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KISSsoft Tutorial: Lifetime analysis of cylindrical gears

1 Task

1.1 Task

To analyze the strength of a cylindrical gear pair as specified in ISO6336, method B. A load spectrum is used in this example. The safety factors, service life and permissible power rating are to be calculated.

The following data is specified for this cylindrical gear pair:

	Gear 1	Gear 2
Module [mm]	6	6
Helix angle [degrees]	5	5
Pressure angle [degrees]	20	20
Number of teeth [-]	25	76
Width [mm]	44	43
Material	18CrNiMo7-6 case-hardened	18CrNiMo7-6 case-hardened
Nominal torque [Nm]	3360	follows
Nominal speed [Rpm]	440	follows
Application factor [-]	1.25	1.25
Required service life [h]	20’000	20’000

The following load spectrum is to be used:

Frequency [%]	Speed factor [%]	Torque factor [%]
10	20	20
20	50	30
40	80	90
30	100	100

2 Calling the program

2.1 Starting the software

You can call KISSsoft as soon as the software has been installed and released. Usually you start the program by clicking "Start→Program Files→KISSsoft 03-2011→KISSsoft". This opens the following KISSsoft user interface:

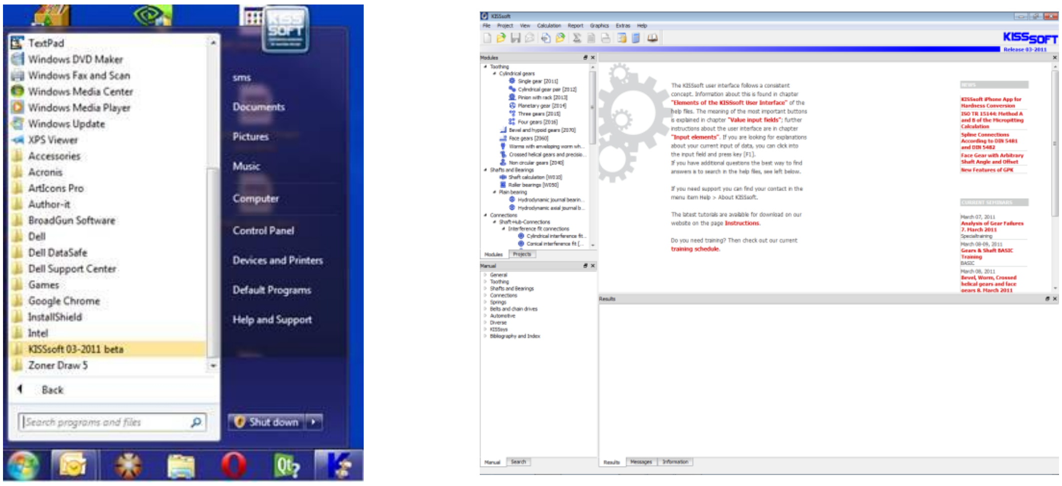


Figure 2.1 Starting KISSsoft, initial window

3 Entering the data

3.1 Inputting the load spectrum

KISSsoft provides a range of different options for you to input load spectra. If the load spectrum is stored in the database it is also available to other calculations. In contrast, if you use the "**Own input**" option to enter the load spectrum, it is only available to the current calculation.

3.1.1 Database: direct entry

After you have opened the database tool as shown in Figure 3.2 with authorization to write data to it (you may have to run KISSsoft as the Administrator), you now have a range of options for defining load spectra in the database. Select **"Load spectra"** from the list and click on **"Edit"** to call the appropriate table.

