familiarize users with the functionalities and provide an initial impression of its computational capabilities in analysing aspects related to the use of parallel shafts.

As a limitation, only topics and settings are mentioned or dealt with here, that are appropriate for an assumed familiarity with the product and the exercise content. Please do not hesitate to <u>contact MESYS</u> if you have any questions when using the software.

1.2 Software version

This tutorial was created with MESYS Shaft Calculation version 12-2024 from 11.02.2025.

1.3 Notes

A blue arrow indicates an invitation to the reader. A green arrow indicates a conclusion or effect.

2 MESYS Shaft Systems

2.1 General

To get an idea of the possibilities of MESYS Shaft Systems, we cordially invite you to visit the MESYS website at the specific address for <u>Shaft Systems</u>



Please also consult the corresponding articles for shafts or gears under <u>Home/Downloads</u>/Categories according to Fig. 2:





2.2 Description



MESYS Shaft Systems is a software extension to MESYS Shaft Calculation. This makes it possible to display parallel and coaxial shafts in groups (Fig. 4) and to assign further relationships, connections, conditions or loads to them. This makes it possible to analyse the general dynamic and static states of a gear system or specific resulting bearing states.

With an additional license, gear calculations based on corresponding standards (ISO 21771-1 / ISO 6336) can be carried out (Cylindrical gear pairs).



Figure 4

Figure 3

3. Software Manual **3.1 Online Manual**

software The onlinemanual can be accessed via the user interface by selecting the "Help" menu under "Manual F1" (Fig. 5).

You can open the online manual locally at any time with position-specific content directly via your F1 keyboard or find it via the website.



3.2 Manual as PDF

The software manual can also be found as a PDF file in the main languages within the MESYS installation directory (Fig. 6).

File Home Share	View			
\leftrightarrow \rightarrow \checkmark \uparrow \square \rightarrow This P	C > Local Disk (C:) > Mesys 12-2024			
	Name	Date modified	Туре	Size
> 📌 Quick access	MesysHertz64.exe	11/02/2025 16:46	Application	42,710 KB
V 🛄 This PC	MesysManual.exe	11/02/2025 16:46	Application	24,932 KB
3D Objects	Te MESYS-Manual.pdf	11/02/2025 10:22	PDF Document	14,142 KB
> Desisten	i MesysManual-DE.exe	11/02/2025 16:46	Application	24,890 KB
) Desktop	The MESYS-Manual-DE.pdf	11/02/2025 16:43	PDF Document	14,080 KB
> Documents	MesysManual-JA.exe	11/02/2025 16:46	Application	24,822 KB
> 👆 Downloads	The MESYS-Manual-JA.pdf	11/02/2025 10:30	PDF Document	11,462 KB
> 🁌 Music	MesysManual-KO.exe	11/02/2025 16:46	Application	24,983 KB
> E Pictures	MESYS-Manual-KO.pdf	10/02/2025 08:46	PDF Document	11,286 KB
> 😽 Videos	R MesysRBC64.exe	11/02/2025 16:46	Application	46,888 KB
> the Local Disk (C)	MesysReport64.dll	11/02/2025 16:47	Application exten	370 KB
> = u422457 sub1 01u4224	MesysShaft64.exe	11/02/2025 16:46	Application	59,980 KB

Figure 6

MESYS Axial-Radial-Rollerbearings



4. Project of a Shaft system 4.1 Content of the tutorial

A single-stage planetary gearbox equipped with a 4 kW electric drive is to be designed for the automation of pick & place in an integral production system. For this task, a computational confirmation for the intended configuration of the planetary gearbox is to be found using MESYS Shaft Systems.

4.2 Initial situation

4.2.1 Requirements

The following requirements shall be taken into account due to the interfaces to system components:

Input speed:		2000	rpm
Engine torque:	approx.	30	Nm
Output speed carrier:		400	rpm
Torque output:	approx.	150	Nm

4.2.2 Definition of components

4.2.2.1 Number of teeth

The following numbers of teeth are given for the planetary set, which also guarantee mountability at 120°:

Number of teeth	Sun gear	20
	Planets	29
	Ring gear	-79

With fixed ring gear and output via planet carrier:

$$i=1+rac{Z_R}{Z_S}$$

i = 1 + (79 / 20) = 4.95

i: Transmission ratio Z_R : Number of teeth ring gear Z_s : Number of teeth sun gear

Figure 8

With the planet carrier held in place and output via the ring gear:

$$i = \frac{Z_R}{Z_S}$$
 i = 79 / 20 = 3.95

With the sun gear held in place and output via the carrier:

$$i = \frac{Z_R}{Z_R + Z_S}$$
 i = 79 / (79 + 20) = 0.797

At an input speed of 2000 rpm, this results in an output speed via the planet carrier of 404.04 rpm with the ring gear held in place. This fulfils the requirement from 4.2.1.





4.2.2.2 Geometries and positions



Figure 9

Please note the simplified geometries of the shafts to be considered for the calculation.







116 Schnitt A-A 75 32 32

5

27.8 43.8 63.8

Figure 10

Geometrically approximated planet carrier

Ring shaft



The MESYS Shaft Calculation extension FEM Integration (Fig. 12) offers a higher level of realism that may have an effect on the planet carrier. Here it is possible to import shafts, housings or planet carriers as STEP or Nastran meshes.

