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Tutorial

Shaft Systems - Starter
Single-Stage Planetary Gearbox

Table of contents

1. Foreword

1.1 Aim of the tutorial

This starter tutorial for the Shaft Calculation extension MESYS Shaft Systems 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 contact MESYS if you have any questions when using the software.

1.2 Software version

This tutorial was created with MESYS Shaft Calculation version 12-2025.

1.3 Notes

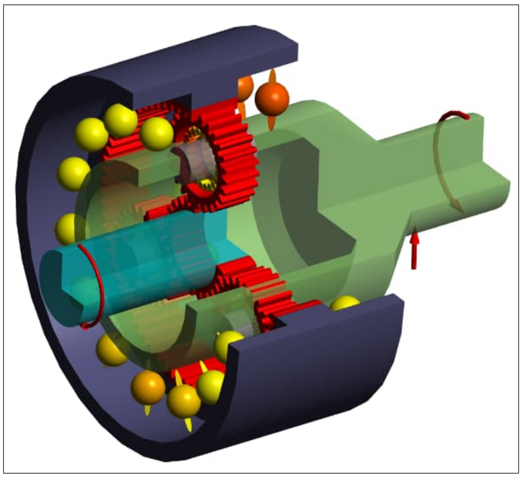
A blue arrow indicates an invitation to the reader.
A green arrow indicates a conclusion or effect.

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 Shaft Systems

Figure 1



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

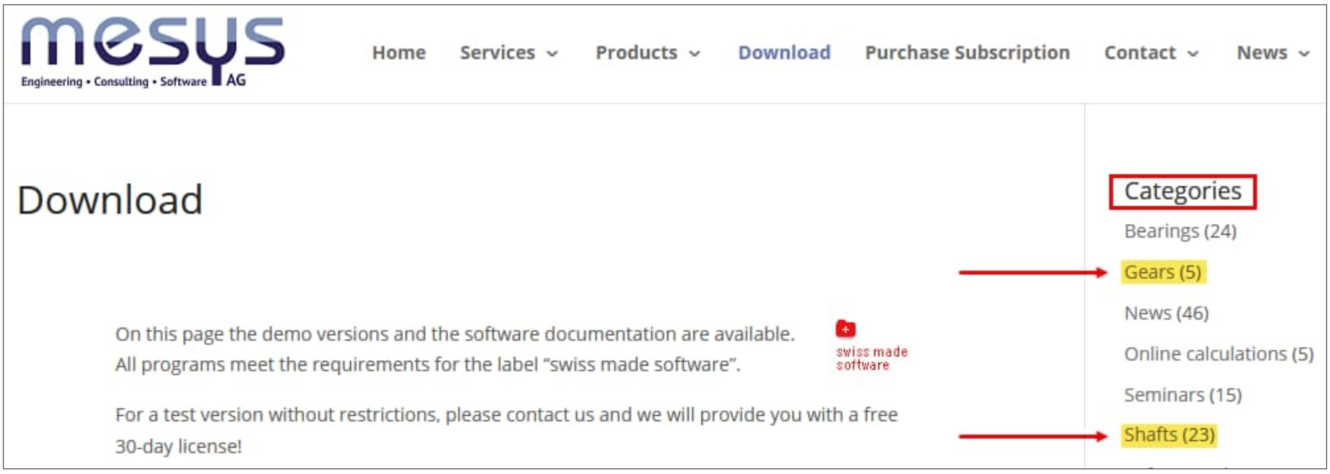


Figure 2

2.2 Description

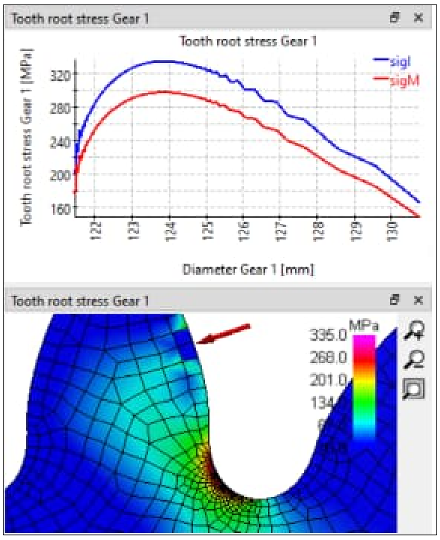


Figure 3

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).

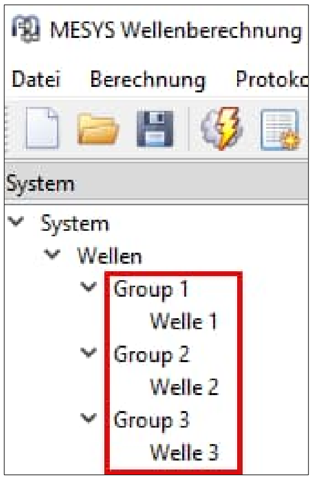


Figure 4

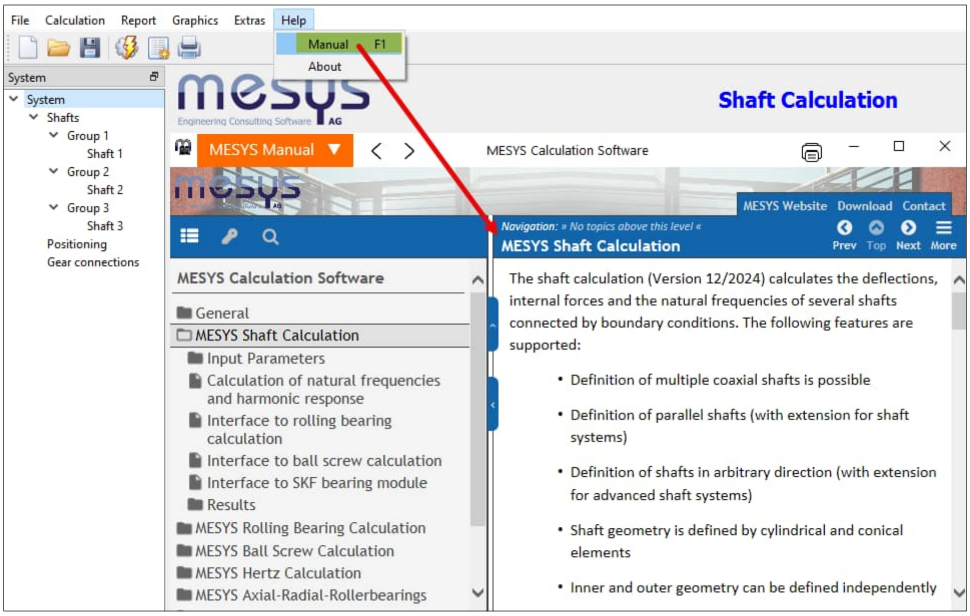
3. Software Manual

3.1 Online Manual

The software online-manual 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.

Figure 5



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).

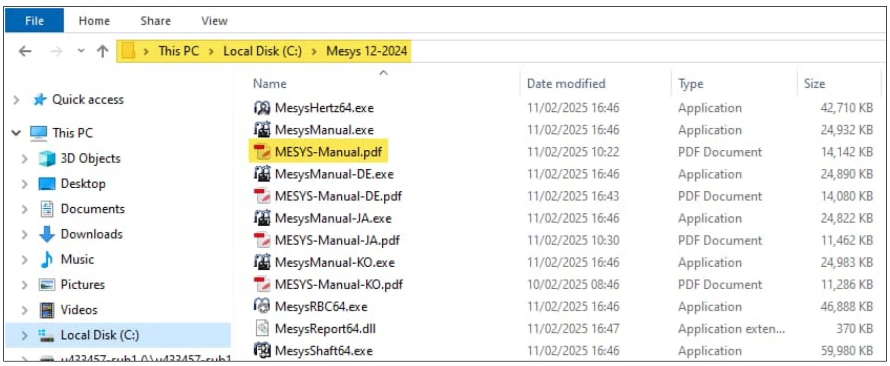


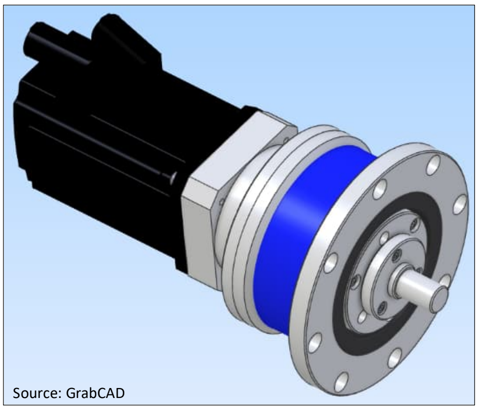
Figure 6

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.

Figure 7



Source: GrabCAD

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

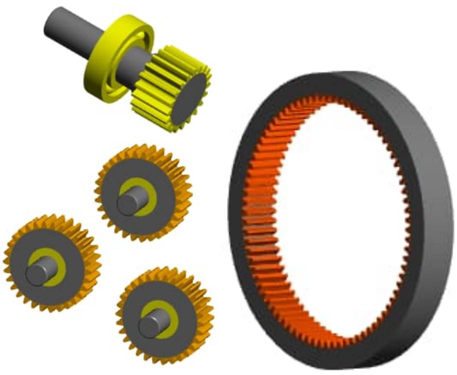


Figure 8

With fixed ring gear and output via planet carrier:

$$i = 1 + \frac{Z_R}{Z_S}$$

i = 1 + (79 / 20) = 4.95

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

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

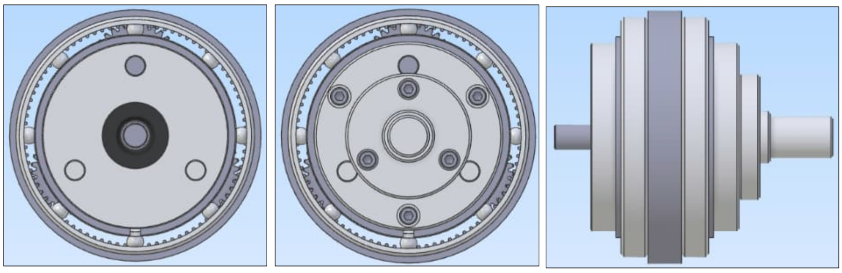
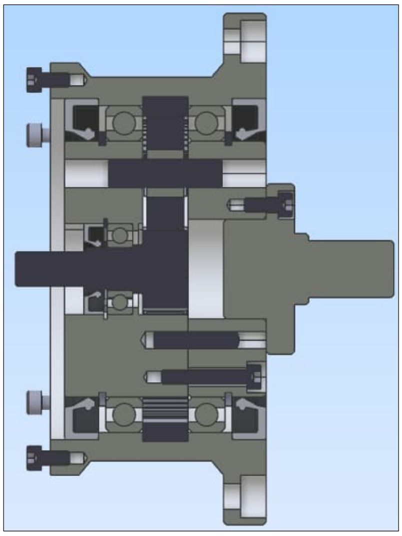
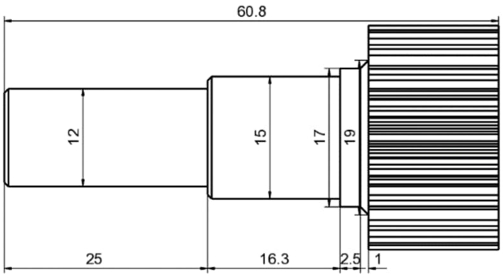


