KISSsoft 03/2018 – Tutorial 12

Sizing a Planetary Gear Set for Precision Mechanics

Contents

1 Task

To size a planetary gear set with an input torque of 450 Nmm (0.45 Nm) at 10000 rpm. The nominal transmission ratio is 4.25. The required service life is 20,000 hours, with an application factor of $K_A = 1.25$.

The package size (outer diameter of the gear rim) is 35 mm, including 3 mm material between the root diameter and the outer diameter. The gears are made of sintered powdered metal. The module must be greater than 0.5 mm (due to manufacturing requirements). The tooth form must be optimized to make full use of the fact that the gears are not manufactured using the hobbing process. The calculation method used here is the one specified in AGMA: 2101-D04.

2 Starting KISSsoft

2.1 Starting the software

You can call KISSsoft as soon as the software has been installed and activated. Usually you start the program by clicking «Start→Program Files→KISSsoft 03-2018→KISSsoft 03-2018». This opens the following KISSsoft user interface:
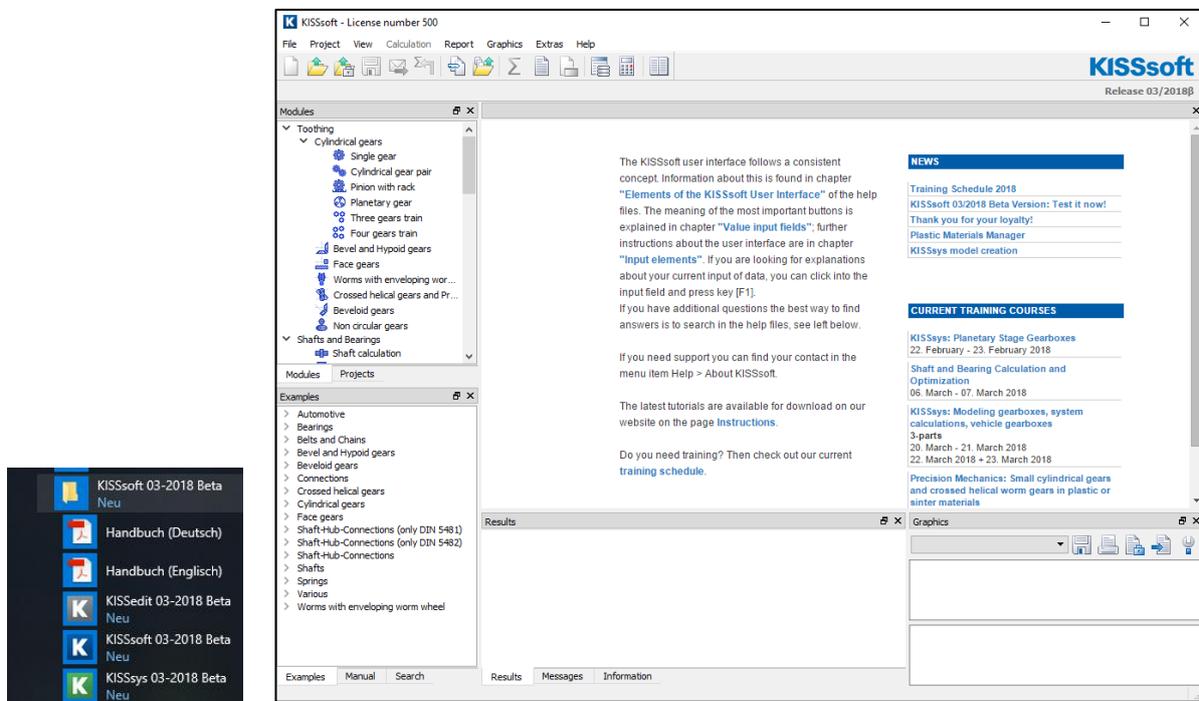

Figure 1.   KISSsoft main window

2.2 Starting the «Planetary gear» calculation module

In the **«Modules tree»** window, double-click the **«Modules»** tab to call the calculation for a **«Planetary gear»**, see Figure 2.
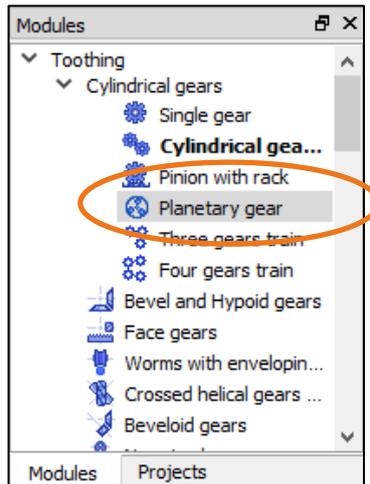
Figure 2.   Selecting the «Planetary gear» calculation module from the «Modules» window

2.3 Basic settings

As some of the solutions found during the draft design phase will have geometric errors (which cause KISSsoft to cancel the calculation automatically), we recommend you go to the module specific settings and activate «Allow large profile shift» and «Don't abort when geometry errors occur». This allows the KISSsoft software to continue with a calculation even if an error has occurred. See Figure 3.
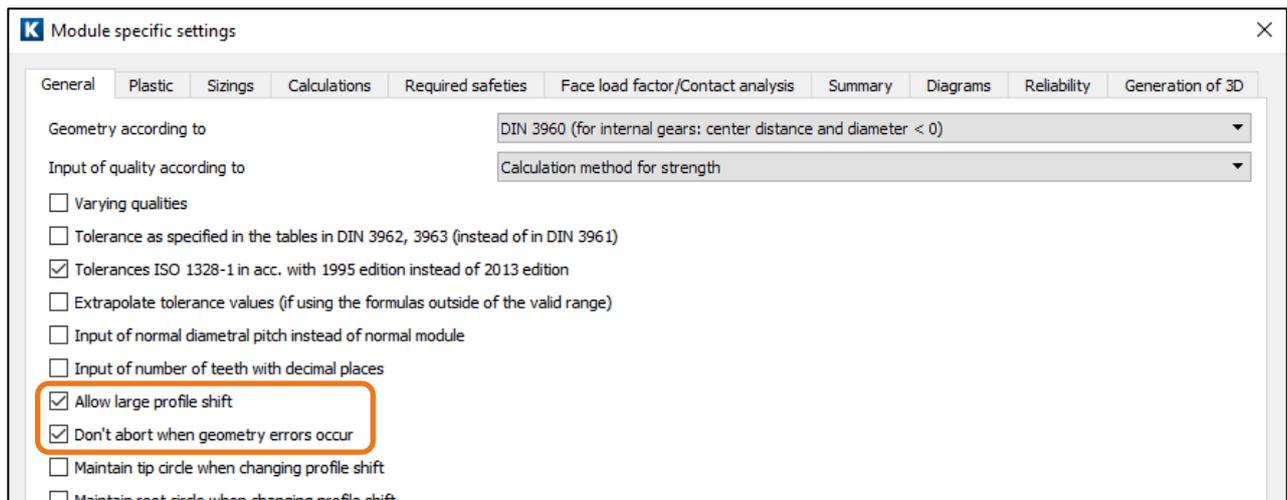