71

81



4.2.2.3 Parameters

Shaft	Element	Name	Position	Parameters
			[mm]	
Sun	Axial position	Х	0	
	Coupling	Input	0.5	T = 30Nm
	Rolling bearing	B1	29.5	Deep groove ball bearing 16002 generic, radially supported; outer ring (OR) connected to planet carrier
	Cyl. Gear	GS	52.8	mn=1.25, α=20, b=16, z=20
	Support	Support Motor	5	Axially and radially supported
	Speed			Activated, 2000 rpm



8	Axial position	Х	0	
	Support Pin	PL1	0	Planetary Support all fixed; connected to Carrier
	Support Pin	PL2	40	Planetary Support all fixed; connected to Carrier
	Rolling bearing	B2	20	Needle bearing 10x17x13 mm; Z=11, Dw=3.5, Dpw=13.5,
				Lwe=13; radially and axially supported; OR connected to
				Planet
Carrier	Axial position	Х	17	
	Rolling bearing	B3	8	Deep groove ball bearing 61818 generic; radially and axially
				supported to the left; OR connected to housing
	Rolling bearing	B4	63.5	Deep groove ball bearing 61818 generic; radially and axially
				supported to the left; OR connected to housing
	Reaction coupling	Output	110	Width=5
Planet	Axial position	х	13.5	
	Cyl. Gear	GP	6.5	mn=1.25, α=20, b=13, z=29
Ring	Axial position	Х	44.8	
	Cyl. Gear	GR	8	mn=1.25, α=20, b=16, z=-79
	Support	Support	8	Everything fixed
	Speed			Activated, 0 rpm

Table 1

4.3 Illustration

4.3.1 Creating the file

The idealized gearbox is then to be examined under the <u>intended configuration</u> and with the desired loads.

Start the MESYS Shaft Calculation or open a new file via the "New" icon or the "File" menu and select "New" (Fig. 13).

The project for the Shaft calculation can be given a name and a description under 'System' (Fig. 14).

ß	MESYS Shaft Ca	lculation			
Fil	Calculation	Report	Graphics	Extras	Help
(🍕 💽			
SY	stem	P	m	0	CIIC
~	System			U	202
	✓ Shafts Shaft		Engineerin	o Consultine	g Software AG

Figure 13

File Calculation Report	Graphics Extras Help		
🗋 늘 💾 🥳 📑		Give the project a sample name	
System	mocur	and save the file.	
✓ System	LIIO202		Shaft Calculation
✓ Shafts	Engineering Consulting Software AG		
Shaft			
	Project name Single-Stage Plan	netary Gearbox	
	Calculation description Starter Tutorial St	haft Systems	
Figure 14	Settings Lubrication Display set	tings	

4.3.2 Groups

Separate groups are required to calculate parallel Shafts.

System 🗗		🗋 늘 💾 🧳 📑 🚔
 System Shafts Main Group Shaft 	Please assign a group via the context menu 'Shafts' and name it 'Main group'.	System System System Shafts Group 1 Add Group Add Coaxial Group
Figure 15	Group name Main Group Position	Rotation





4.3.3 Components

4.3.3.1 Assignment

System &	l			
 ✓ System 	1		Assign 3	shafts to the Main Group and name them according to
✓ Shafts			<u>Table 1</u> .	
🖌 🖌 Main Group		l		
Sun			Assign 2	Shafts to the Planetary Group and name them accord-
Carrier				
Ring			ing to Ta	able 1.
Planetary Group		_		
Pin 4		Add Shaft		
Planet		Delete Group	5	Figure 18

4.3.3.2 Geometries

All geometries should be transferred at this point.

Figure 19

ystem p ✓ System ✓ Shafts ✓ Main Group Sun Carrier Ring ✓ Planetary Group Pin Planet Positioning	Please reproduce the g ometry of the main group according to the <u>illustrations in 4.2.2.2</u> .	e- Take the geometries for the planet pin and planet from Figures 20 / 21 below.	
Gear connections	Outer Geometry Length [mm] Diameter 1 [mm] Diameter 2 [mm]	L=60.8mm Inner Geometry	L=0mm
	1 0.5 11 12 2 24.5 12	Planetary Group Pin	Figure 20
Figure 19	4 15.8 15	Planet Positioning Gear connections Geometry Loading Supports Sections Setting:	5 L=40mm
 Planetary Group Pin Planet 		Length [mm] Diameter 1 [mm] Diameter 2 [mm]	
Positioning Gear connections	General Geometry Loading Supports Sections	Settings L=13mm Inner Geometry	L=13mm
Figure 21	Length [mm] Diameter 1 [mm] Diameter 2 [mm] 1 13 34	Length [mm] Diameter 1 [mm] Diameter 2 [mm]	





Alternatively, the shaft geometries can be created via import in STEP format. Please refer to the manual for further information.



4.3.3.3 Positions in space

At this point, let us enter the basic axial positions to provide a basis for the subsequent <u>positioning</u> of the shafts in function of the splines.