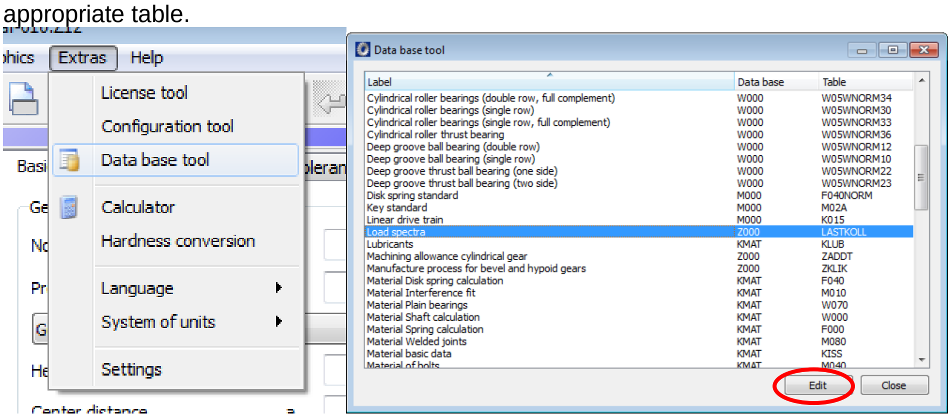


Figure 3.2 Calling the load spectrum database

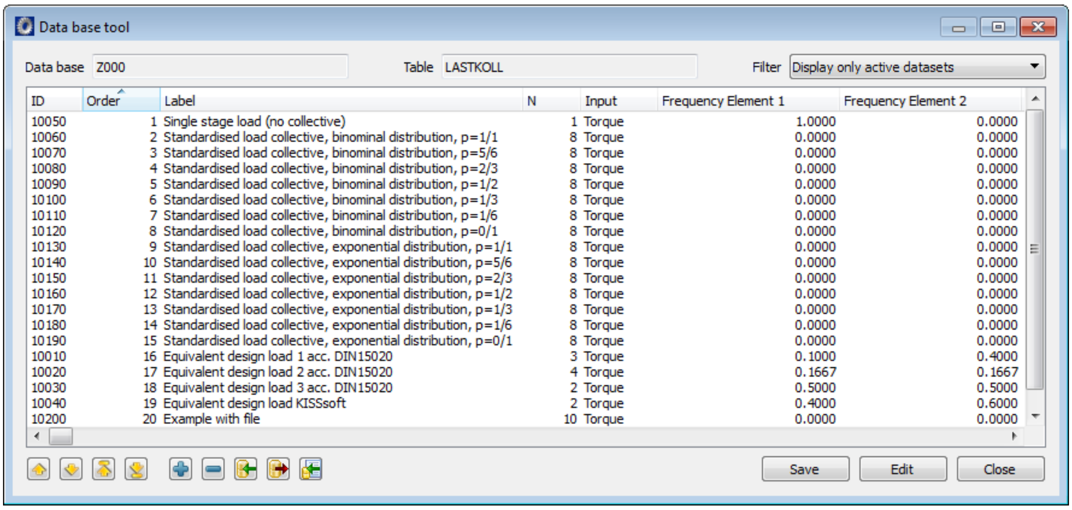


Figure 3.3 Generating a new data record

Click **"+"** to create a new data record. If a data record is marked, its data is copied and "_NEW" is attached to its label. If no data record is marked, a new one will be created. Now enter a description. You now see information about the "frequency, power or torque and speeds" for the corresponding load level elements. You can also specify whether the load spectrum refers to the torque or the transmitted power. Once you have finished entering data for this load spectrum, click **"OK"** and then click **"Save"** to save this data record. Then click "**Close**" to close the database tool and return to the KISSsoft system's initial screen. The load spectrum is now available for analysis.

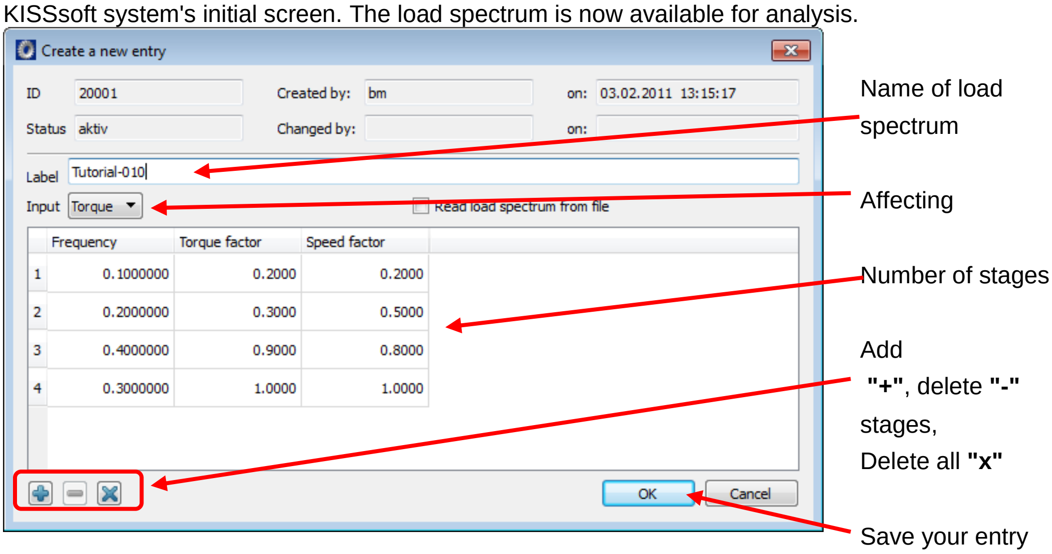


Figure 3.4 Inputting the load spectrum

3.1.2 Database: data input from a file

You can also transfer a load spectrum to the database as a file. To do this, enter the required load spectrum in a text editor as shown below:

Frequency Torque/Power/ Speed

For example:

0.1	0.2	0.2
0.2	0.3	0.5
0.4	0.9	0.8
0.3	1.0	1.0

This file is saved as a file with the file extension *.**dat** (in this example "Example-Tut-010.dat", for preference in the ...\KISSsoft 03-2011\ext\DAT folder (for more information, see Figure 3.5) or in any other folder (for more information see Figure 3.6).

In the KISSsoft installation folder you will find a folder called C:\Program Files\KISSsoft 03-2011\ext\DAT. If you store files with the file extension *.dat in this folder, the KISSsoft system will be able to find them automatically. In this case, you only need to enter the following:

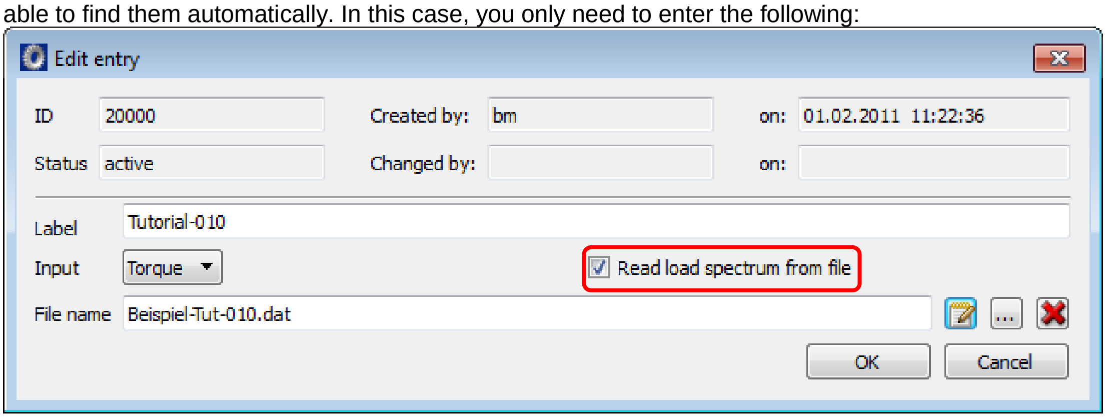


Figure 3.5 Inputting the file description in which the load spectrum was saved

If you save the file with the load spectrum to a different folder, you must also store the entire path + file name in the "File name" field. If the path name is too long, follow the steps described above:

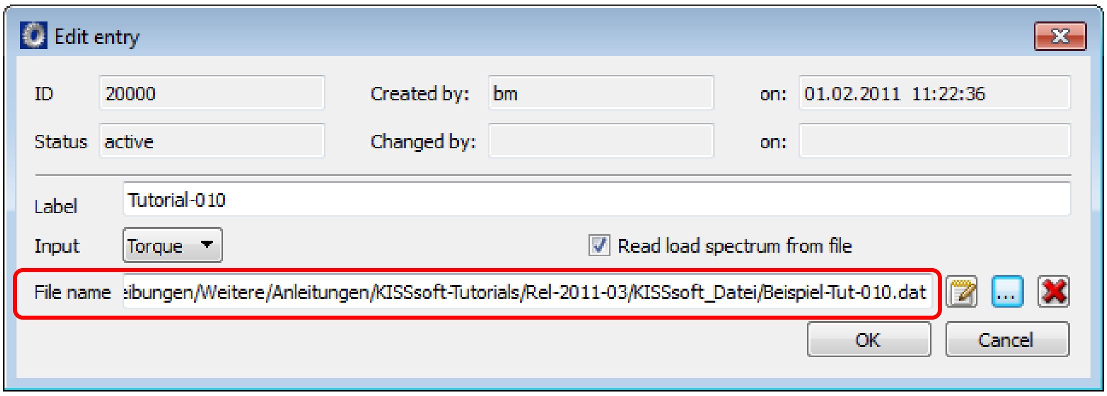


Figure 3.6 Inputting the entire path including the file description

3.1.3 Own input

After you have clicked the Figure 3.7 plus button as shown in , you can now define load spectra in the database using the **"Own input"** function. Click the plus button to call the **"Input load spectrum"** window. Here you can either input a load spectrum directly or load it from a file. Then click **"OK"** to assign the load spectrum to the calculation.