Figure 3.   «Module specific settings» for this example

2.4 Setting constraints

Click [OK] to return to the main dialog. Go to the «Basic data» tab and input the required number of planets (Figure 4).
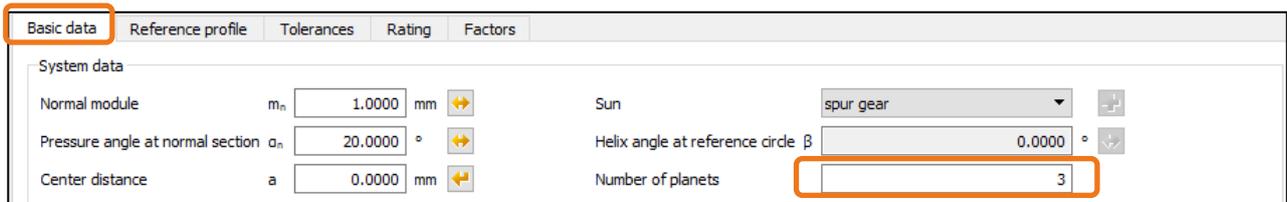

Figure 4.   Defining the number of planets

2.4.1 Defining materials

Figure 5. Specifying the materials

2.4.2 Defining the calculation method and ratings

Specify the required calculation method (1). Then input the application factor (2) and the service life (3). Click the **«radio button»** next to the Power field to define the load, see Figure 6.

Figure 6. Set the calculation method, application factor, service life, and rating details

If the AGMA 2101-D04 method is used for a planetary gear set, it is a good idea to activate the graphical method for factor Y (as this influences the calculation of root stress). Click on the **«Rating» [Details]** tab (4). Activate the graphical method (5) and define where the force is to be applied (6).

Figure 7. Specifying the application of force and the graphical method

To specify the unit used for torque, click the right-hand mouse button on the appropriate field (Figure 8).
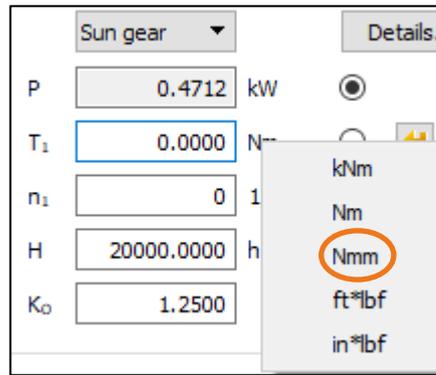

Figure 8.   Specifying the unit for torque

Define the reference gear (1), the calculated value (2) (if the torque and number of rotations have been defined, the performance will be calculated) and input the data for the number of rotations and torque (3) (see Figure 9).
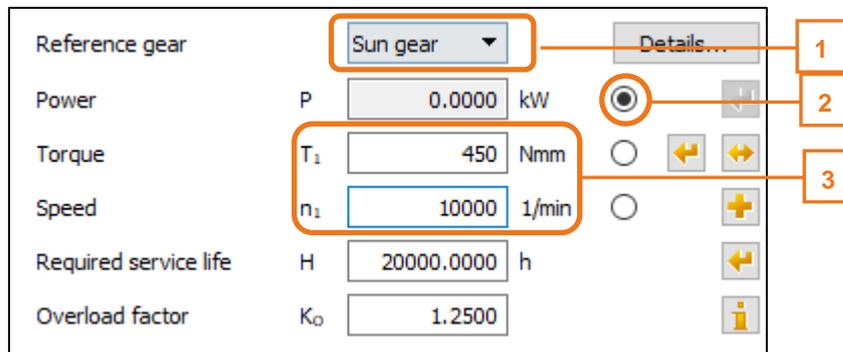

Figure 9.   Specifying the load

2.4.3   Specifying additional factors

The load distribution coefficient K_γ increases the load placed on an individual planet. In this case, the value 1.0 has been defined in the **«Factors»** tab.

Figure 10. Defining the load distribution coefficient

2.5   Rough sizing

Open Rough sizing and input the additional details.

Figure 11. Call the Rough sizing function

Then enter the nominal transmission ratio. If KISSsoft were to calculate a design with the basic settings, it would result in a very small module. For this reason, you should lower the value range for the number of teeth from 9 to 14, to force KISSsoft to select a larger module. It is not usually necessary to change the default value for the number of teeth. Click on **[Calculate]**.
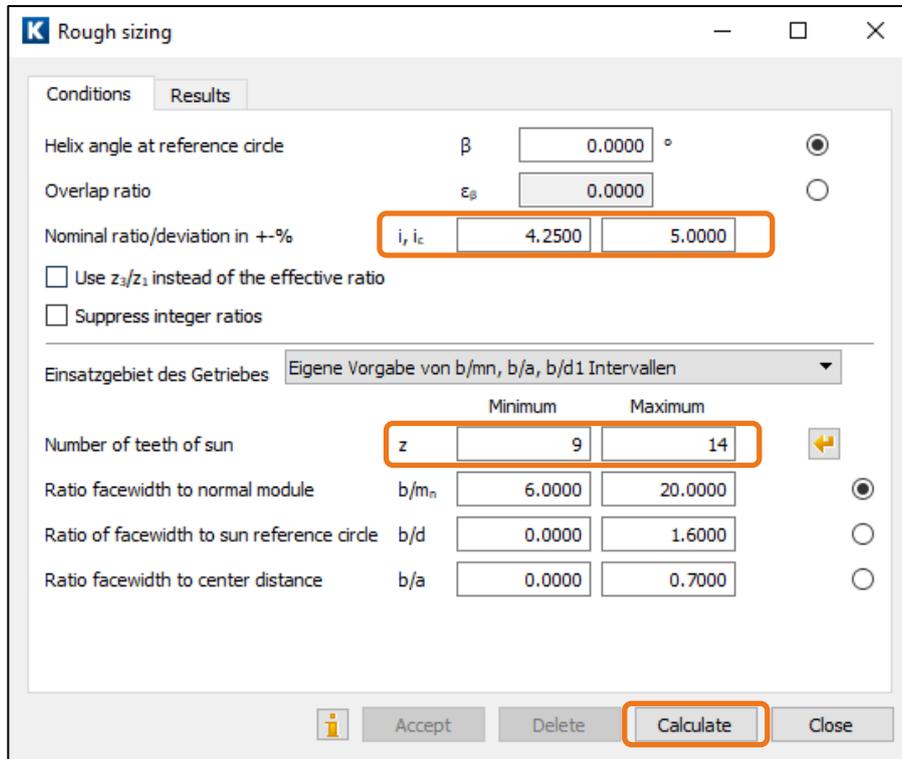

Figure 12. Rough sizing settings and Run calculation

Confirm the messages displayed for gears 1 to 3 Figure 13 by clicking **[OK]**.
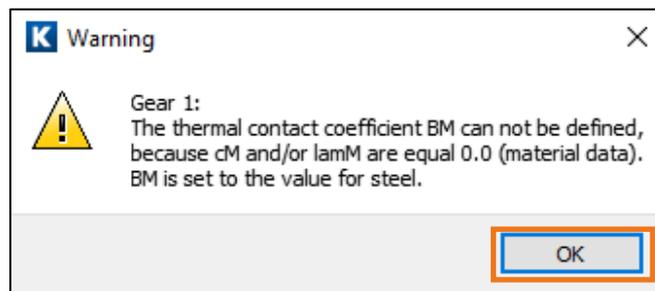
Figure 13. Information about the missing coefficients

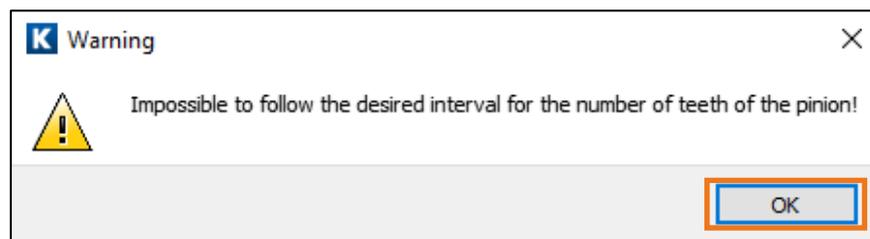Confirm the displayed messages by clicking **[OK]**

Figure 14. chanced interval

Look at the results. If you are happy with the results, select the relevant solution and click on **[Accept]**, see Figure 15.