System & System Shafts Main Group Sun Carrier Ring Planetary Group Pin Planet	Move the x-position of the Carrier to x = 17 mm according to the specifications in Table 1 so that it can be aligned with the sun shaft in relation to the planned position of the gear.					
Positioning Gear connections	General Geometry Loading Supports Sections Settings					
	General Strength					
	Name Carrier Load factor (static) KA_s 1					
	Material Steel V 🌵 Load factor (fatigue) KA_f 1					
Figure 24	Position x 17 mm Overload case Constant stress ratio 🗸					



System Ø System Shafts Main Group Sun Carrier Ring Planetary Group Pin Danet	Move the x-position of the planetary ge cording to the specifications in <u>Table 1</u> s the planned position of the sun gear & r	ar to x = 13.5 mm ac- o that it can align with ing gear teeth.				
Positioning Gear connections	General Geometry Loading Supports Sections Settings					
	General	Strength				
	Name Planet	Load factor (static)	KA_s 1			
	Material Steel 🗸 🔂	Load factor (fatigue)	KA_f 1			
Figure 25	Position x 13.5 mm	Overload case	Constant stress ratio \checkmark			

The ring shaft should only be brought into the correct axial position during <u>gear positioning</u>. Leave it in its current position for the time being.

4.3.3.4 Coordinates

System & System Shafts Main Group Sun Carrier Ring Planetary Group Pin Planet	The location of the groups in space can be viewed at any time under selection in the System tree and then via the Group tab on the far right.	2D 3D 2 2 3D 2 2 2 2 2 2 2 2 3 2 3 2 3 2
Positioning Gear connections	Group name Main Group	Group
	X-Position x 0 mm Rotation angle φ 0 Y-Position y 0 mm Rotation vector rx 0	
Figure 26	Z-Position z 0 mm Rotation vector ry 0 Rotation vector rz 0 0 0 0 0	Bearings

4.3.4 Gears

4.3.4.1 Input

System & V System V Main Group Sun Carrier Ring V Planetary Group Pin Planet		Select the 'Sun' shaft in the System tree and assign an ele- ment under the 'Load' tab with ' 💠 '.	y g	Select the 'Cylindrical gear' type from the dropdown on the right.					
Gear connections	General Cylindr	Geometry Loading Supports Sections Settings ical gear x=52.8mm, 'GS'		4	Cylindrical gear				
		Now assign the gearing data		*	Name GS Position Width		× 52.8	mm	mm
		shafts concerned and assign a designation to each.			Torque Direction of tor Angle to conta	que	Own Input	τ 0	Nm ~
]		Number of teet Normal module	h e		z 20 mn 1.25	mm
		Leave the remaining fields un- touched.			Normal pressur Helix angle	e angle		α _n 20 β _n 0	
]		Number of teet	h of mating gear	_spur gear	z2 0 a 0	mm
Figure 27						Definition	n of gear body		



Cylindrical gear				~	Cylindrical gear				~
Name GR					Name GP				
Position	x 8		mm 🤙		Position	x	6.5	mm 🦛	
Width		b	16	mm	Width		ь	13] mm
Torque		т	0	Nm	Torque		т	0	Nm
Direction of torque	Own Input			~	Direction of torque	Own Input			~
Angle to contact		ζ	0	•	Angle to contact		ζ	0	•
Number of teeth		z	-79]	Number of teeth		z	29]
Normal module		mn	1.25	mm	Normal module		mn	1.25	mm
Profile shift coefficient		x	0]	Profile shift coefficient		x	0]
Normal pressure angle		α,	20	•	Normal pressure angle		α,	20	•

Diamet acou



4.3.4.2 Gear connections

In the next step, the gears must be assigned to each other. The 'Gear connections' window can be viewed under the system tree (Fig. 29). Figure 29



You can define the shafts and gears that are in contact here. At the same time, the basic data of the gear pair is displayed. In addition to the entries on the individual shaft, the gear data can also be modified contemporary in this window and after the calculation step evaluated with regard to safety (Fig. 29).

Connect the two pairs of teeth as shown in Fig. 30 and select suitable colours.

System								M. C. Fashing and state	T1 [Nim1]	T3 [Nim]	CE1	CED	CLI	1 51
× System	 Cylindrical gear pairs 	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH	GS-GP	-	- 12 [IVIII]	SFI	362	эп	5
✓ Shafts	GP-GR	-	-					GP-GR	-	-				
✓ Main Group	Planetary gear sets	T1 [Nm]	T2 [Nm]	T3 [Nm]	SF1	SF2	SF	Planetary gear sets	T1 [Nm]	T2 [Nm]	T3 [Nm]	SF1	SF	2 5
Sun	Bevel gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH	Bevel gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH	1 SH
Carrier	Worm gears	T1 [Nm]	T2 [Nm]	SF	SH	SW	5	Worm gears	T1 [Nm]	T2 [Nm]	SF	SH	SV	/ :
Ring	Couplings	T1 [Nm]	T2 [Nm]					Couplings	T1 [Nm]	T2 [Nm]				
 Planetary Group 	Belt connections	Smin	Fmin [N]					Belt connections	Smin	Fmin [N]				
Pin														
Planet														
Gear connections														
			A DOM		0.1	-			0	olor	1	Color	1	
			olor		Color			Shaft	Planet	0101	Ring	COIDI	~	
	Shaft	Sun		Planet		~		Share	ridrict		- King			
	Gear	GS		∽ GP		~		Gear	GP		GR		~	
	Position	52.8		6.5		m	m	Position	6.5		8			mm
	Number of teeth	20		29				Number of teeth	29		-79			
	Width	16		13		m	m	Width	13		16			mm
	Profile shift coefficient	0		0		8	3	Profile shift coefficient	0		0			=
	Normal module		mn	1.25	mm			Normal module		mn	1.25	mm		
	Normal pressure angle		an I	20	•			Normal pressure angle		α _n	20	•		
	Helix angle		β	0	•			Helix angle		β)	•		
	Helix direction	Spur gea	r	~ Spurg	ear	~		Helix direction	Spur gea	ər	~ Spur	gear	~	
	Center distance		a)	mm			Center distance		a)	mm		
	Circumferential backlas	h	j.	0.1	mm			Circumferential backlas	h	j, (0.1	mm		
	Gear mesh stiffness		c _y	20	N/mn	n/µm 📑	*	Gear mesh stiffness		c _y	20	N/mr	n/µm	*
	Efficiency		ŋ [100	%			Efficiency		n [100	%		
Figure 20	Calculation	MESYS				~	2	Calculation	MESYS				~	Φ