Figure 9



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

Shaft sun wheel



Geometrically approximated planet carrier

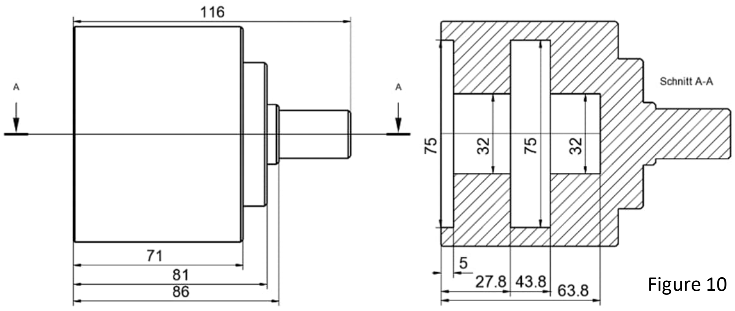


Figure 10

Ring shaft

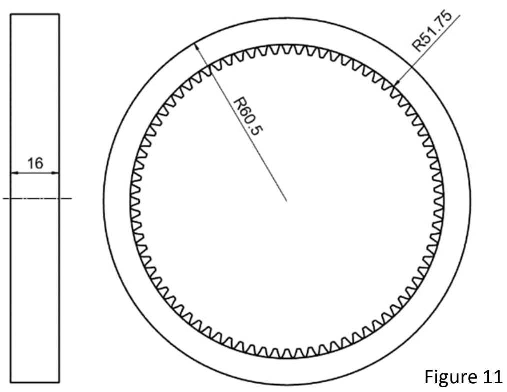


Figure 11

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.

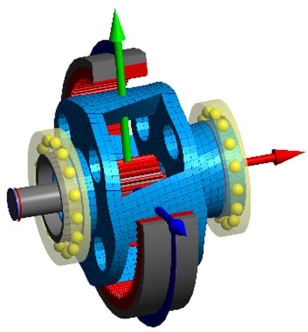


Figure 12

4.2.2.3 Parameters

Shaft	Element	Name	Position [mm]	Parameters
Sun	Axial position	X	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	X	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	X	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	X	13.5	
	Cyl. Gear	GP	6.5	mn=1.25, α=20, b=13, z=29
Ring	Axial position	X	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 intended configuration 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).

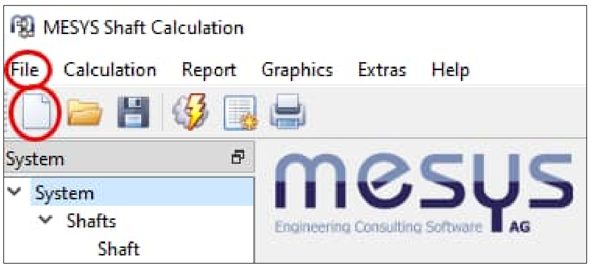


Figure 13

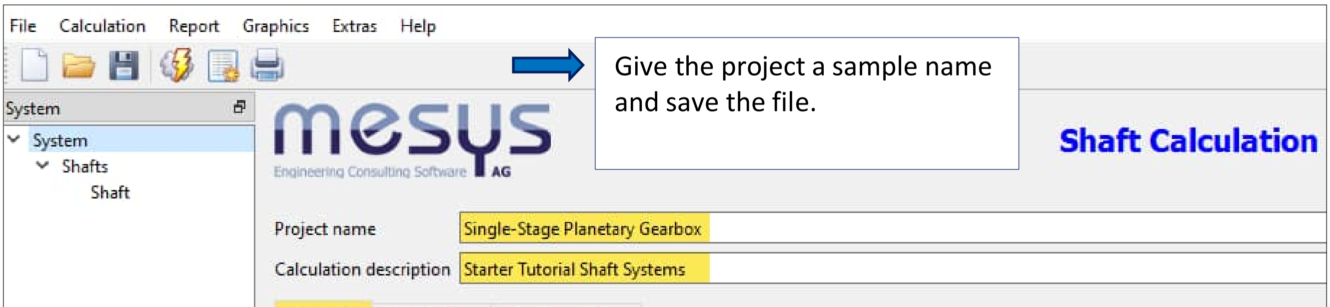


Figure 14

4.3.2 Groups

Separate groups are required to calculate parallel Shafts.

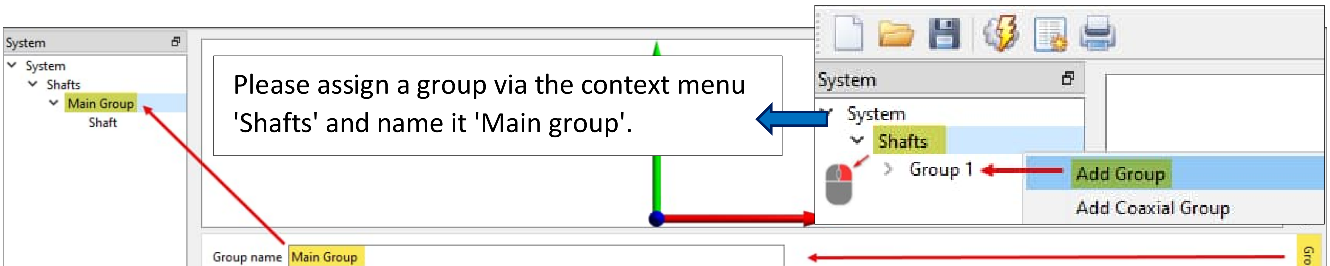


Figure 15

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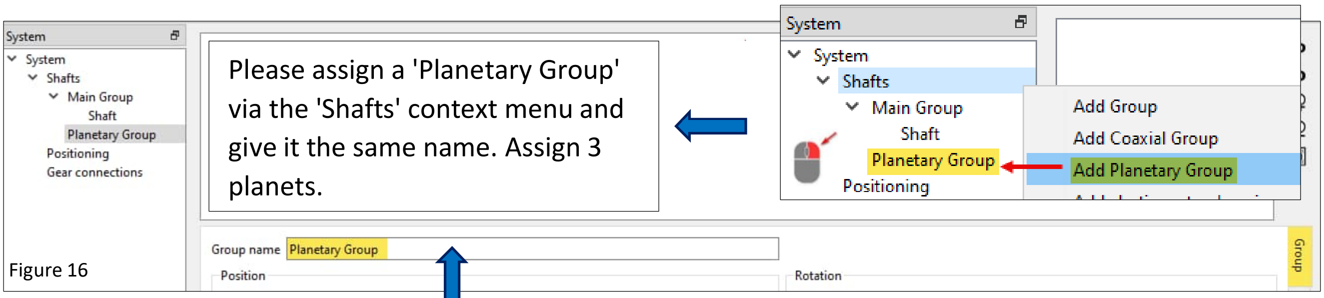


Please assign a 'Planetary Group' via the 'Shafts' context menu and give it the same name. Assign 3 planets.

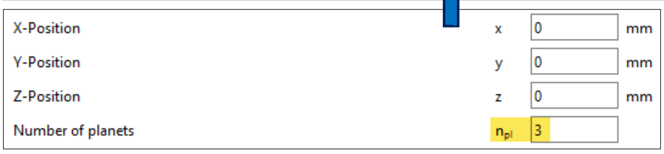


Figure 16

Please note that you can alternatively assign a prefabricated "Planetary gearbox" system via the context menu on 'Shafts' (Fig. 17).

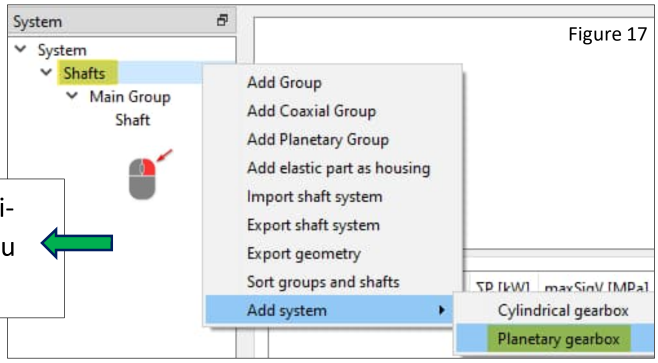
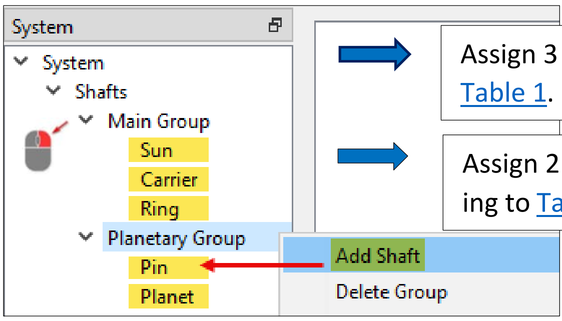


Figure 17

4.3.3 Components

4.3.3.1 Assignment



Assign 3 shafts to the Main Group and name them according to Table 1.