Figure 15. Results of Rough sizing

The main dialog is now filled with data from the solution generated by the Rough sizing function. Close Rough sizing.

Note:
As long as the Rough sizing function is open, you can transfer any other solution into the main dialog screen. However, the results are no longer available after you close Rough sizing. The Fine sizing function also reacts in this way.

As the module is smaller than 1.0, we recommend you use a different standard for the tolerances. To do this, go to the **«Tolerances»** tab. In the dialog, select the tooth thickness deviation «DIN 58405 10e» for each gear, Figure 16. Here, 10 indicates the quality (interval width), where 10 means «lower quality». The letter «e» represents the definition of the interval limit and therefore also the backlash. For this reason, you should go to the **«Basic data»** tab and also set the corresponding quality setting to 10, (see also (1a) in Figure 18.
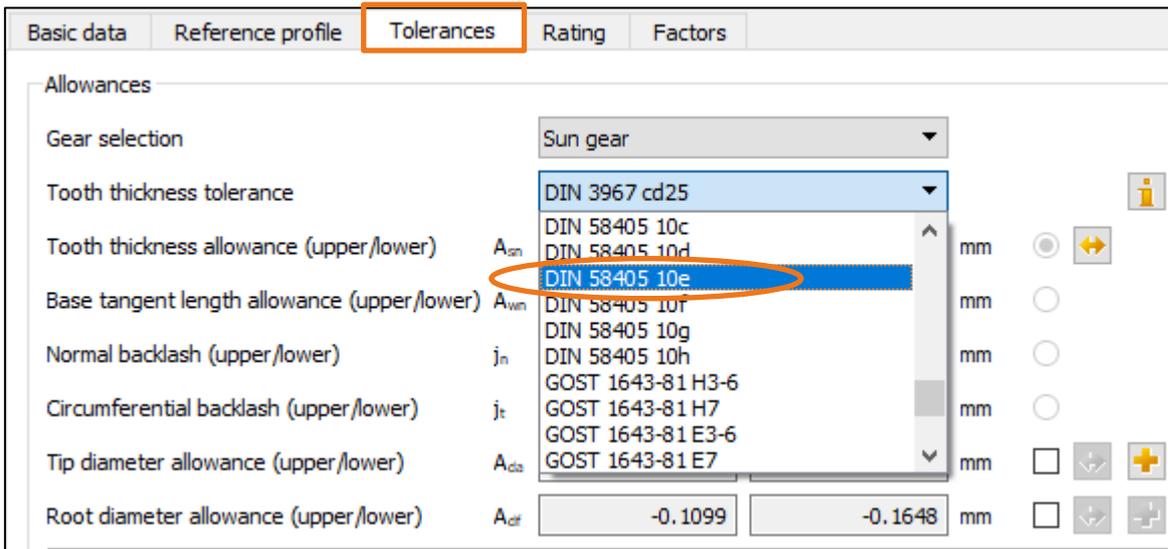
Figure 16. Setting the tolerance

After you have defined the tolerances, you may want to input a better value for the facewidth (in this example we are leaving the values unchanged (1), see Figure 18. Click **[Calculate F5]** (2). You now see the first results of the roughly sized planetary gear set in the «Results overview», see also (2a) in Figure 18.
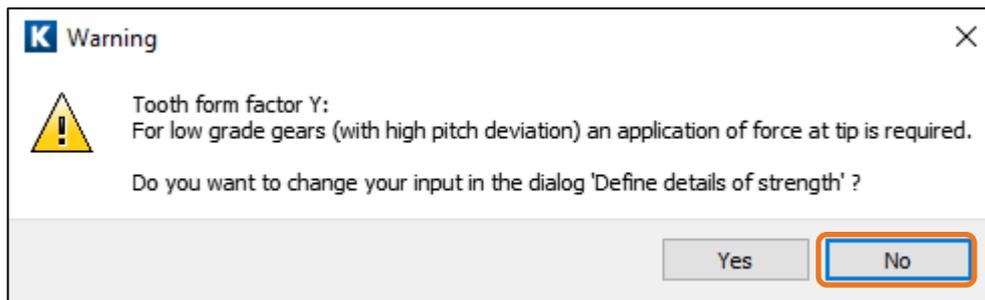Click [No] to close the message displayed in Figure 17.

Figure 17. Changing the tooth form factor

2.6 Fine Sizing

This completes the presizing step. This is used to provide the Fine sizing function with values that are approximately the correct size for the subsequent processing steps. Now, to generate an optimized solution, click the Fine sizing (3) button Figure 18.
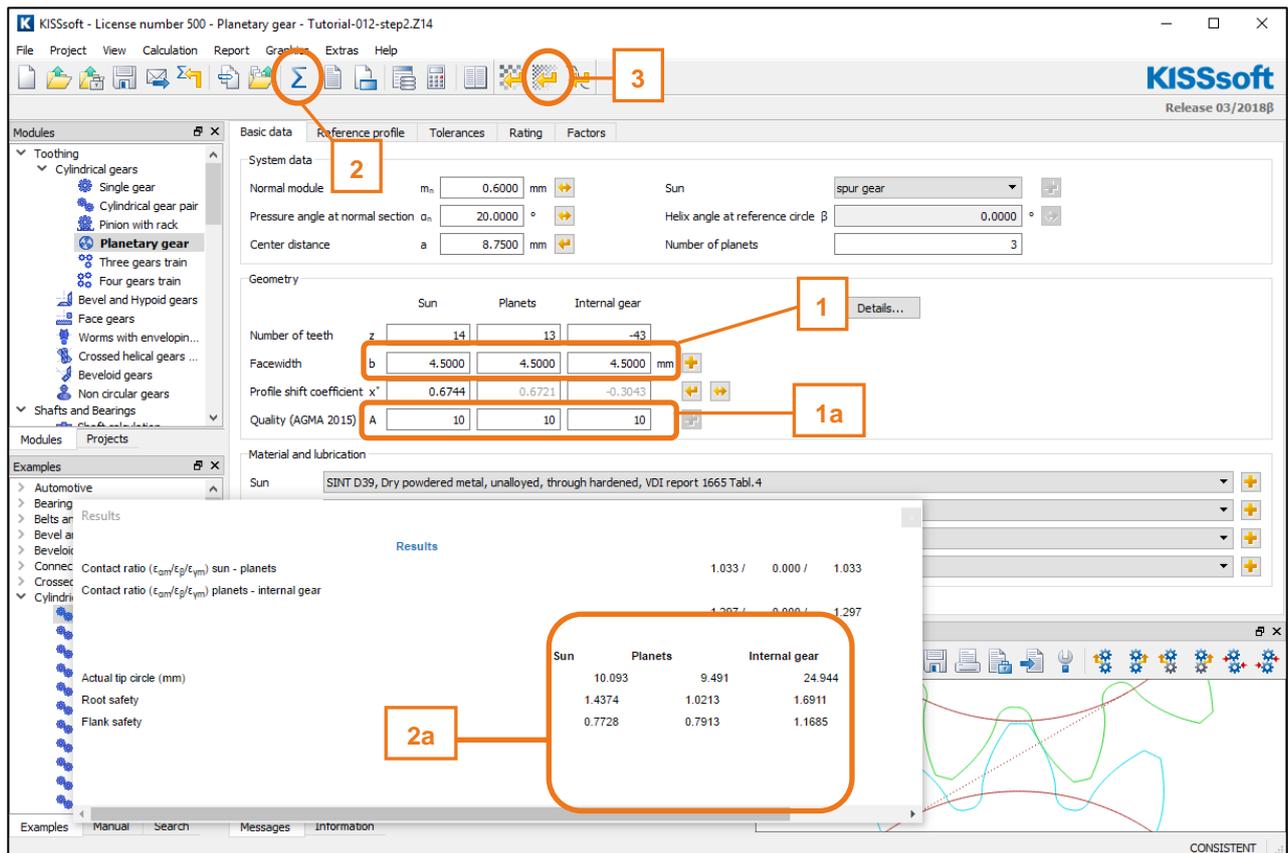
Figure 18. Calculate, check the results, and call the Fine sizing function