If there is a need to work with the license for <u>Cylindrical gear</u> <u>pairs</u>, the gear calculation according to Fig. 30 can be activated via 'Calculation' and evaluated via the relevant inputs and outputs.

We would like to refer you to further publications or the manual under <u>Gear connections</u>.



Leave the remaining gear-specific parameters and calculation modes unchanged for the scope of this tutorial.

4.3.4.3 Positioning

The groups or shafts should now be aligned relative to each other as a function of the gear connections. A purely axial positioning of the shafts, even in detail, as in <u>chapter 4.3.3.3</u>, is not yet sufficient. In the following process, we bring all gearings into a mathematical relationship with each other. The 'Positioning' window can be activated under the system tree (Fig. 31). The <u>positioning</u> can be carried out using various criteria, such as based on gears or groups in relation to each other

		0
System 🗗	Group 'Planetary Group' according gear pair 'GS-GP'	
✓ System	Shaft 'Ring' according gear pair 'GP-GR'	
✓ Shafts		
Main Group		
Sun		
Carrier		
Ring		
 Planetary Group 		
Pin	Open the window for 'Positioning' via the system tree and use the	
Planet	open the window for rositioning via the system tree and use the	
Positioning		
✓ Gear connections	- Dutton to activate 2 positioning s with the criteria below.	
CC CD		
Group according gear pair	✓ Shaft according to gear pair	~
Group	Planetary Group	~
Cylindrical gear pair	Cylindrical gear pair GP-GR	~

Leave the offset in the x-direction dx and the angle ϕ at 0.

As a result, the group and shaft are now aligned, which can also be called up and viewed in the right-hand window of the 'Gear connections', 'Positioning' dialog and also in the window for 'Shafts' via the system tree (Fig. 32)

As already mentioned, the <u>coordinates of the groups</u> or shafts can also be viewed numerically by selecting the system tree and then the 'Group' tab on the far right.



4.3.5 Supports

4.3.5.1 Rolling bearings

As part of the design, an additional roller bearing should be placed on the sun gear shaft in addition to the motor bearing.

System System System Sun Carrier Ring Planetary Group Pin Planet Bearings B1 Positioning Gear connections GS-GP GP-GR Figure 33	Select 'Sun' in the system tree, assign an element under the 'Sup- ports' tab on the right with ' 🐈' and select the type 'Rolling bear- ing' in the dropdown on the right.								
	Rolling bearing x=29.5mm, 'B1' Rolling bearing Name and position the rolling bear- ing with the corresponding parame- ters from Table1. Name B1 'Geometry, Material, Temperature, Lubrication' is connected Use extended calculation model 'Shaft is supported radially Shaft is supported radially Shaft is supported axially to the left Shaft is supported axially to the right								



MESYS AG



From here, the rolling bearing module for a specific bearing selection can be accessed via the '+' button at the bottom right, via a window, or in the system tree directly via the substitute designation 'B1' now shown here (Figure 34).

System & System Shafts Shafts Main Group Sun Carrier Ring Planetary Group Pin Planet		Please enter the Rolling bearing module.										
✓ Bearings B1	General Geo	ometry Loading Suppor	ts Sect	ons Se	ttings							
Positioning V Gear connections	Rolling bearing	3 x=29.5mm, 'B1'						Rolling bearing V				
GS-GP								Name B1				
or div								Position x 29.5 mm 🧔 🔿				
								Type Deep groove ball bearing Shaft connected to inner ring				
System 🗗	General Bea	ring geometry Bearing con	figuration	Materia	al and Lub	rication	Loadin	Ing Track roller				
 ✓ System ✓ Shafts 	Deep groove b	all bearing	-				~ 4	Select bearing from database				
✓ Main Group Sup	Inner diameter			d	15	m	m 👍 🖡	✓ Dynamic load rating Cr 5.17027 kN				
Carrier	Outer diameter			D	32	m	m 🔶 🛽	✓ Static load rating COr 2.52046 kN				
Ring V Planetary Group	Manufacturer	name	di [mm]	De [mm]	B (mm)	C [kN]	CO IKN	A Fatigue load limit Cur 0.13135 kN				
Pin Planet	SKF	*6002-2RSL	15	32	9	5.85	2.85	Bearing clearance \qquad User input as operating clearance \vee				
✓ Bearings	SKF	*6002-2RSH/VA947	15	32	9	5.85	2.85	Diametral clearance Pd 0 mm 🚍				
B1 'Generic 16002' Positioning	SKF	*6002-2RSH	15	32	9	5.85	2.85	Assign a 'Deen groove hall hear-				
✓ Gear connections GS-GP	SKF	*16002	15	32	8	5.85	2.85	ingl under the lbeeving george				
GP-GR	SKF	*16002-2Z	15	32	8	5.85	2.85	ing under the bearing geome-				
	GMN	HY 6002	15	32	9	5.3	2.55	try' tab using 'Bearing from data-				
	GMN	6002	15	32	9	5.3	2.7	base'. Select generic bearings				
	Generic	16002	15	32	8	5.17027	2.52046	with the designation from Table				
	Generic	6002	15	32	9	5.17027	2.52046	1				
Figure 34	FAG	6002-2RSR	15	32	9	5.9	2.85	× <u><u></u></u>				