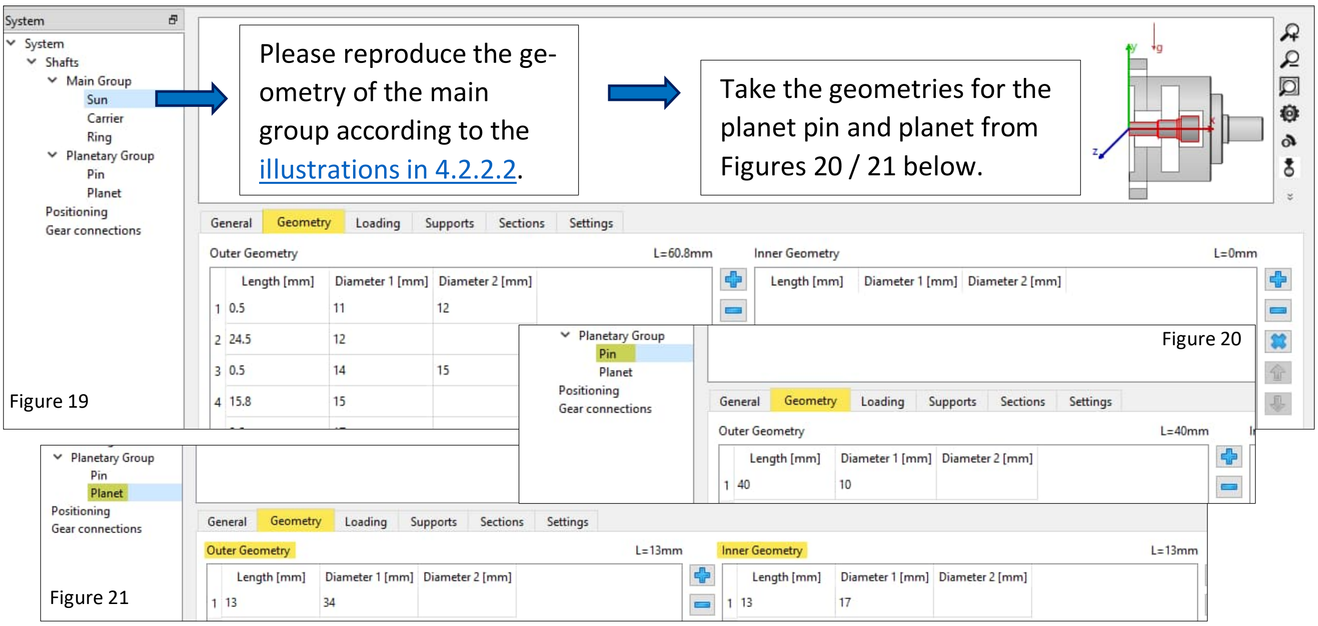
Assign 2 Shafts to the Planetary Group and name them according to Table 1.

Figure 18

4.3.3.2 Geometries

All geometries should be transferred at this point.

Figure 19



Please reproduce the geometry of the main group according to the illustrations in 4.2.2.2.

Take the geometries for the planet pin and planet from Figures 20 / 21 below.