Firstly, check the value for the nominal ratio (this may have changed slightly during Rough sizing) (1). Then input the required values range and the increments for the module (KISSsoft will automatically select very small values) (2). Define the target value for the gear rim reference circle (3). To define the correct diameter, deduct 3 mm of the material underneath the root diameter from the gear's outer diameter (35 mm), twice. This gives a measurement of 29 mm. Then reduce this again by a further 2*1 mm for the dedendum (this value does not need to be correct because the permitted deviation is set to 10%).

Click the «Sizing button» for the center distance (4) to display the possible value range for this value. In order to force the gear's root diameter to be small enough to ensure sufficient material remains below the tooth root, you must input a suitable value in the relevant field (here: 35 – 2*3 mm = 29 mm) (5),
see Figure 19.

Figure 19. Settings for Fine sizing

Then make the other settings in the **«Conditions III»** tab. Along with the results of Fine sizing, you can also evaluate the current variant in the list.
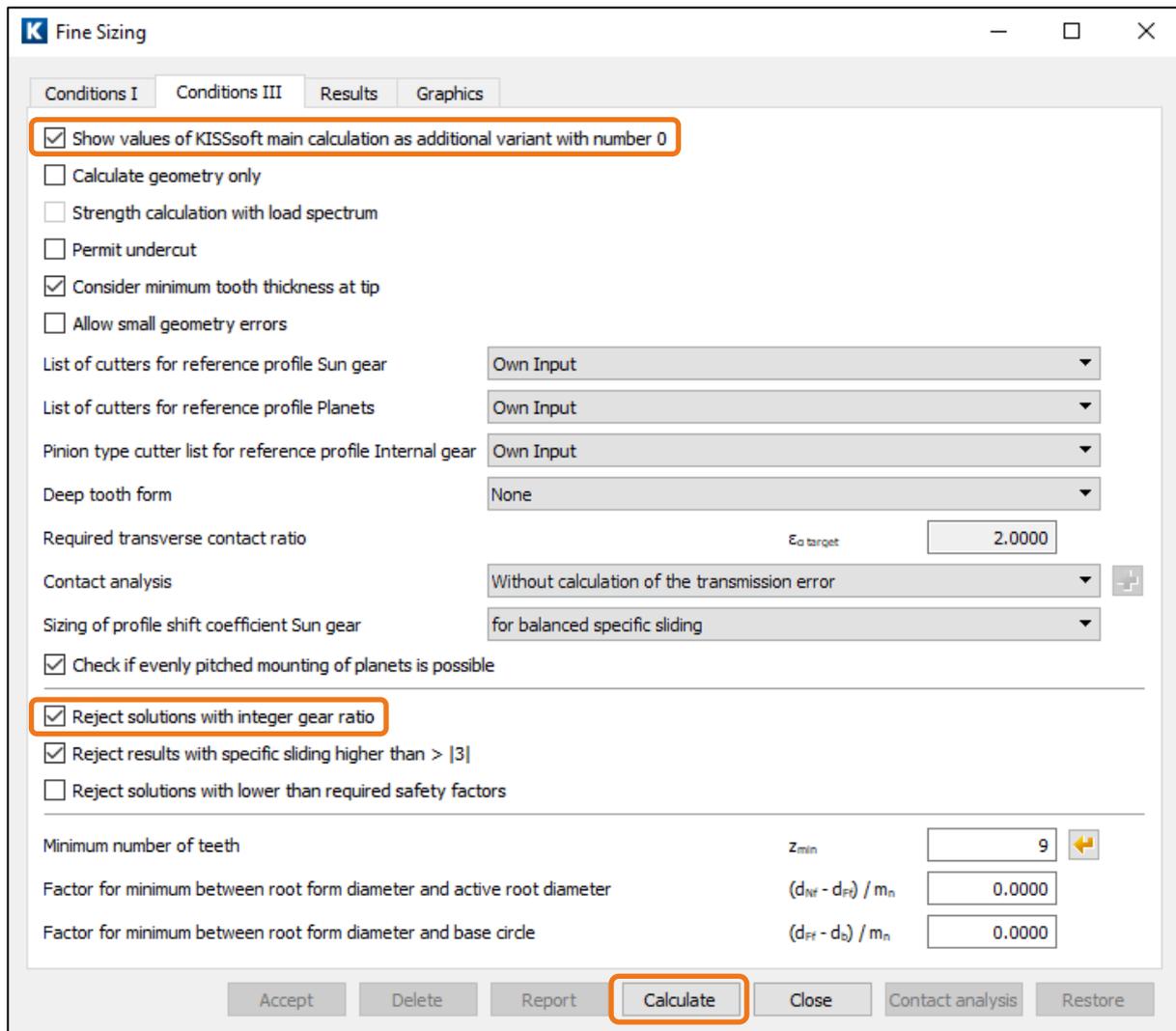
Figure 20. Additional settings

Click [Calculate] to start Fine sizing. If a solution is found, click on the **«Graphics»** tab. (If not, a message appears to tell you no solutions could be found.)

If you now only take the safety factors into account, solution 9 appears very promising: the root safety is big enough, and the flank safety is more than sufficient. As you can usually improve tooth root safety by modifying the root geometry, flank safety is more important in this case.