Due to the radial space conditions, the load and the intended service life, a customized drawn cup needle roller for B2 is to be used on the planets.

System &	
System Shafts Shafts Main Group Sun Carrier Ring Planetary Group Planet Searings	Please enter the Rolling bearing module.
B1 'Generic 16002'	General Geometry Loading Supports Sections Settings
B2	Rolling bearing x=20mm, 'B2' 👘 Rolling bearing 🗸 🗸
 Gear connections 	
GS-GP	Name B2
GP-GR	🐺 Position x 20 mm <
Figure 35	Type Needle bearing
System &	General Bearing geometry Bearing configuration Material and Lubrication Loading Track roller
✓ Shafts	Needle bearing V 🔂 Enter inner geometry V
✓ Main Group Sun	Inner diameter d 10 mm 🤯 Dynamic load rating Cr 0 kN
Carrier	Outer diameter D 17 mm 🔄 Static load rating COr 0 kN
Ring	Fatigue load limit Cur 0 kh
Planetary Group Pin	Width B 13 mm Falgerbalantik Carlo K
Planet	Number of rolling elements Z 11 Searning clearance User imputs soperating clearance
✓ Bearings B1 'Generic 16002'	Diameter of rolling elements Dw 3.5 mm Diametral clearance Pd 0 mm
B2	Pitch diameter Dpw 13.5 mm 😭
Positioning V Gear connections	Effective length of roller Lwe 13 mm Figure 36

Select 'Enter the internal geometry' (Fig. 36) and transfer the values according to <u>Table 1</u>.

The load ratings are calculated automatically in the first calculation step in accordance with ISO 281.





Now fit the roller bearings for the planet carrier (B3 / B4) according to the parameters in Table 1 (Fig. 37).

For the purposes of this tutorial, please leave bearing settings such as 'bearing clearance' or related fits untouched. Please refer to the <u>Starter Tutorial Basics</u> for rolling bearing calculation.

Bearing clearance	User input as operating clearance $$
Diametral clearance	Pd 0 mm 😑

4.3.5.2 Boundary conditions

System 5 System Shafts Main Group Carrier Ring Planetary Group Pin Planet Bearings B1 'Generic 16002' B2 B3 'Generic 61818' Positioning Gear connections GS-GP GP-GR	Select 'Sun' in the System tree.
	Rolling bearing x=29.5mm, 'B1' Support Support X=5mm, 'B1' Support x=5mm, 'Support Motor' Image: Support Motor Assign an element under the 'Support' tab on the right with 'Image: and select the 'Support' type in the Name Support datally Shaft is supported axially to the left Shaft is support axially to the right
Figure 38	Constant of the right. Constant of the

Assign the corresponding parameters from <u>Table 1</u> for this Support.

Assign the <u>ring gear</u> a 'Support' with the corresponding parameters from <u>Table 1</u>.

As our gearbox will also receive an input torque, a recording of the <u>sum of all torques</u> should be defined. The 'Coupling for reaction torque' element provides this definition (Fig. 39).

System System System Sun Garrier Ring Planetary Group Pin Planet Sun Planet	Select ' <u>Carrier</u> ' in the system tree.	
 Bearings B1 'Generic 16002' B2 B3 'Generic 61818' B4 'Generic 61818' Positioning Gear connections 	General Geometry Loading Supports Sections Settings Rolling bearing x=63.5mm, 'B4' Coupling reaction moment x=110mm, 'Reaction coupling' Image: Coupling for reaction torque Image: Coupling for reaction torque Image: Coupling for reaction torque Name Output Image: Coupling for reaction torque Position x 110 Image: Coupling for reaction torque Image: Coupling for reacting for reaction torque Image	
GS-GP GP-GR	Assign an element under the 'Supports' tab on the right with '	
	type 'Coupling for reaction torque' in the dropdown on the right. Assign the corresponding parameters from <u>Table 1</u> for this coupling.	

Please note that the width of the coupling display and the activation for modal analysis are not relevant for this calculation.