Figure 19

Figure 20

Figure 21

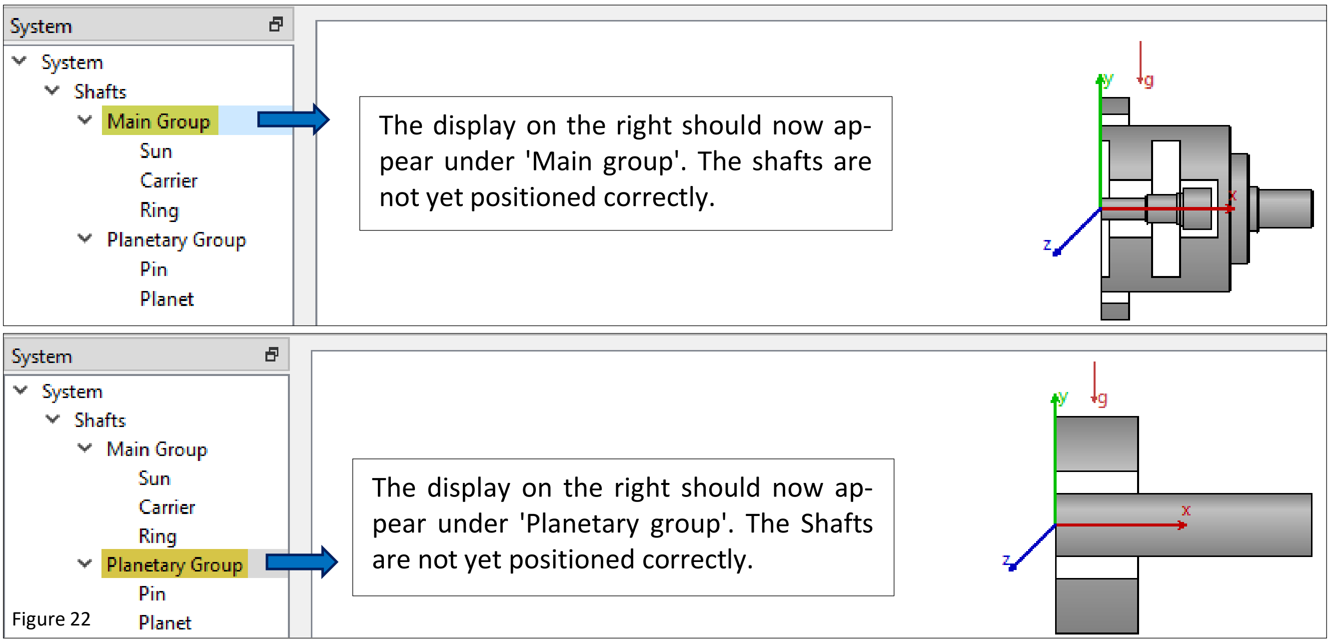


Figure 22

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

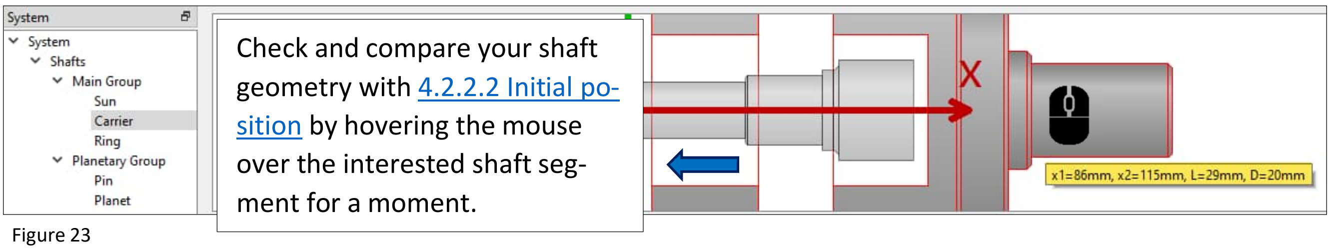


Figure 23

4.3.3.3 Positions in space

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

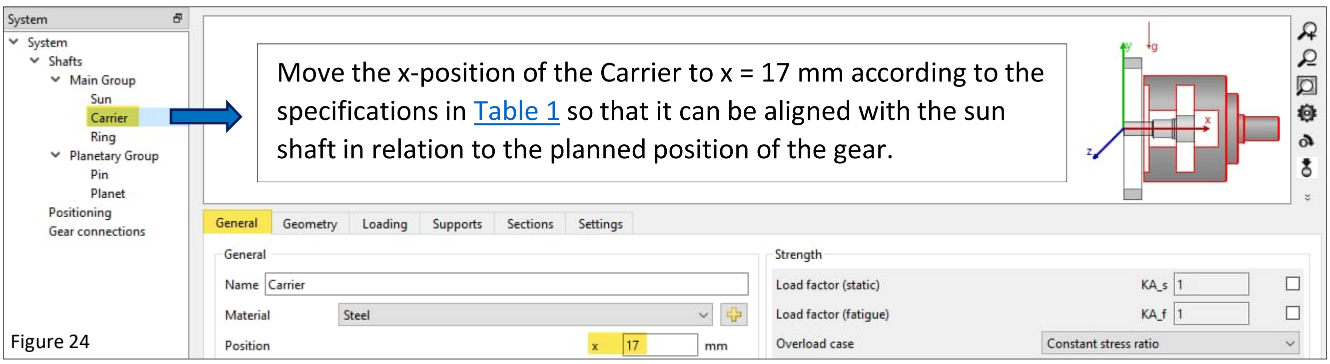


Figure 24

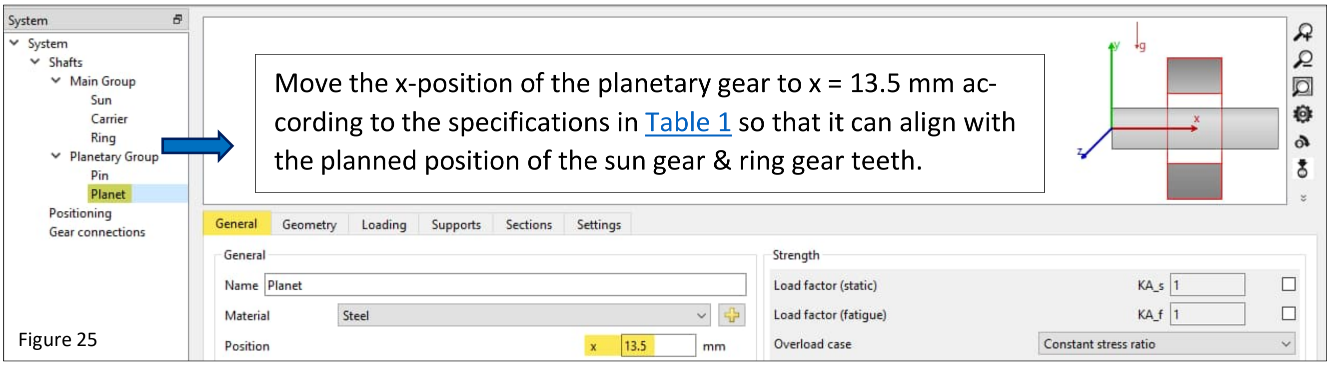


Figure 25

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

4.3.3.4 Coordinates

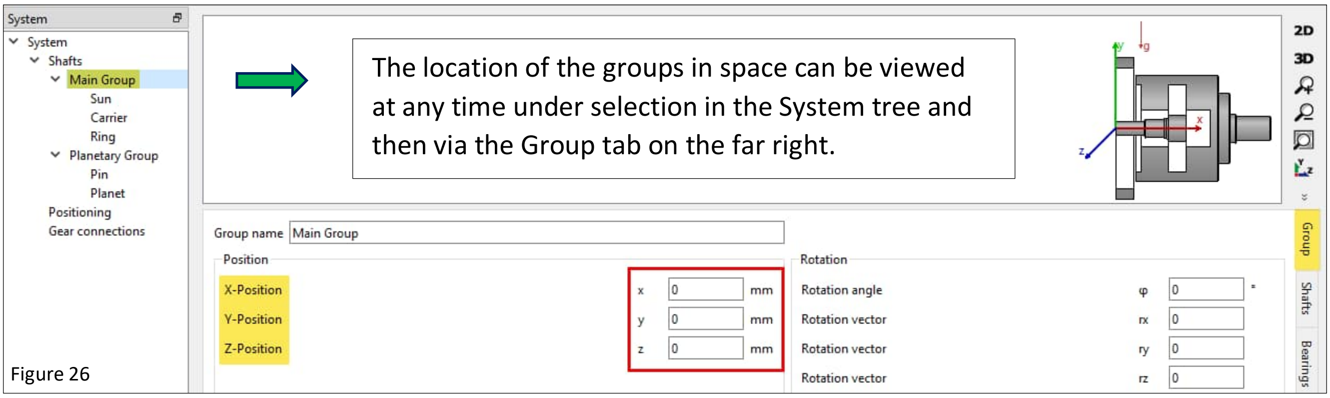


Figure 26

4.3.4 Gears

4.3.4.1 Input

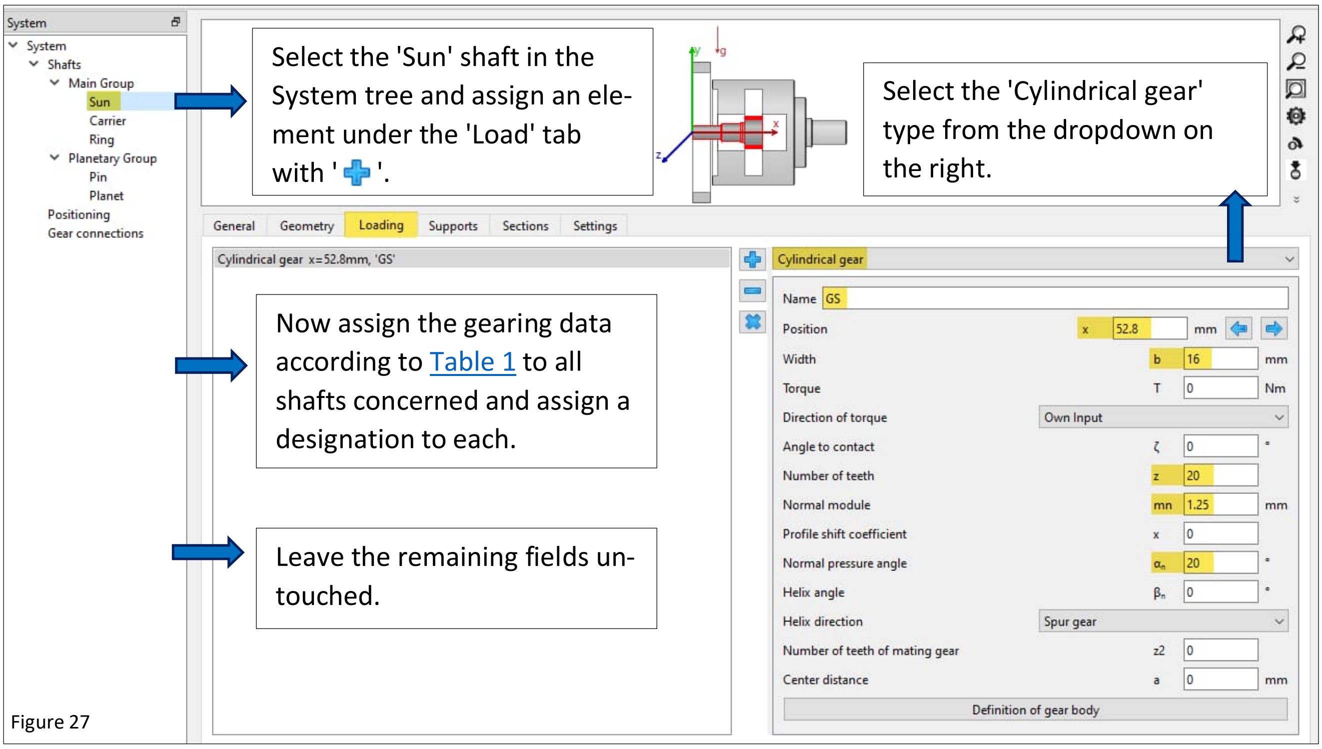


Figure 27

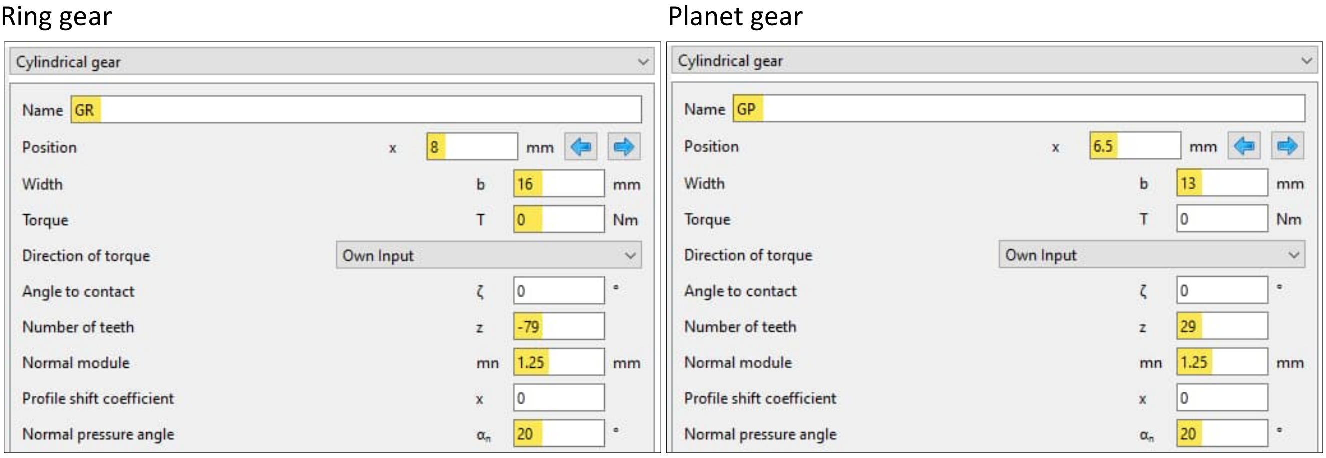


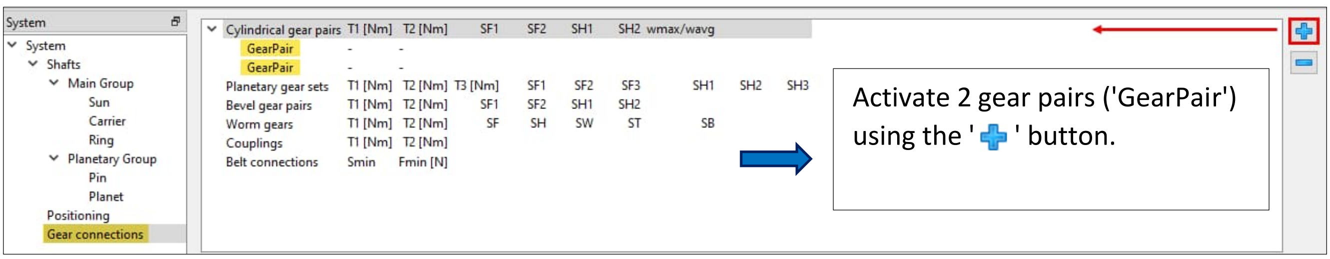
Figure 28

➡ Enter negative numbers of teeth for internal gears.

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.

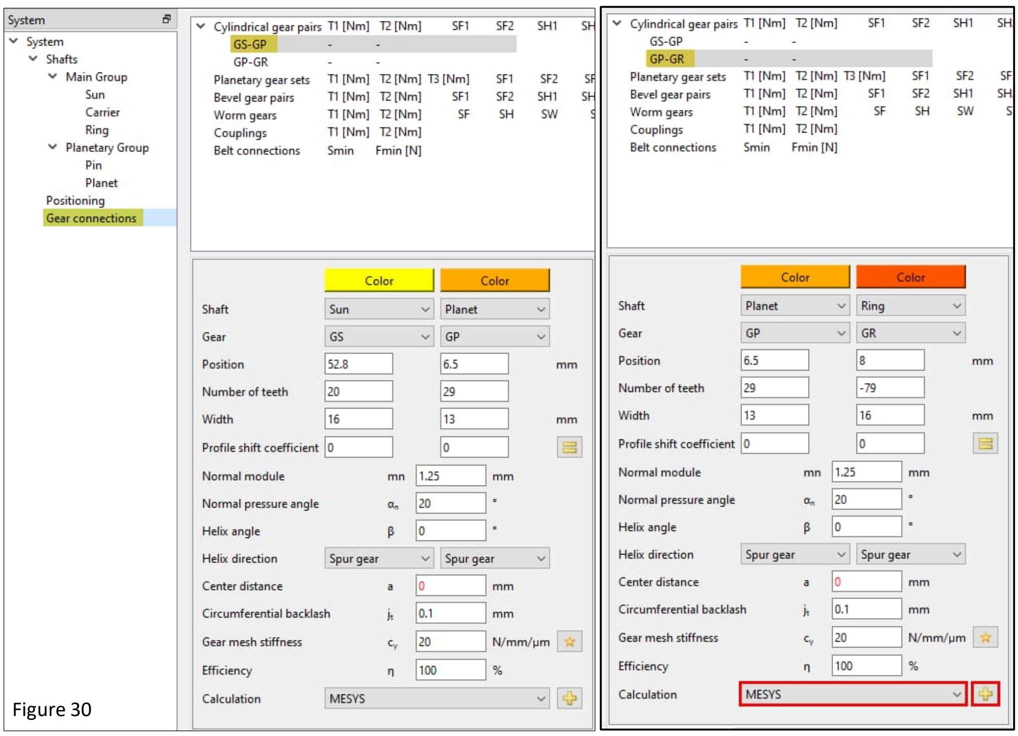


Figure 30

If there is a need to work with the license for [Cylindrical gear pairs](), the gear calculation according to Fig. 30 can be activated via 'Calculation' and evaluated via the relevant inputs and outputs.