Normally, you would also check the other criteria (such as transverse contact ratio, specific sliding, etc.). As this is closely connected with the particular problem you are dealing with, this issue is not discussed here, and the tutorial moves on to solution 12. Please refer to the tutorials list at the end of this document for more information about the Fine sizing function.
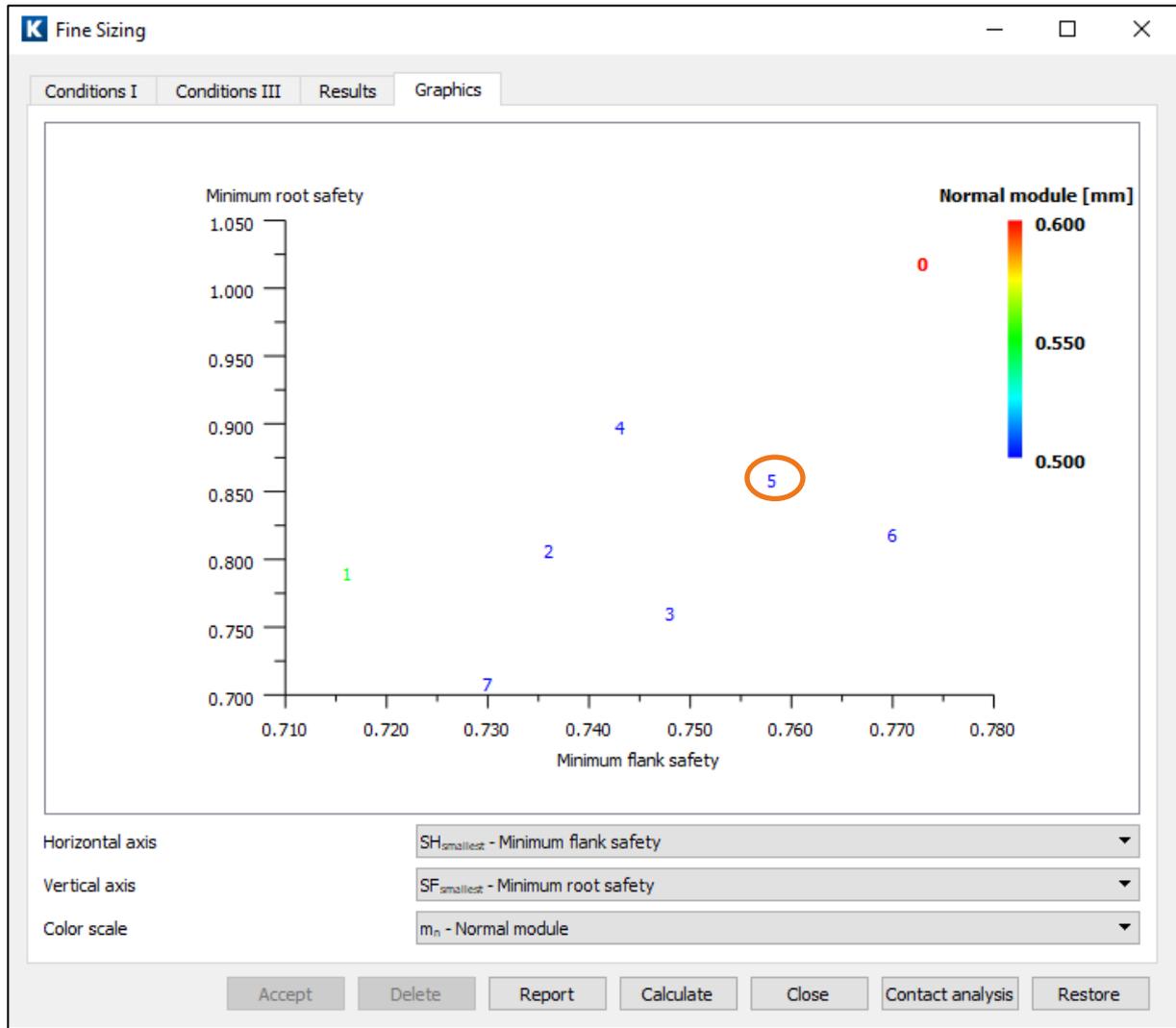
Figure 21. Graphical representation of the results

Go to the Fine Sizing **«Results»** tab and select a variant by double-clicking on variant 12 or clicking the **[Accept]** button (Figure 22).
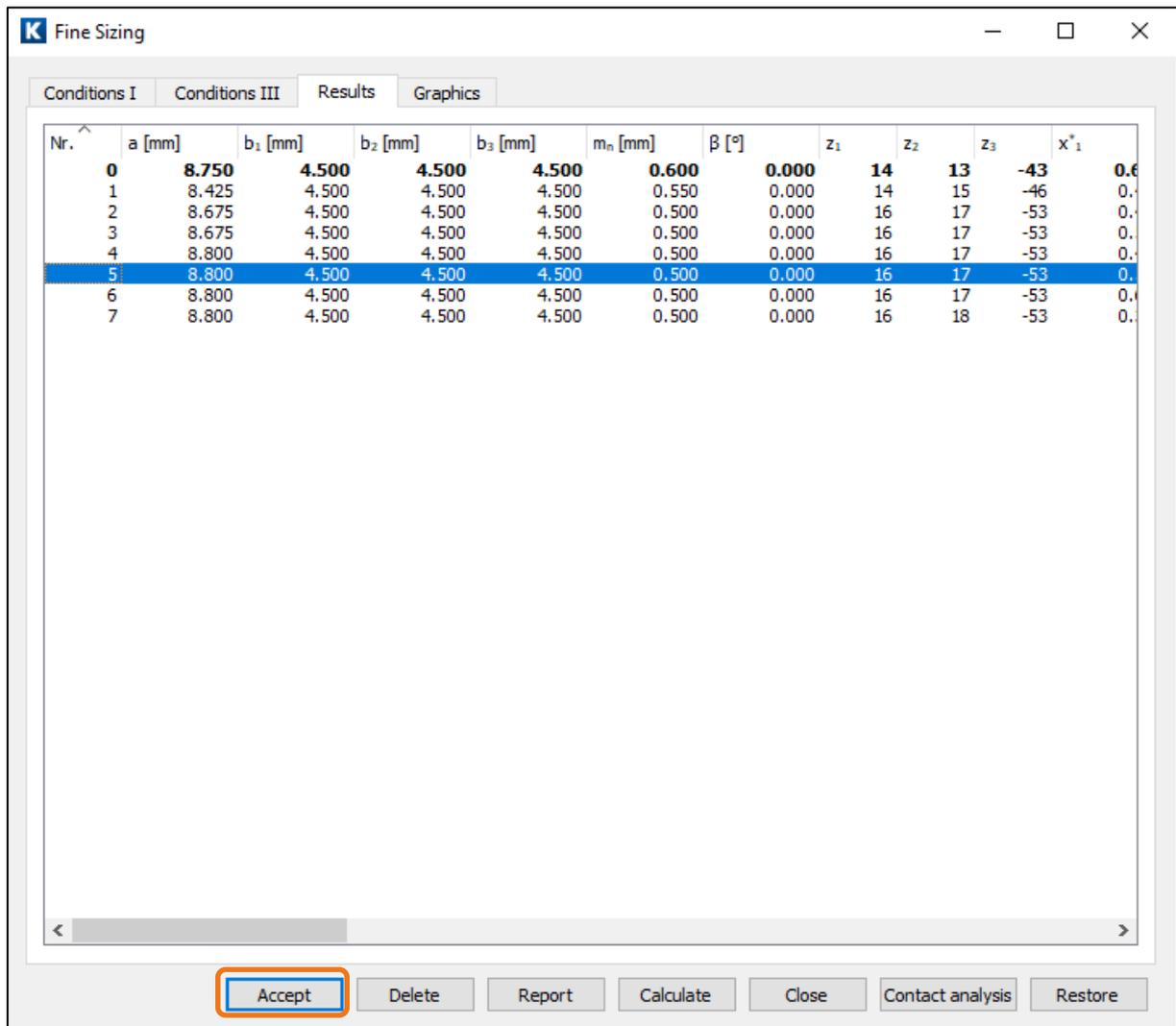
Figure 22. Selecting a solution