System & System Subafts Main Group Sun Carrier Ring Planetary Group Planet Bearings	Select ' <u>Pin</u> ' in the System tree, assign an element under the 'S ports' tab on the right with ' 🛟 ' and select the type 'Planet su port' in the dropdown on the right.	up- ip-
B1 'Generic 16002' B2 B3 'Generic 61818' B4 'Generic 61818' Positioning SG-GP GP-GR Figure 40	General Geometry Loading Supports Settings Rolling bearing x=20mm, 'B2' Planetary support x=20mm, 'PL1' Planetary support x=40mm, 'PL2' Name PL1 Planetary support x=40mm, 'PL2' Position Connect to shaft 'Carrier' Shaft is supported axially Shaft is supported against tilti Shaft is supported against tilti Shaft is supported against tilti	x 0 mm (m) (m)

Last but not least, the axial support of the planets, which is missing trough the drawn cup needle roller, should also be added. Such supports realized by stop covers or collar rings, for example, can be illustrated here as shown in Figure 41.



4.3.6 Loads

4.3.6.1 Speeds

System 5 System Shafts Main Group Garrier Ring Planetary Group Pin Planet	Select ' <u>Sun'</u> in the Syste the right under the 'Ger ing to <u>Table 1.</u>	m tree, activate the box for speed on neral' tab and enter the value accord-	
 Bearings B1 'Generic 16002' B2 B3 'Generic 61818' 	General Geometry Loading Supports Section	ons Settings Strength	
B4 'Generic 61818'	Name Sun	Load factor (static)	KA_s 1
Positioning	Material Steel	V Load factor (fatigue)	KA_f
GS-GP	Position	x 0 mm Overload case	Constant stress ratio \checkmark
GP-GR	Speed	n 2000 rpm 🗹 Diameter at heat treatment	d _{aff} 0 mm 🗆
Figure 42	Temperature	T 20 °C Number of load cycles	N 1 10 ⁶

Please activate the speed for the <u>Ring Shaft</u> and enter 0 rpm.

4.3.6.2 Torque

The input torque for the planetary gearbox is 30 Nm as defined in the requirements.



The 'Direction of torque' can be defined either by its sign or by selecting "Shaft is driven" / "Shaft is driving".

System 8 System Shafts Main Group Carrier Ring Planetary Group Pin Planet Searings	Select 'Sun' in the System tree, assign an el ing' tab on the right with ' ' and select th dropdown on the right.	ement under the 'Load- e 'Coupling' type in the	
B1 'Generic 16002' B2 B3 'Generic 61818' B4 'Generic 61818' Positioning CGear connections GS-GP GP-GR	Cylindrical gear x=52.8mm, '65' Coupling x=5mm, 'Input'	Coupling Coupling Name Input Position x 5 Width Torque Direction of torque Own Input	

4.3.7 Lubricant

Please assign the lubricant as shown in Fig. 44

System &	mes	US		Shaft Calculation	Figure 44
✓ Shafts	Engineering Consulting Softw	are AG			
 Main Group 					
Sun Carrier	Project name	Single-Stage Planetary Gear	rbox		
Ring	Calculation description	Starter Tutorial Shaft System	ns		
 Planetary Group Pin 	Settings Lubricat	tion Display settings			
Planet	150 1/0 50 minorel a	1		Oil behindlige without on line Eller ICO 4405 (17/14	
✓ Bearings	150 VO 08 minerar 0			On lubrication without on-line linter 1504400 -/ 17/ 14	Т
B1 'Generic 16002'	Oil			Temperature	TOil 70 °C
B2 Needle bearing	10 10 1000		40 50		
B3 'Generic 61818'	Viscosity at 40°C		nu40 68 mm*	's Oil density	ρ 880 kg/m*
B4 'Generic 61818'	Viscosity at 100°C		nu100 9 mm ²	/s Pressure viscosity coefficient	α 0.0153881 1/MPa
Positioning	_				
 Gear connections 	contains effective	EP additives		FZG load stage	FZG 12

This concludes the input of the parameters for the mathematical representation of the gearbox.

5. Calculation

5.1 Settings

For gear calculations, the "Required life H" should be defined in the 'Settings' window of the System tree / System if possible (Fig. 45). In addition to the evaluation of the gearing, this value is also included in the calculation of the shaft strength in accordance with DIN 743. For more information, see the manual under <u>Required service</u> <u>life</u> or <u>Strength calculation</u>.

System 🗗	MOCUL				ente ottoponte est				
✓ System	1116202				Shaft Calcula	ation			
✓ Shafts	Engineering Consulting Software AG								
 Main Group 									
Sun	Project name Single-Stage Pla	netary Gearbox							
Carrier	Caladatian description (States Tates in 19	The fit Container							
King	Calculation description Starter Tutonal S	snart systems							
Pin	Settings Lubrication Display set	ttings							
Planet	Consider weight			4	Housing material	teel		× 4	3
P1 'Generic 16002'									-
B2 Needle hearing	Angle for weight	ſ	-90		Housing temperature		T _h 20	*(С
B3 'Generic 61818'	Calculate natural frequencies				Required life		H 20	000 h	
B4 'Generic 61818' Positioning	Consider gyroscopic effect			÷	Bearing reliability		S 90	%	
 Gear connections 	Maximum frequency	f	max 1000	Hz	Strength calculation		Infinite life according DIN 743		~
GS-GP GP-GR	Number of frequencies	1	N _{freq} 10		Bearing position		Definition for each bearing		~
	Consider gears as stiffness	Increase shaft diameter		\sim	Shear deformations		According Hutchinson	~	22
	Consider gears as point load	Gear is load only		~	Consider nonlinear sha	ft model			
	Consider housing stiffness	3D-model using central no	des						_
Figure 45	Consider configurations	3D-model							
		3D-model with teeth							



It is also useful to make a selection for the possible settings at "Consider gears as stiffness " (Fig. 45). With "Increase shaft diameter", for example, the shaft diameter is increased to root diameter plus 0.4*module automatically. For the root diameter a dedendum of the reference profile of 1.25 is assumed. Please refer to the corresponding contents of the other settings in the manual under <u>Consider gears as stiffness</u>.