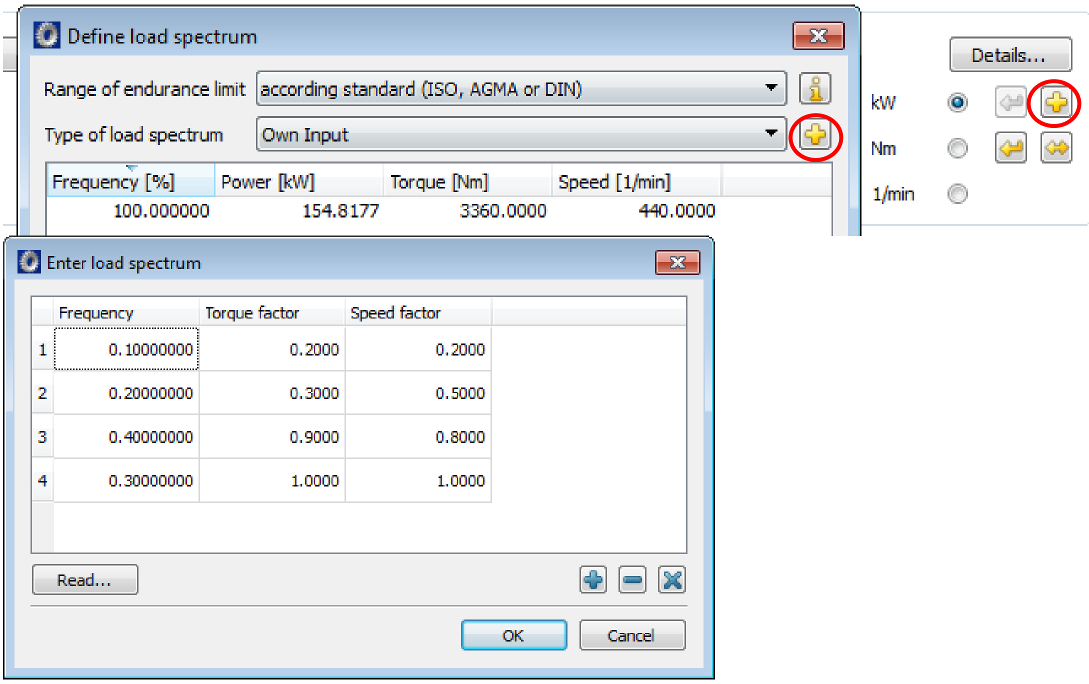


Figure 3.7 Calling "Own input" load spectrum

3.2 Inputting toothing data

To call the cylindrical gear calculation, go to the modules tree window in the KISSsoft main screen. There, click the **"Modules"** tab and then click **"Cylindrical gear pair [Z012]"**. Then input the toothing data specified below:

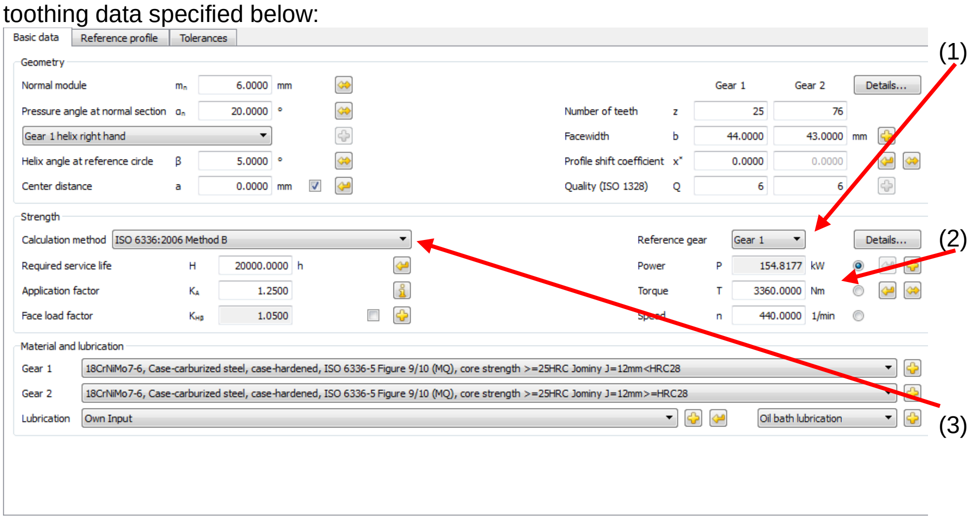


Figure 3.8 Inputting toothing and load data

(1) Reference gear

(2) Load: here you must input two of the three values (speed, torque, power)