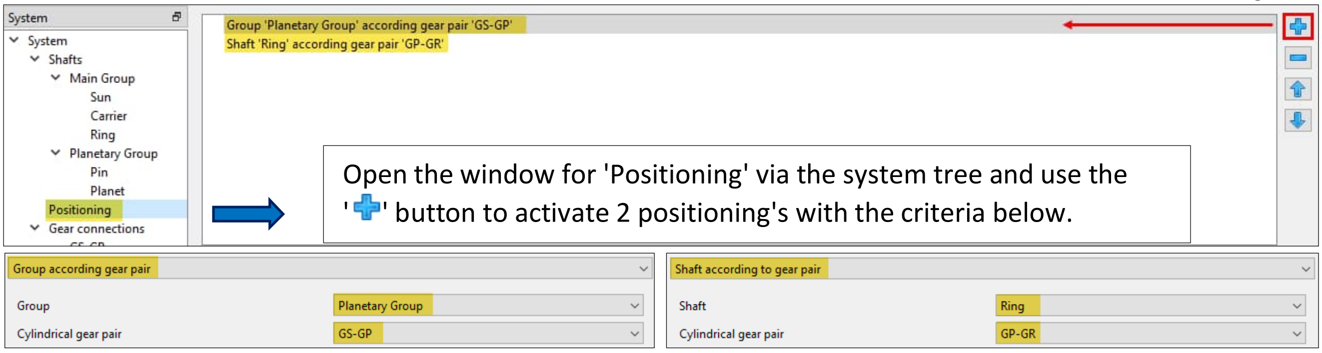
We would like to refer you to further publications or the manual under [Gear connections]().

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

4.3.4.3 Positioning

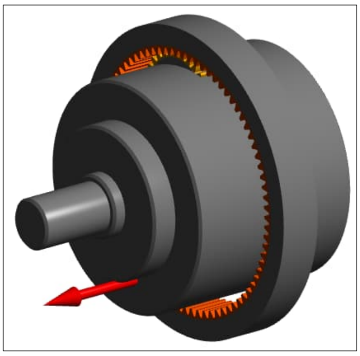
The groups or shafts should now be aligned relative to each other as a function of the gear connections. A purely axial positioning of the shafts, even in detail, as in chapter 4.3.3.3, is not yet sufficient. In the following process, we bring all gearings into a mathematical relationship with each other.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

Figure 31



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

Figure 32



- 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 coordinates of the groups 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.

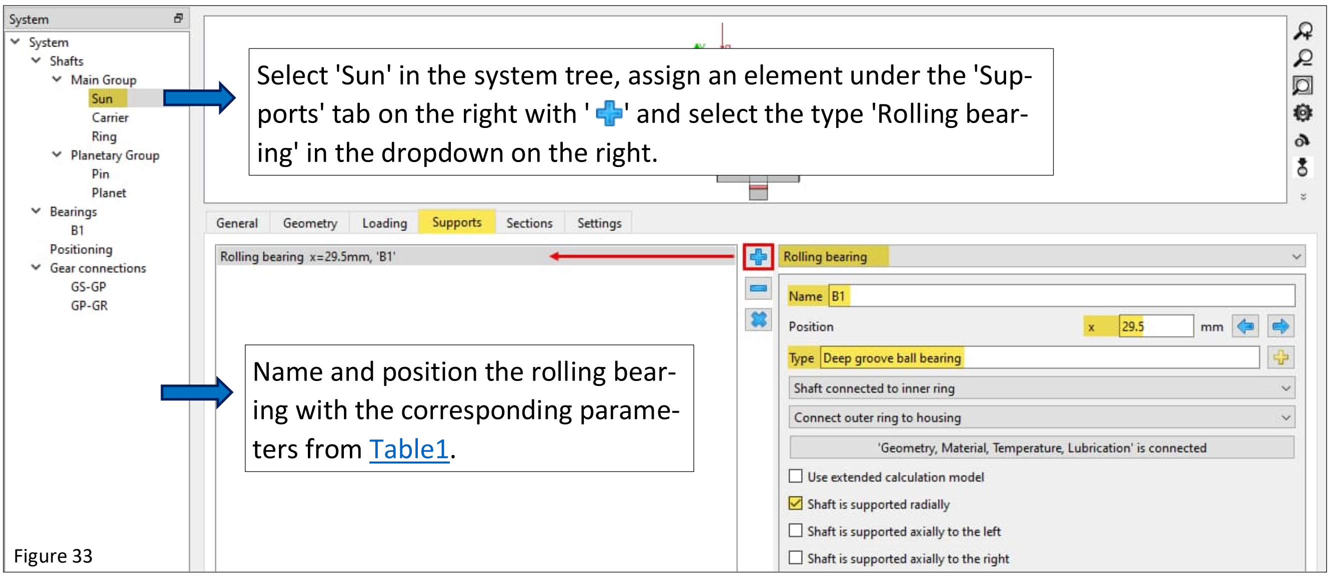


Figure 33

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).

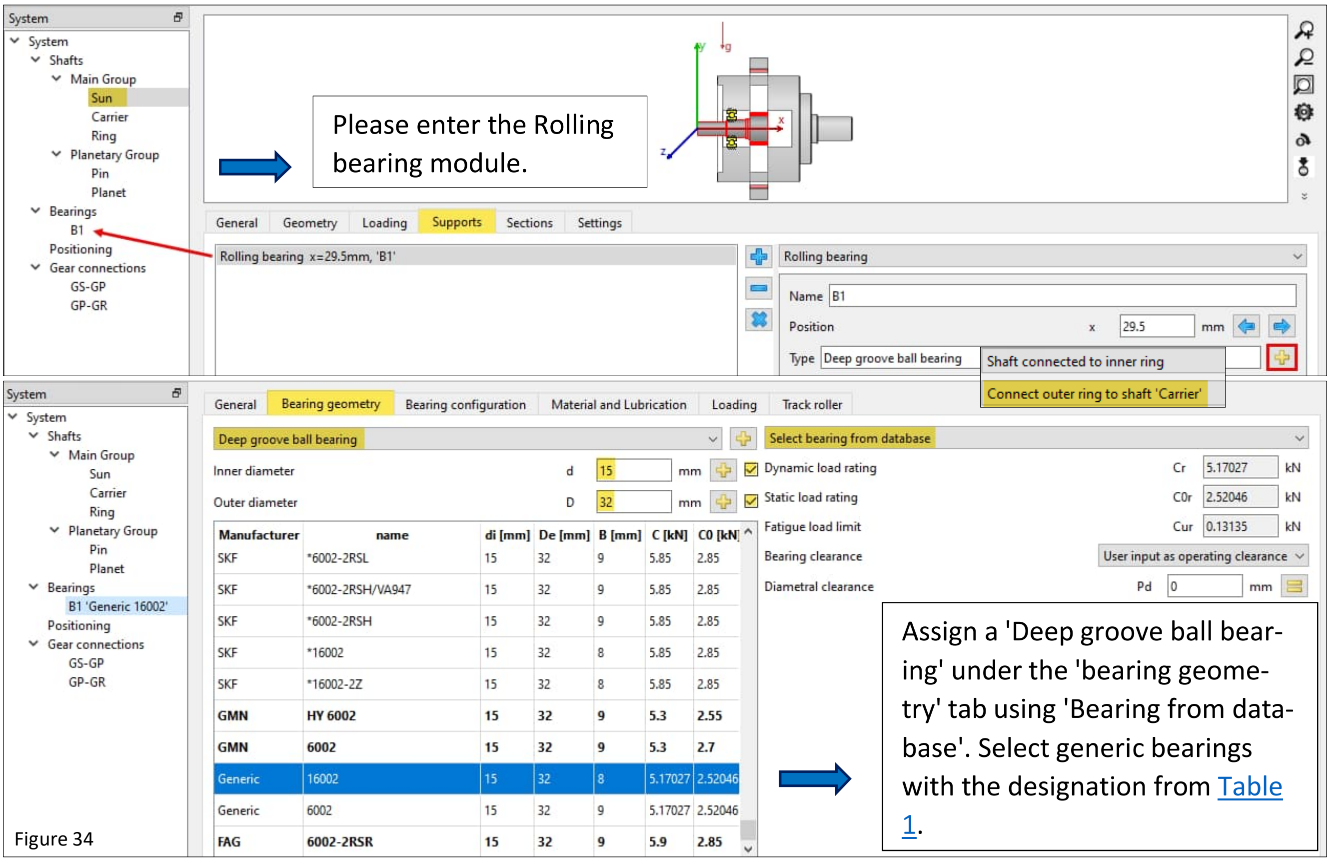


Figure 34

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.

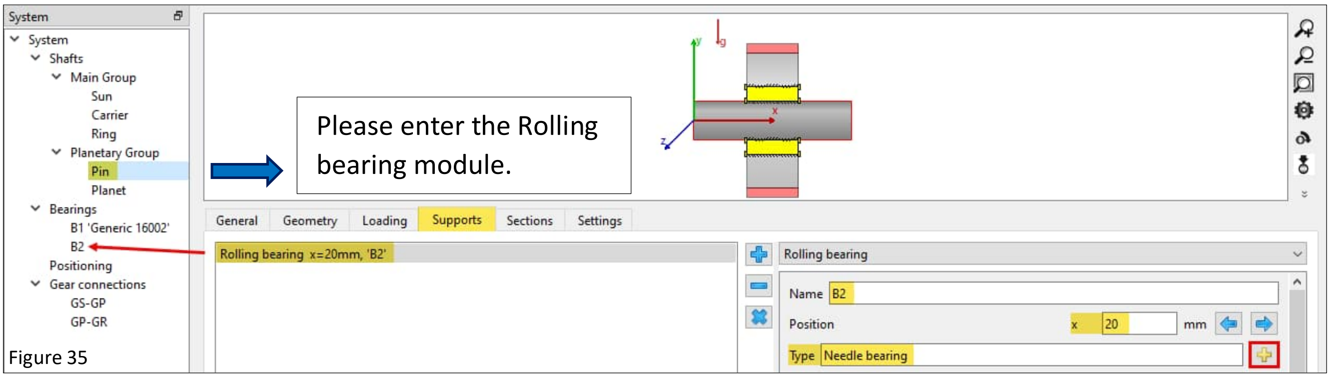


Figure 35

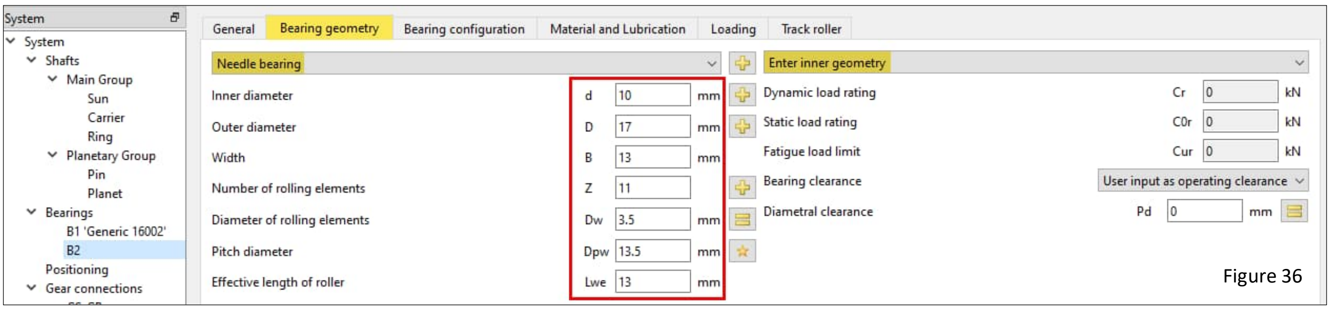


Figure 36

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

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

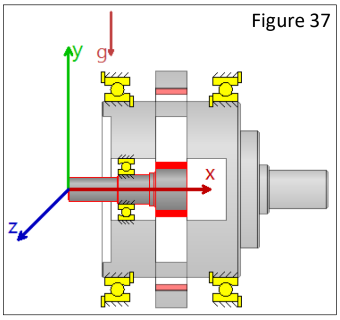


Figure 37

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 Starter Tutorial Basics for rolling bearing calculation.