5.2 Calculation step

The calculation step can be carried out via the menu item 'Calculation'/Calculate', directly via the icon under the ribbon or simply by pressing F5.

Please start the calculation.

Note the green tick at the bottom right, which confirms the consistency of the calculation step.

1

Calculate

6 Results

(6.1 Overview of	results Fig	gure 46
	Result overview		8
	Minimal bearing reference life	minL10rh 128220 h Minimal bearing modified reference life minLnmrh 17956.2 h Minimal static safety for bearings (ISO 17956) minS0eff 8.83033	
	Maximal equivalent stress	maxSigV 163.751 MPa Minimal root safety for gears minGearSF 2.58534 Minimal flank safety for gears minGearSH 0.910531	
	Maximal displacement in x	maxUx 0.000207665 mm Maximal displacement in radial direction maxUr 0.108541 mm Maximal bearing stress pmax 1352.28	MPa

The results overview at the bottom of the window shows the most important results (Fig. 46). Its contents can be configured as required via the Extras / Results overview menu.

The choice of a higher viscosity lubricant shows that the modified reference service life (Figure 47) could be increased substantially and to the level of <u>value H</u>.

	ISO VG 100 mineral oil VG 100 mineral oil VI Iubrication without on-line filter ISO4406 -/17/14
Minimal bearing reference life	minL10rh 128220 h Minimal bearing modified reference life minLnmrh 20906.2 h Minimal static safety for bearings (ISO 17956) minS0eff 8.83033
Maximal equivalent stress	maxSigV 163.751 MPa Minimal root safety for gears minGearSF 2.58534 Minimal flank safety for gears minGearSH 0.929774
Maximal displacement in x	maxUx 0.000207666 mm Maximal displacement in radial direction maxUr 0.108541 mm Maximal bearing stress pmax 1352.28 MP

6.2 Overview of gear connections

6.2.1 Gear calculation

The gearing results also promote values as a function of the activated license. In this example calculation, the gear calculation has been activated (Fig. 30), even if the entries have not been edited.

System 🗗	General Geometry Reference profile Details for stren	ath							
✓ System	deneral desineary indicate provide a statistic terrain								
✓ Shafts	Dynamic factor	K _v 1.02888	Tip relief	C₂ 0 0 μm					
 Main Group Sun 	Mesh load factor	Κ _γ 1	Root relief	C _r 0 0 μm					
Carrier	Face load coefficient	К _{нр} 1.25	Surface roughness flank	R _{zH} 6 6 µm					
Ring V Planetary Group	Profile modifications compensate deflections		Surface roughness root	R _z , 18 18 μm					
Pin	Limited pitting allowable		Web thickness	b _s 0 0 mm					
✓ Bearings	Required safety factor root	S _{Fmin} 1.4	Number of meshes	N _M 1 1					
B1 'Generic 16002' B2 Needle bearing	Required safety factor flank	S _{Hmin} 1	Reversed bending	No ~ No ~					
B3 'Generic 61818'			Mean stress influence factor	Y _M 1					
Positioning	The gear calculation can be	a anonad by a	olocting the gear pair in t	be system tree //Coor					
 Gear connections GS-GP 	The gear calculation call be	The gear calculation can be opened by selecting the gear pair in the system tree / Gear							
GP-GR	connections'. The gear par	connections'. The gear parameters can be edited here and the entries are then read							
Figure 48	back when the gear calcula	ation is closed							

н

F5

0



6.2.2 Results of gear connections

In the window for 'Gear connections' (Fig. 49), torques, safety factors for tooth root and flank safety (SF / SH) and the width load distribution (wmax / wavg) according to ISO 6336 are displayed for each toothing.

Performance data, geometric data and profile shift factors (x1 / x2) are displayed in the lower window.

It is noticeable in the context of our design that the flank safety 'SH' of 0.93 is below the usual values for standard industrial gears. However, a look at the window for gear connections shows acceptable values for tooth root safety SF and width load distribution wmax/wavg for both gear pairs.

Applying a profile shift factor of 0.3 each to VZ_SR and VZ_PL, for example, substantially increases the tooth root safety SF and increases the flank safety to> 1 (Figure 50).