When you return to the main dialog (Figure 23) the **«Results overview»** window gives a brief overview, whereas the entire data record for the selected solution is displayed in the report. Click «F6» to generate the report. At this point the sizing of planetary gear set is completed.
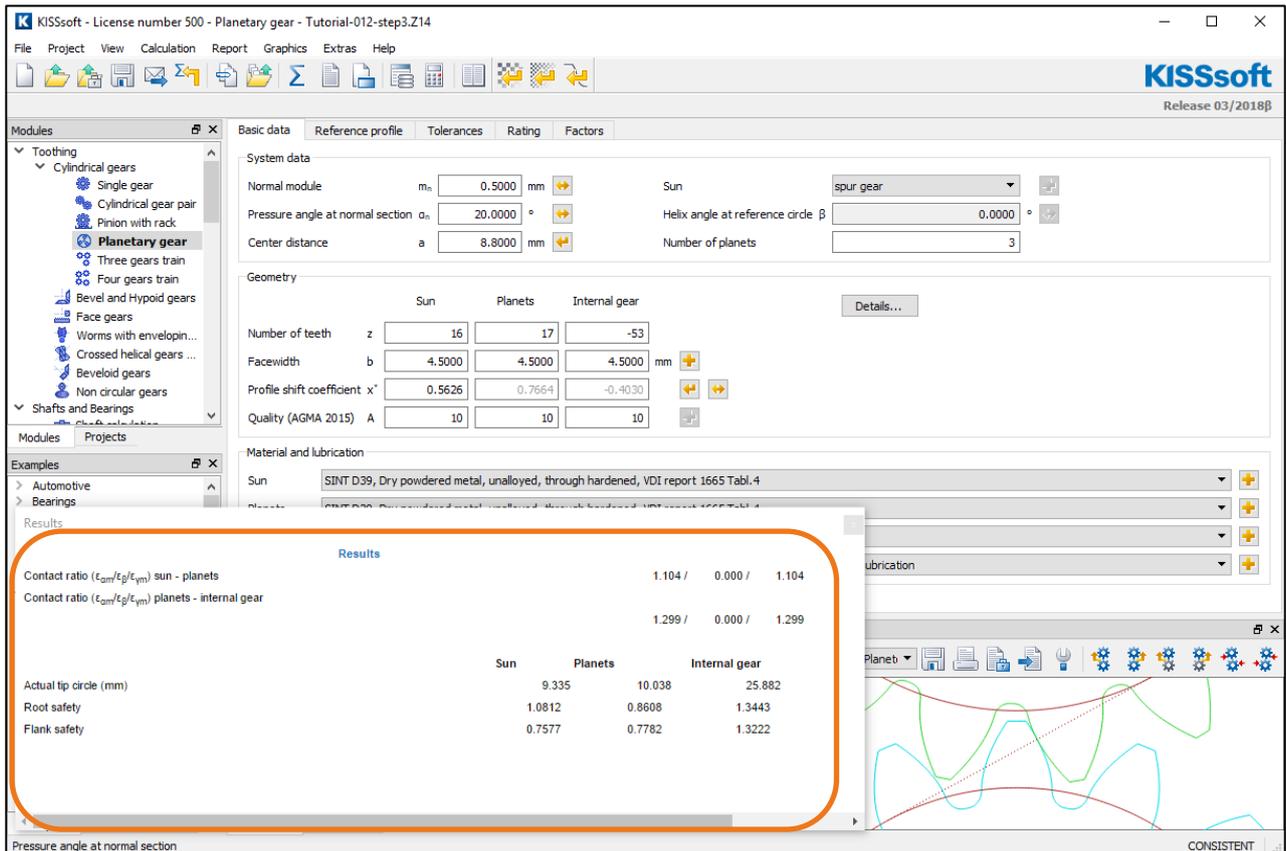
Figure 23. Overview of calculation results

2.7 Optimizing the tooth form

If the design of the gears is satisfying finished, the next step is to optimize the tooth form. As the gears are not manufactured by the hobbing process (in this case, sintered), you can make modifications at no additional cost. This section describes the most common modifications to the tooth form of sintered gears. For more details on this topic, please refer to the tutorials list at the end of this document.

To input the tooth form modification, click the «**Calculation**» -> «**Modifications**» menu option. See Figure 24.
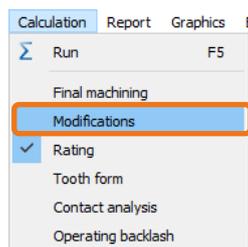

Figure 24. Enabling the «Modifications» tab

To improve initial tooth contact, and to take into account the shrinkage associated with the sintering manufacturing process, you must define tip rounding. To do this, select «**Rounding**» from the «**Drop-down list**» for «**Type of tip modification**» and enter any value (here: 0.05 mm, which is already fairly large) in the input field for all the gears 1 to 3 (see Figure 25).
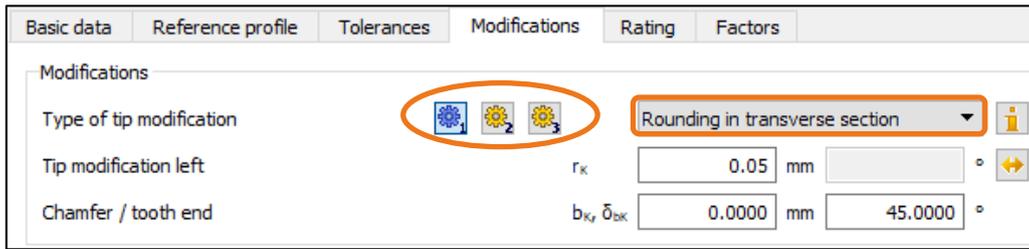
Figure 25. Tip modification «rounding» the tooth form