4.3.5.2 Boundary conditions

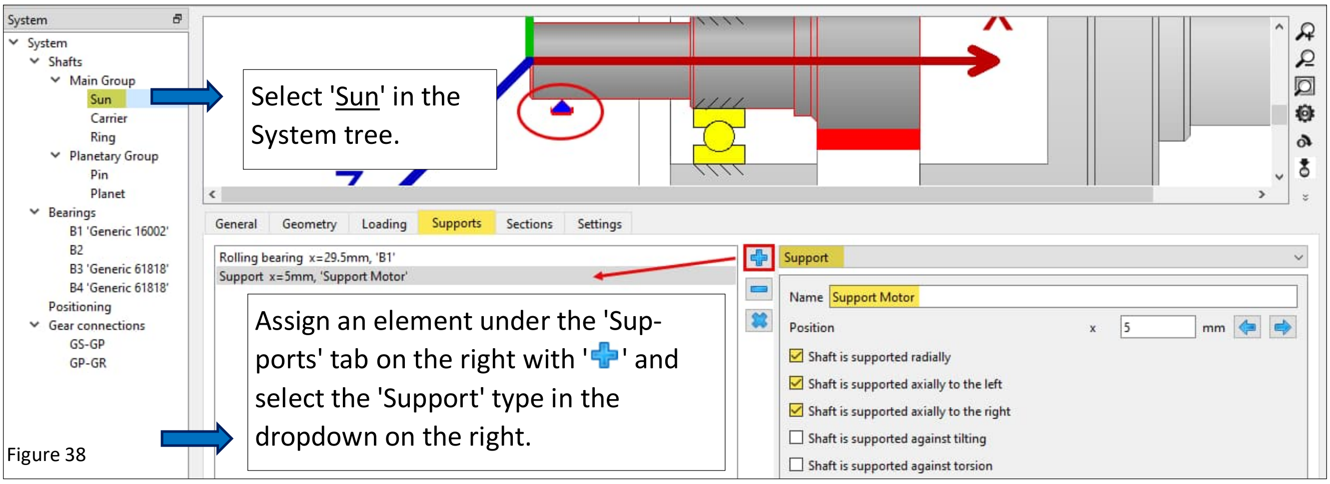
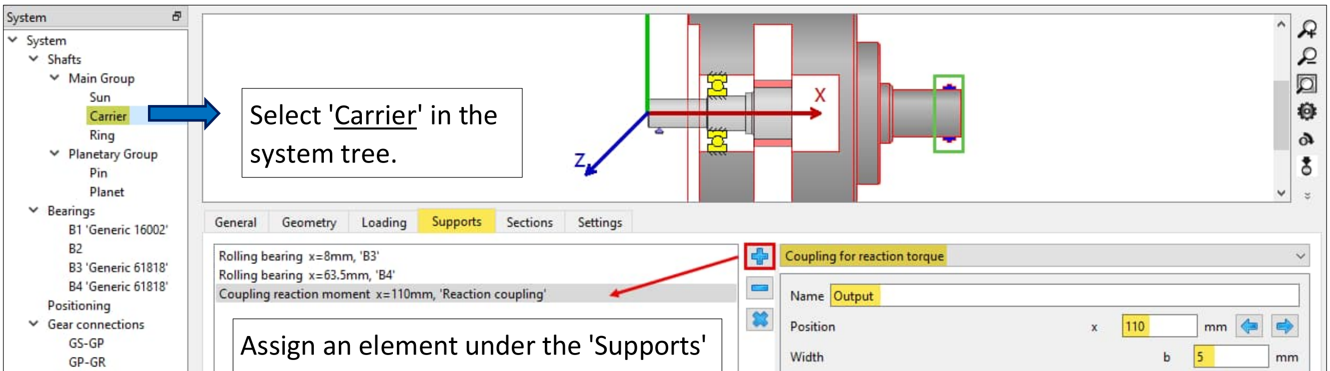


Figure 38

Assign the corresponding parameters from Table 1 for this Support.

Assign the ring gear a 'Support' with the corresponding parameters from Table 1.

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



Assign an element under the 'Supports' tab on the right with '' and select the type 'Coupling for reaction torque' in the dropdown on the right.

Assign the corresponding parameters from Table 1 for this coupling.

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

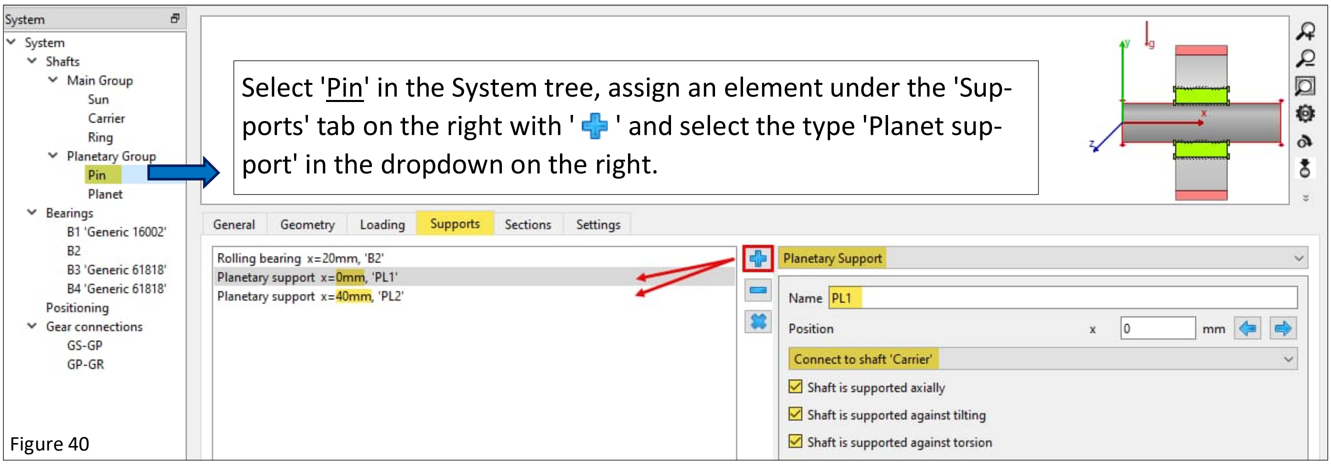


Figure 40

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.

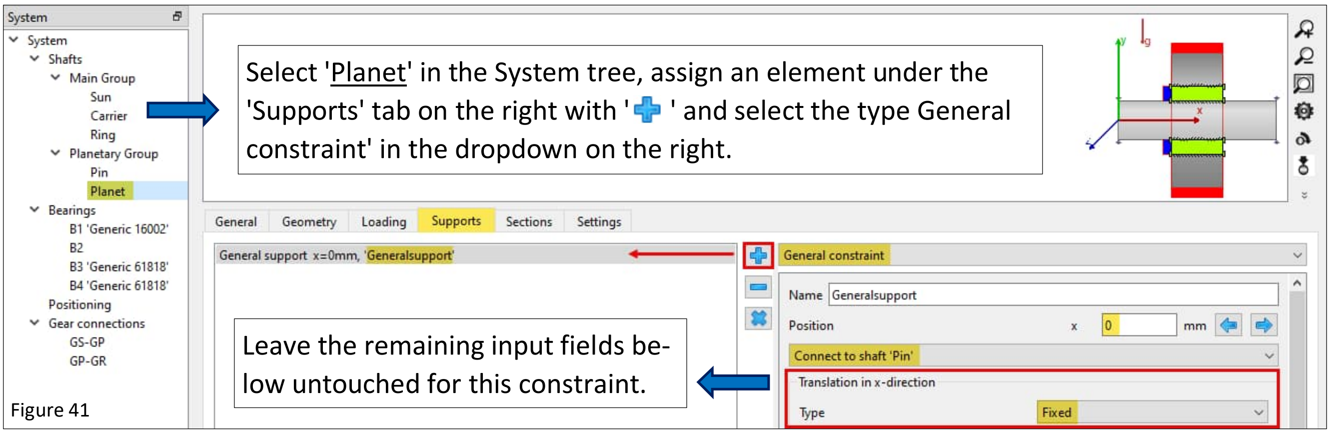


Figure 41

4.3.6 Loads

4.3.6.1 Speeds

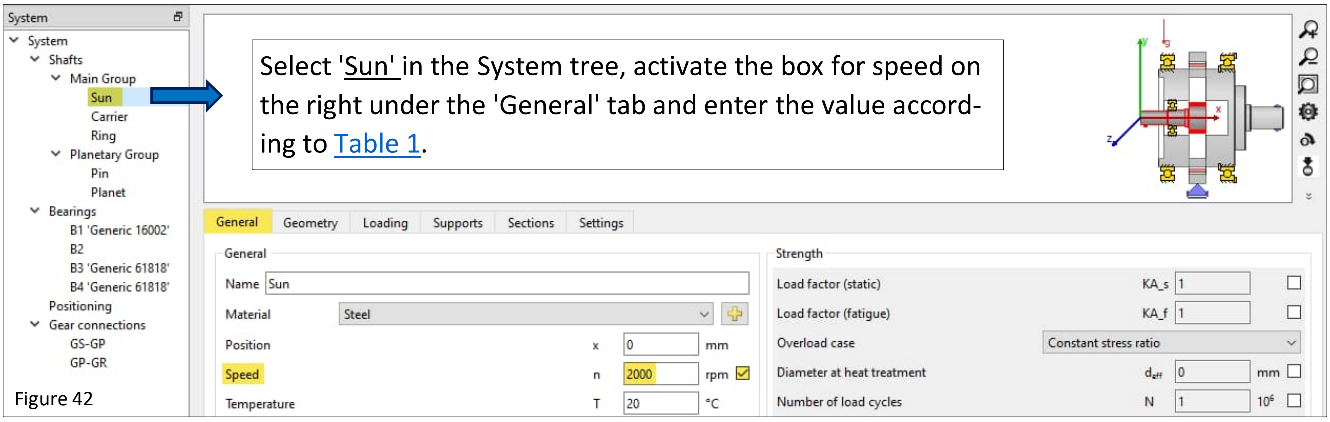


Figure 42

Please activate the speed for the Ring Shaft 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".