									0
n 67	✓ Cylind	lrical gear	pairs T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2	wmax/wavg
stem	✓ GS	-GP	-						
Shafts		Planet 1	9.996	14.49	3.06	2.99	0.93	0.98	1.15
 Main Group 		Planet 2	9.998	14.50	3.06	2.99	0.93	0.98	1.13
Sun		Planet 3	10.01	14.51	3.05	2.98	0.93	0.98	1.16
Carrier	→ GF	P-GR	-	-	2.50	2.00	1.00	1.70	1.02
 Planetany Group 		Planet 1	- 14.49	39.48	2.59	2.98	1.09	1.75	1.03
Pin		Planet 2	-14.30	39.49	2.59	2.90	1.09	1.75	1.02
Planet	Planet	any dear si	ets T1 [Nm]	T2 [Nm]	T3 [Nm]	SE1	SE2	SE3	SH1
Bearings	Bevel	gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2	0.11
B1 'Generic 16002'	Worm	gears	T1 [Nm]	T2 [Nm]	SF	SH	SW	ST	SB
B2 Needle bearing			T1 [Mess]	T2 [Nim]					
B3 'Generic 61818'		GS-GP	GP-GR						
B4 'Generic 61818'	Chaff 1	Sun	Dianet						
Positioning	Sharen	Jun	rialice						
Gear connections	Shaft 2	Planet	Ring						
GP-GR	P [W]	2093.51	1057.33						
	n1 [rpm]	2000	-696.621						
	n2 [rpm]	-696.621	1.68873e-88						
	u	1.450	2.724						
	a [mm]	30.625	30.625						
	mn [mm]	1.25	1.25						
	alpha [°]	20.0000	20.0000						
	beta [°]	0.0000	0.0000						
	z1	20	29						
	z2	29	-79						
	x1	0.000	0.000						
	x2	0.000	0.459						
	Cylindrical o	lear pairs	T1 [Nm] T2	[Nm]	SF1	SF2	SH1	SH2 v	wmax/wavg
7 SR and	✓ GS-GP		-	-					
	Plan	et 1	9.995	14.49	3.34	3.10	1.02	1.08	1.12
the tooth	Plan	et 2	9.999	14.50	3.34	3.10	1.02	1.08	1.11
4 / 5	Plan	et 3	10.01	14.51	3.33	3.09	1.02	1.08	1.14
> 1 (Figure	✓ GP-GR		-	-					

Planet 1

Planet 2

-14.49

-14.50

-14.51

39.48

39.50

39.52

2.75 3.51 1.89 1.96

2.75

2.75 3.50 1.89 1.96

3.50

1.89 1.96

Consider load spectrum

Figure 50

1.02

1.02

1.03

Figure 49

If there is a need to work with the license for <u>Cylindrical Gear Pairs</u>, the gear calculation can be activated according to <u>Figure 30</u> and further evaluated using the relevant inputs and outputs. We would like to refer you to the official scope of services or the manual under <u>Gear connections</u>.

Syster × Sy

6.3 Load spectra

A load spectrum can be entered via the system window under the 'Settings' tab. This allows the corresponding input window to be accessed via the system tree.

You can find more information on this in our <u>Shaft Starter Tutorial</u> or in the manual under <u>Calculation with load</u> <u>spectrum</u>.

6.4 Graphical representation of results

6.4.1 Overview

In addition to numerous other graphics under the Graphics menu that are useful for evaluating gears, below the line load and gap width above position for the present calculation (Fig. 51).





The line load (Fig. 51) shows the load on all 3 contacts. The slight difference is due to the weight of the shafts.

The gap width (Fig. 51) indicates the distance between the flanks if the load transfer would only take place at one point. In this case, a flank line correction based on a gap width of max. 0.6 µm would not be economically justifiable

The above diagrams were created with the setting "<u>Increase shaft diameter</u>". Tooth mesh stiffness, shaft and bearing stiffness have an influence on these diagrams. However, manufacturing errors and housing rigidity also have an influence on the real gearbox.

6.4.2 Graphics menu

A large selection of graphical result displays is available via the 'Graphics' menu (Fig. 52).



Flank modifications (GS-GP) Relative displacement (GS-GP) Specific sliding over diameter Specific sliding over profile shift Safety factors over profile shift Tooth root stress Gear 1 Tooth root stress Gear 2 Tooth root stress (2D) Gear 1 Tooth root stress (2D) Gear 2 Tooth form Gear 1 Tooth form Gear 2 Single tooth Gear 1 Single tooth Gear 2 Manufacturing Gear 1 Manufacturing Gear 2 Manufacturing Gear 1 (animated) Manufacturing Gear 2 (animated) Geometry (2D) Gear 1 Geometry (2D) Gear 2 Geometry (3D) Gear 1 Geometry (3D) Gear 2 Gear engagement Gear engagement (animated) Gear engagement (3D) Safety over life Limiting stress over life Permissible stress over life Permissible torque over life

Line load (GS-GP)

Gap width (GS-GP)

Power flow

Animated, with and without Deformation

Tooth root tension

The graphics can be docked to the main program interface with the current outputs and are automatically updated after each calculation (Fig. 53). Drag the graphics into the results overview or under the menu bar.





6.4.3 Export

The 'CAD' menu item can be used to display the shaft system or components from it and can also be exported as a STEP file for further use by clicking on the context menu.

File Calculation Report	Graphics Extras Help		
🗋 🍋 🖪 🚳 🗍	CAD	•	Shaft geo
Surtan	Main Group	•	Shaft geo
system	Planetary Group Equivalent stress Campbell diagram Harmonic response 3D		Shaft geo Group ge_
 System Shafts 			
✓ Main Group			Group geo
Sun			Geometry
Carrier	Geometry 3D		Detailled g



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