You can now input the tooth form modification in the active **«Modifications»** tab. Click the **«Sizing button»** to open the **«Sizing modifications»** window (Figure 26).
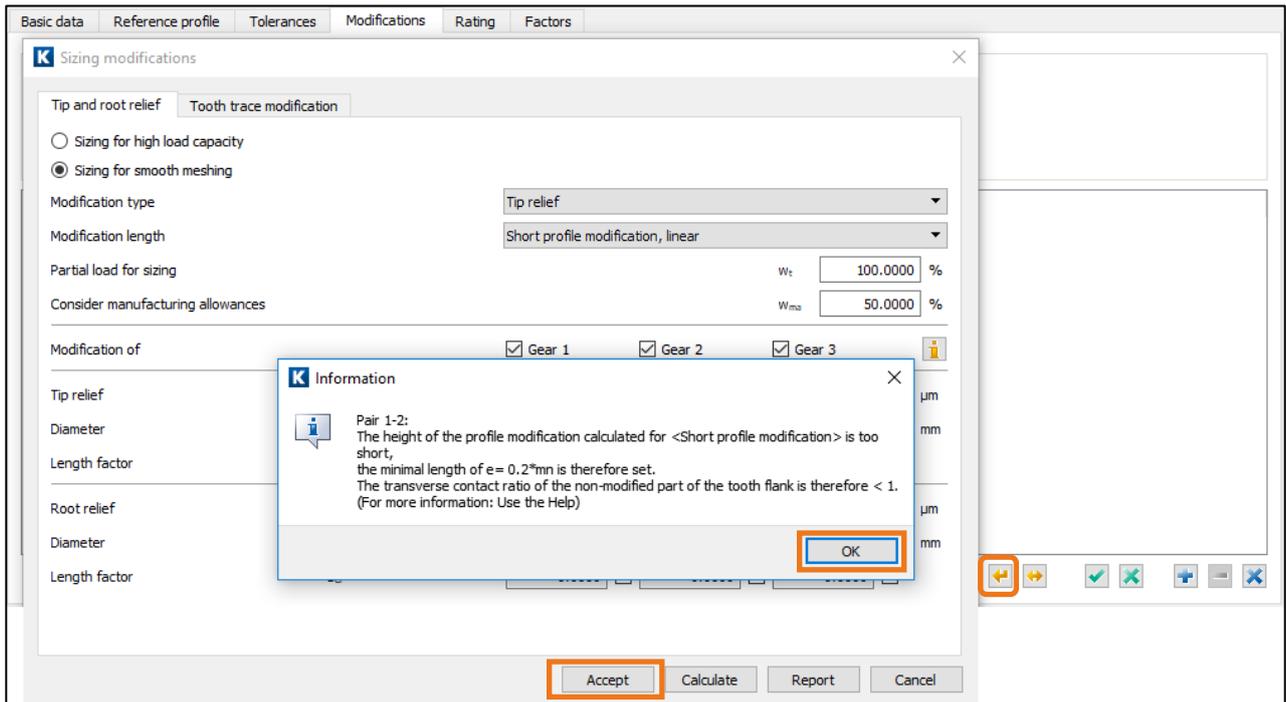

Figure 26. Defining profile correction details

The **«Short profile correction, arc-like»** option is selected for the tip relief to keep the contact impact as small as possible. This should then be carried out on Gear 2. Select **«Short profile modification, arc-like»** and click on the **[Calculate]** button. Then click **[OK]** and **[Accept]** to close this screen. The program then performs the corresponding profile modification. KISSsoft calculates a draft design for the tip relief, which (automatically) starts halfway between the single tooth contact point, with a value based on the calculated bending of the teeth.

The best solution for the root is usually an ellipse with a larger radius at the end of the involute and a smaller radius in the middle of the root area between two teeth. To calculate this, activate the «Tooth form» tab in the menu "Calculation" and then add the option «Insert elliptical root modification». Next, click the «Sizing button» to display a suggested value for the elliptical form.
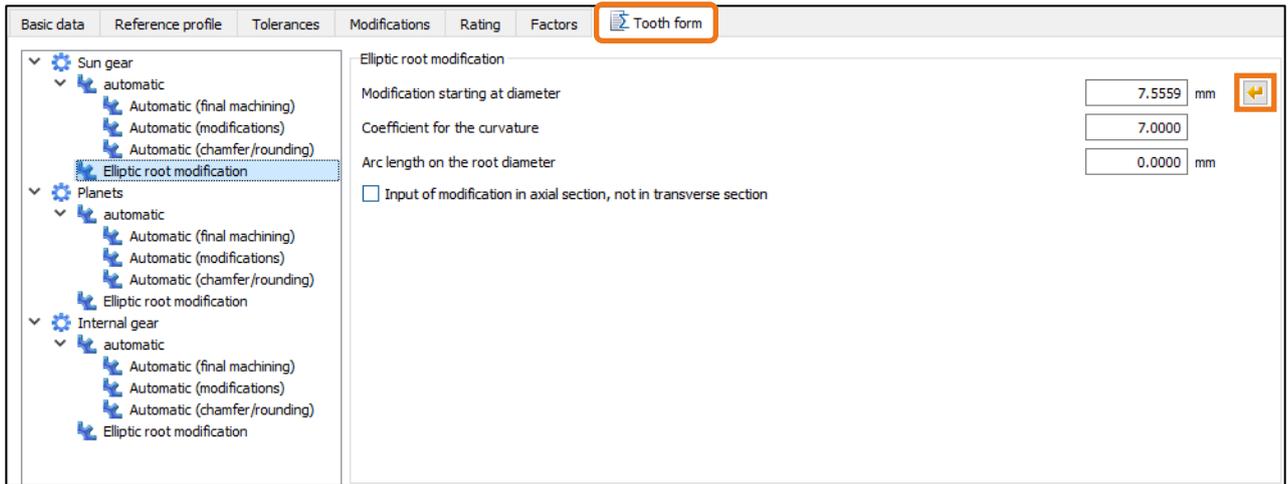
Figure 27. «Elliptical root modification» adds the alternative

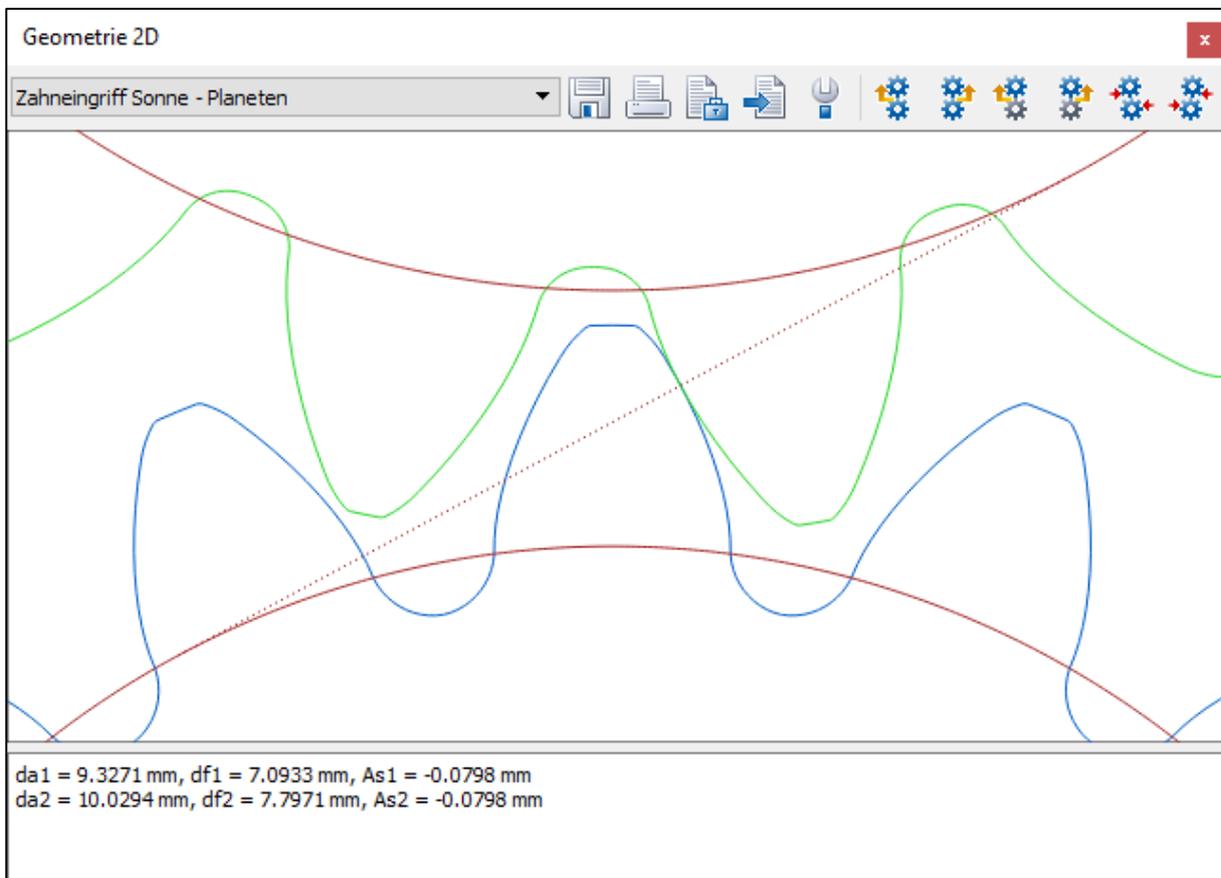After this definition has been performed for all the gears, click the «Σ» icon or press «F5».