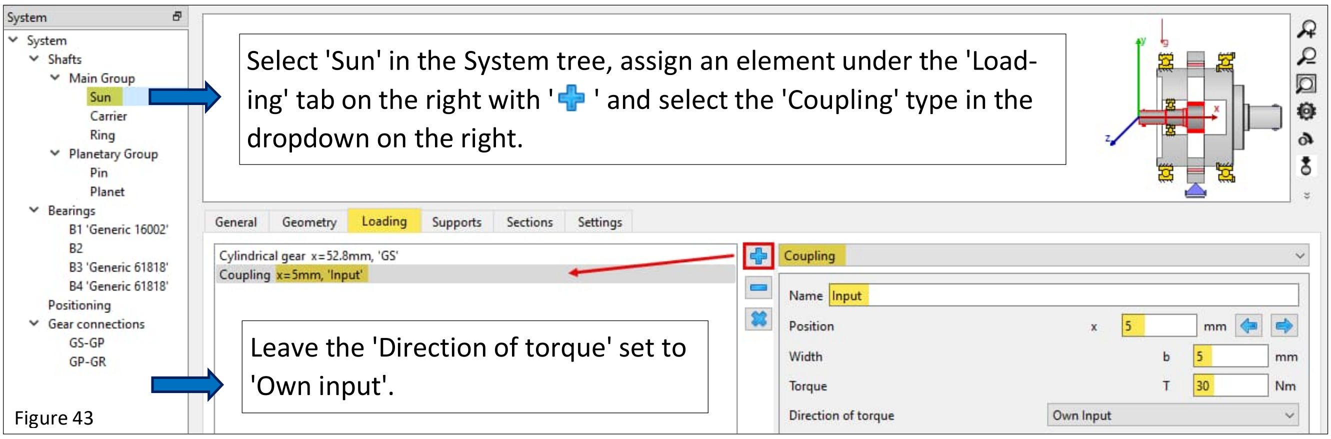


Figure 43

4.3.7 Lubricant

Please assign the lubricant as shown in Fig. 44

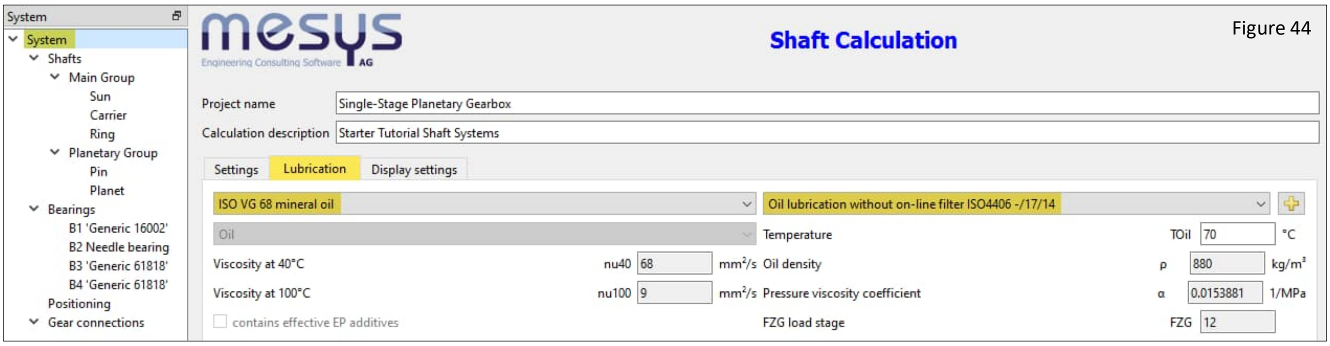


Figure 44

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 Required service life or Strength calculation.

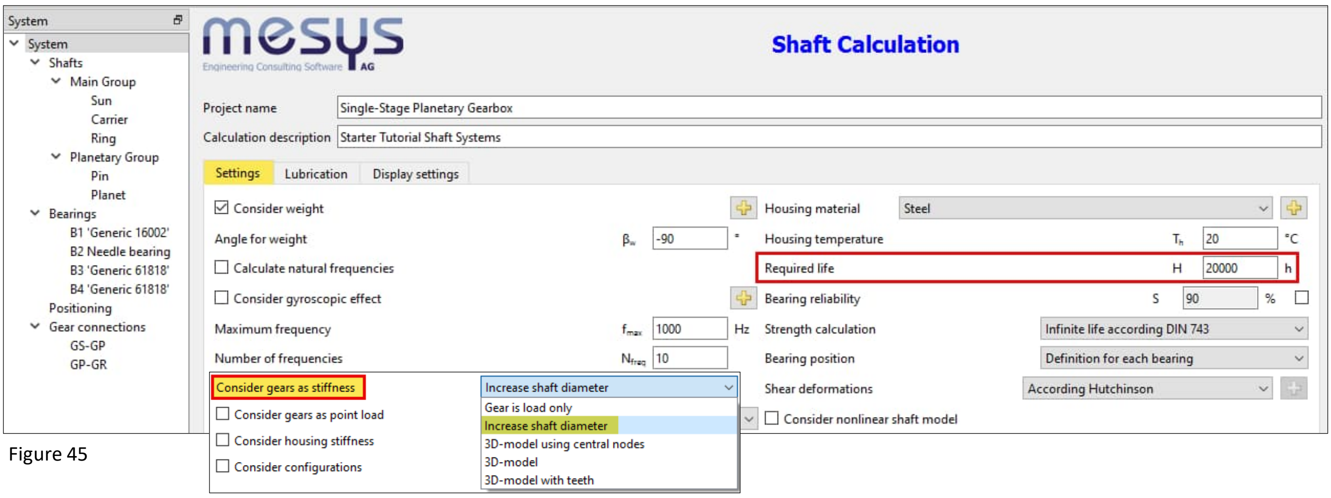


Figure 45

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 Consider gears as stiffness.

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.

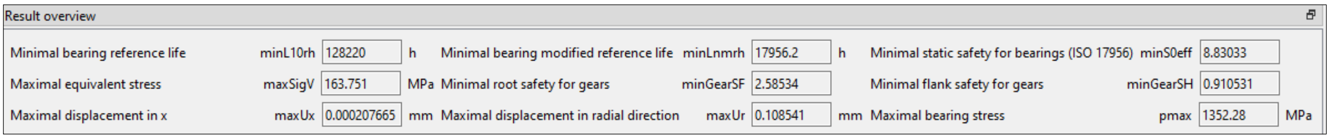
Please start the calculation.

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

6 Results

6.1 Overview of results

Figure 46



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.

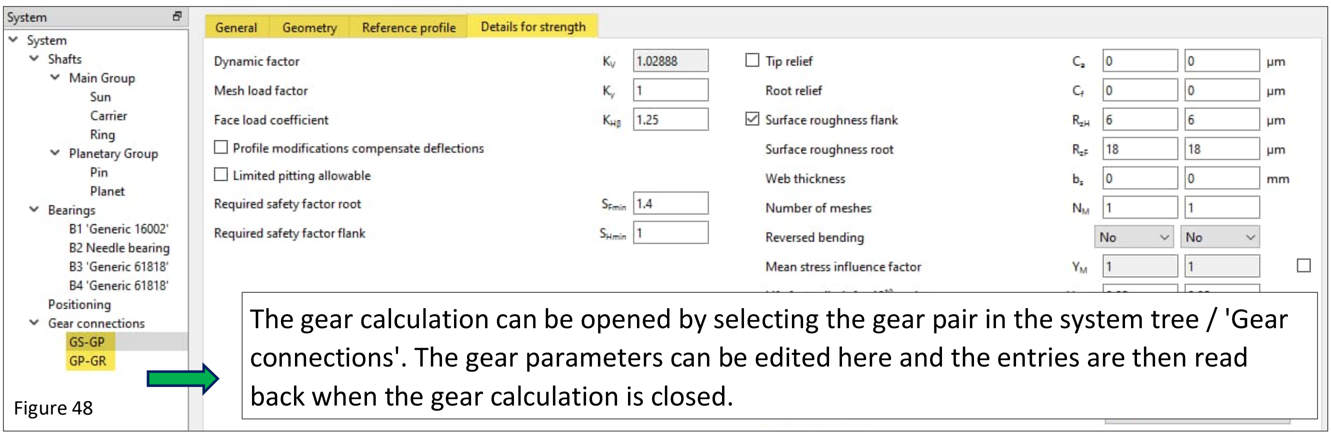
The choice of a higher viscosity lubricant shows that the modified reference service life (Figure 47) could be increased substantially and to the level of value H.

Figure 47

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.



The gear calculation can be opened by selecting the gear pair in the system tree / 'Gear connections'. The gear parameters can be edited here and the entries are then read back when the gear calculation is closed.

Figure 48

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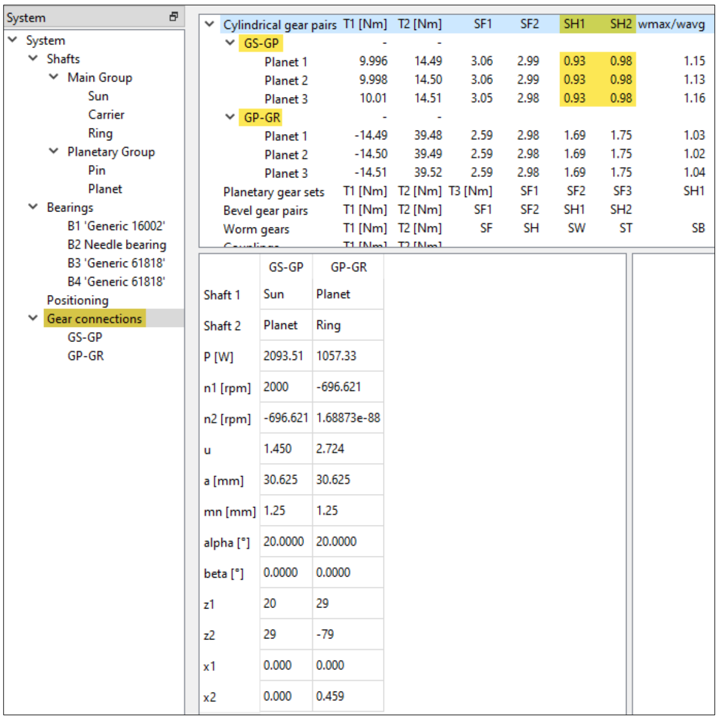
6.2.2 Results of gear connections

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.

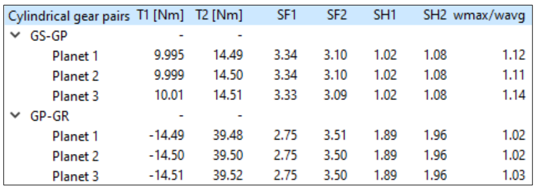


Cylindrical gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2	wmax/wavg
GS-GP	-	-					
Planet 1	9.996	14.49	3.06	2.99	0.93	0.98	1.15
Planet 2	9.998	14.50	3.06	2.99	0.93	0.98	1.13
Planet 3	10.01	14.51	3.05	2.98	0.93	0.98	1.16
GP-GR	-	-					
Planet 1	-14.49	39.48	2.59	2.98	1.69	1.75	1.03
Planet 2	-14.50	39.49	2.59	2.98	1.69	1.75	1.02
Planet 3	-14.51	39.52	2.59	2.98	1.69	1.75	1.04
Planetary gear sets	T1 [Nm]	T2 [Nm]	T3 [Nm]	SF1	SF2	SF3	SH1
Bevel gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2	
Worm gears	T1 [Nm]	T2 [Nm]	SF	SH	SW	ST	SB

	GS-GP	GP-GR
Shaft 1	Sun	Planet
Shaft 2	Planet	Ring
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

Figure 49

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).

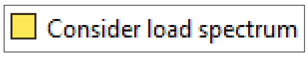


Cylindrical gear pairs	T1 [Nm]	T2 [Nm]	SF1	SF2	SH1	SH2	wmax/wavg
GS-GP	-	-					
Planet 1	9.995	14.49	3.34	3.10	1.02	1.08	1.12
Planet 2	9.999	14.50	3.34	3.10	1.02	1.08	1.11
Planet 3	10.01	14.51	3.33	3.09	1.02	1.08	1.14
GP-GR	-	-					
Planet 1	-14.49	39.48	2.75	3.51	1.89	1.96	1.02
Planet 2	-14.50	39.50	2.75	3.50	1.89	1.96	1.02
Planet 3	-14.51	39.52	2.75	3.50	1.89	1.96	1.03

Figure 50

If there is a need to work with the license for Cylindrical Gear Pairs, the gear calculation can be activated according to Figure 30 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 Gear connections.

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 Shaft Starter Tutorial or in the manual under Calculation with load spectrum.

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).

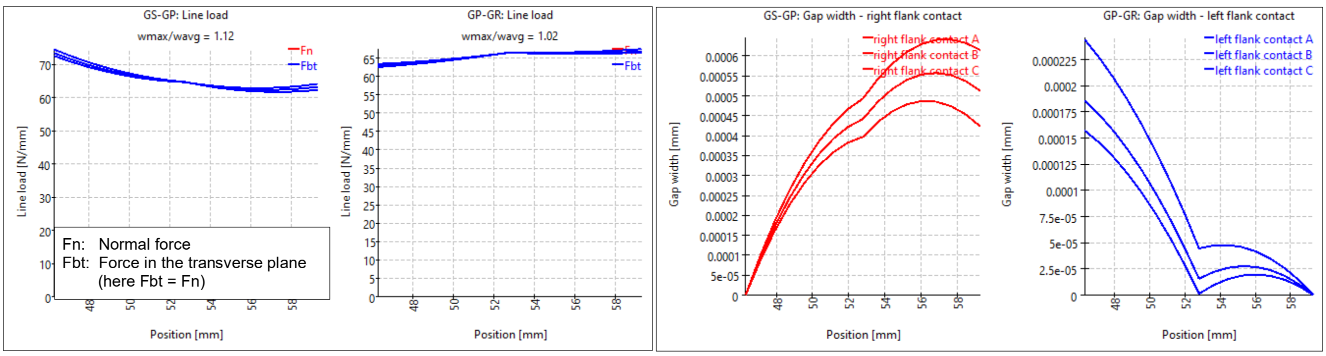
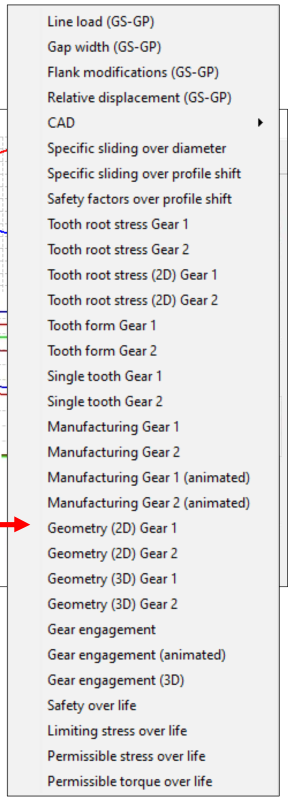


Figure 51

- 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 "Increase shaft diameter". 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).



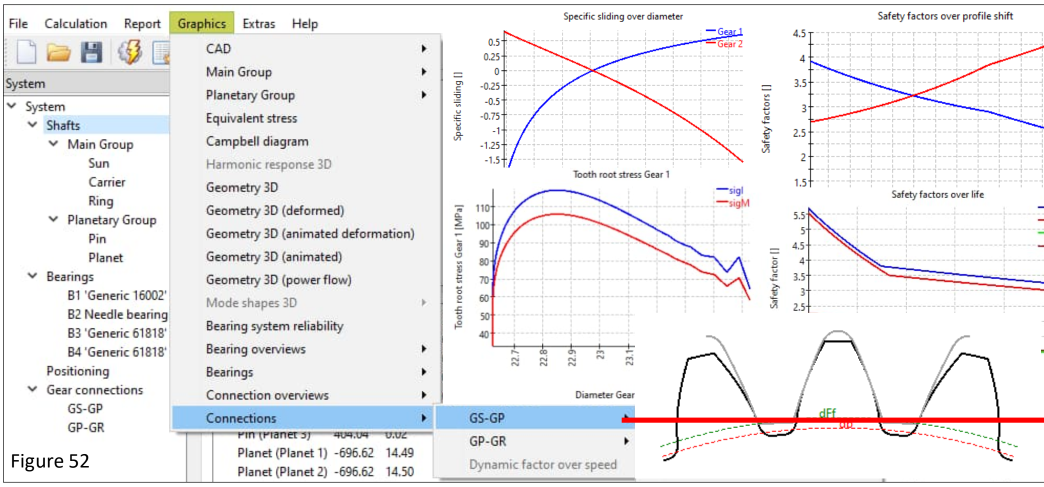
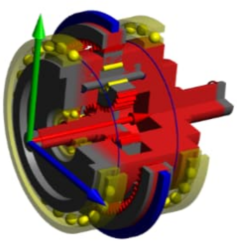
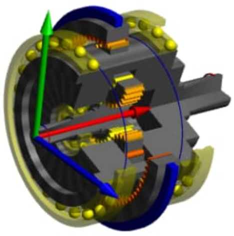


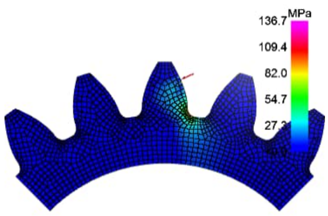
Figure 52



Power flow



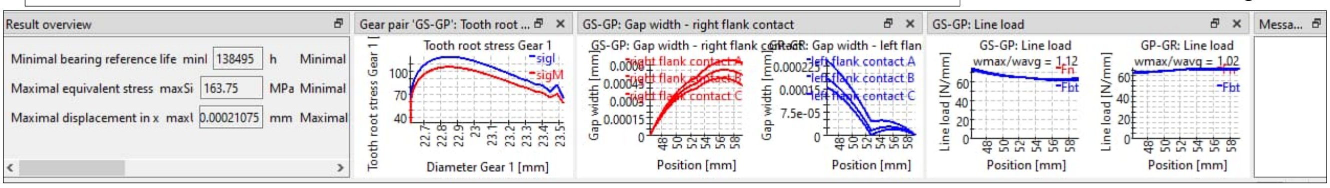
Animated, with and without Deformation



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.

Figure 53



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.

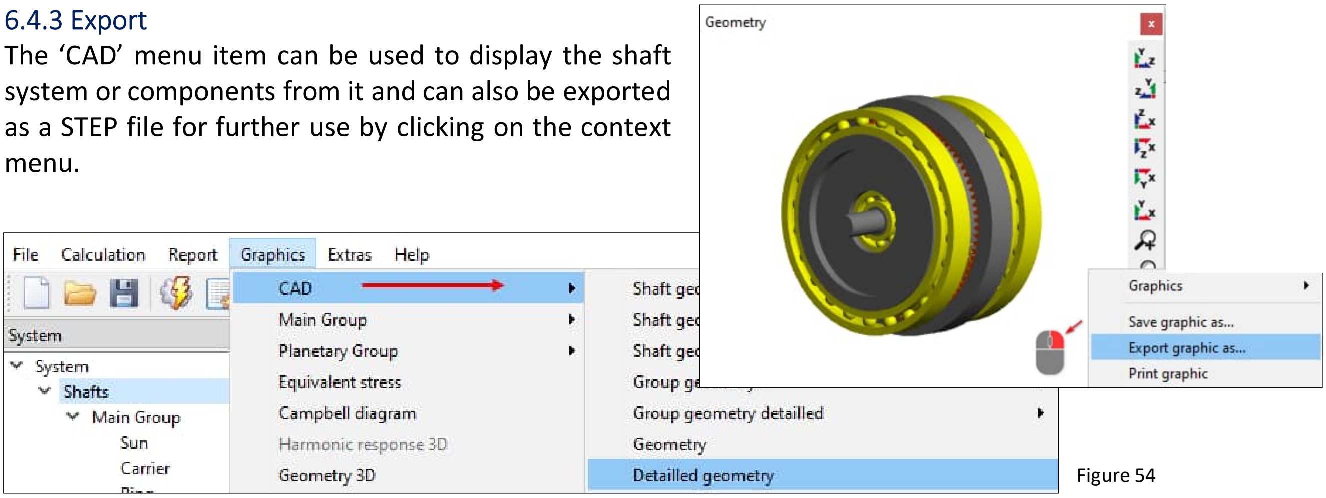


Figure 54

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