Figure 28. Calculating and displaying the tooth form

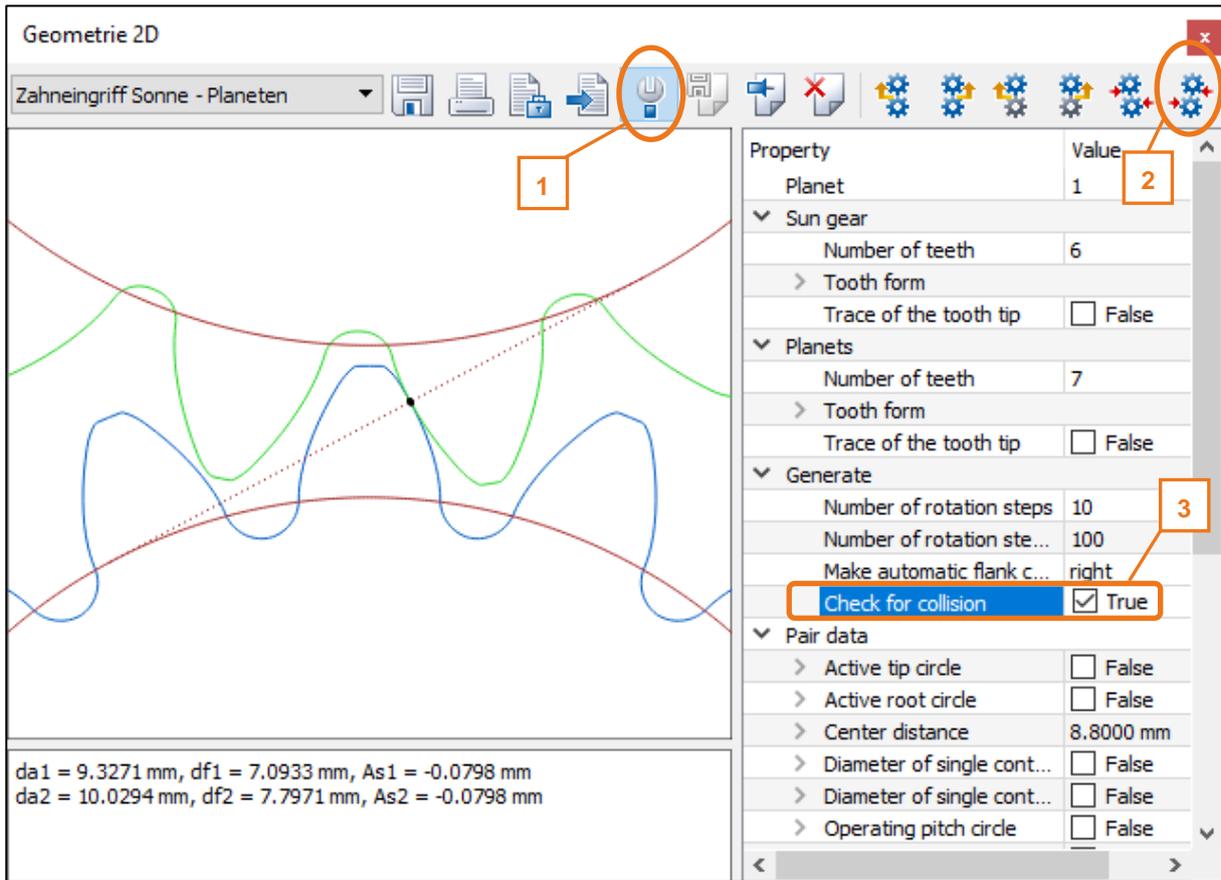In the next dialog, activate the collision check.

Figure 29.   Activating collision check and displaying pair 1

If necessary click the [icon] button (2) and select «Make flank contact (right)». Now you should see small black dots at the points where the two flanks contact each other. A black dot means «meshing or almost meshing», and a red dot means «collision».
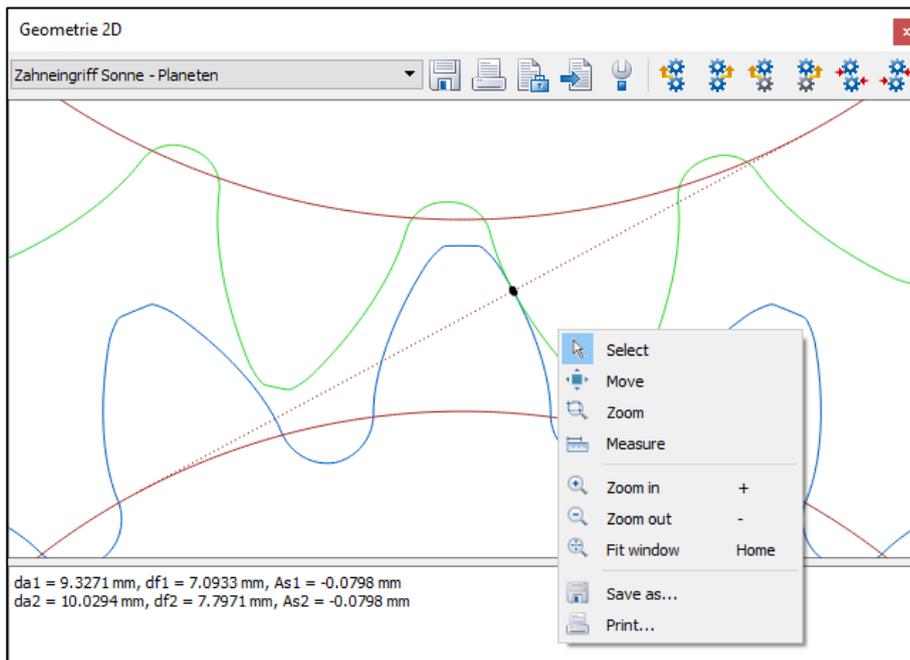

Figure 30.   Automatic connection of flanks, zoom and collision check

Use the «+» and «-» button to zoom in or out, click the right-hand mouse button to open the menu and, finally, click the buttons to animate the graphic. Check whether any of the modifications cause a problem, Figure 30.

When you are satisfied with the result, go back to the main dialog. Click **[Calculate F5]** and use the root safety factor to check whether or not the modifications have improved the root strength.

2.8 Current tutorials

The tutorials listed below include additional details about particular topics that are mentioned in this document:

- Tutorial 009, «Fine Sizing of Cylindrical Gears»
- Tutorial 011, «Tooth Form Optimizations, Tooth Form Modifications specifically for plastic, sintered, wire-eroded and form-forged gears»