(3) Calculation method

3.3 Defining further parameters

3.3.1 Center distance

Click the sizing button  to the right of the Center distance input field to define the center distance. At this point, no profile shift coefficient has been defined and therefore the total profile shift coefficient is zero. To calculate the center distance, click "Calculate" and then transfer this value to the main screen by clicking "Accept".

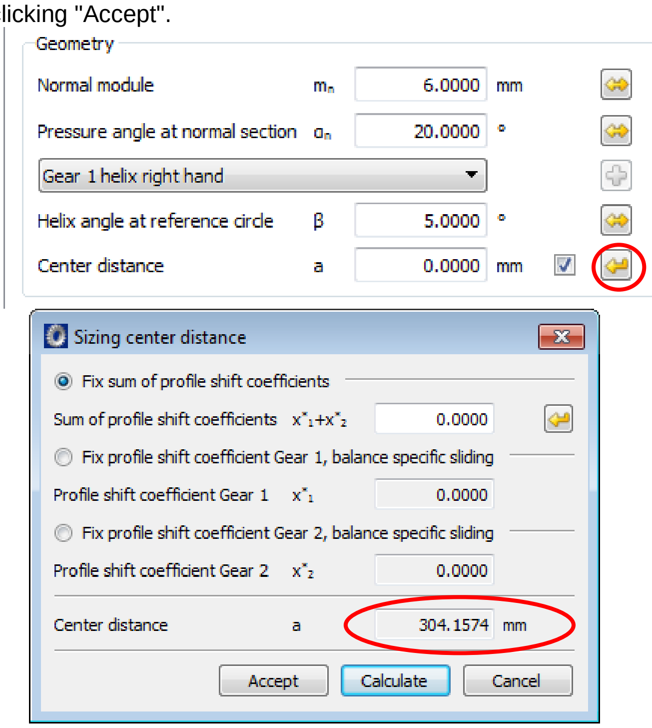


Figure 3.9 Calculating the center distance with a predefined profile shift coefficient total (**here zero**)

3.3.2 Profile shift coefficient

You should select profile shift coefficients so that the minimum specific, balanced sliding is achieved. To do this, click the sizing button  next to the profile shift.

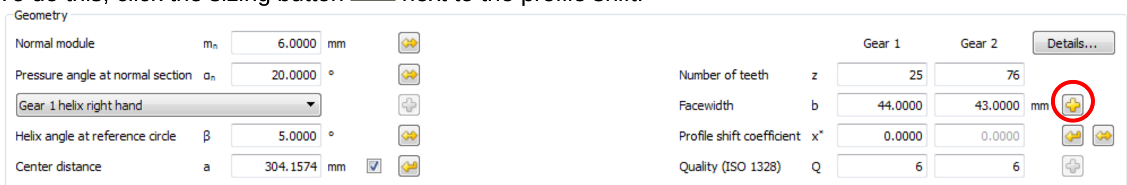
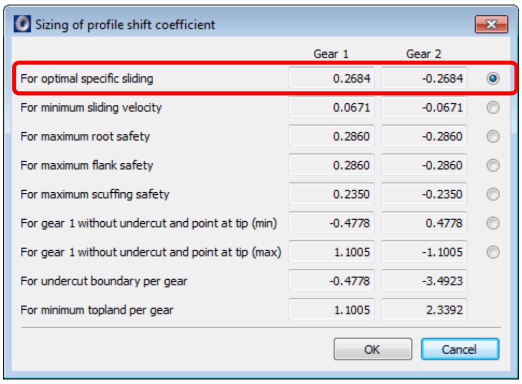


Figure 3.10 "Sizing button" for the profile shift coefficient



You then see the resulting profile shift coefficients for different criteria. In this example, you should select profile shift coefficients for the criterion "For optimal specific sliding".

Figure 3.11 Sizing the profile shift coefficients

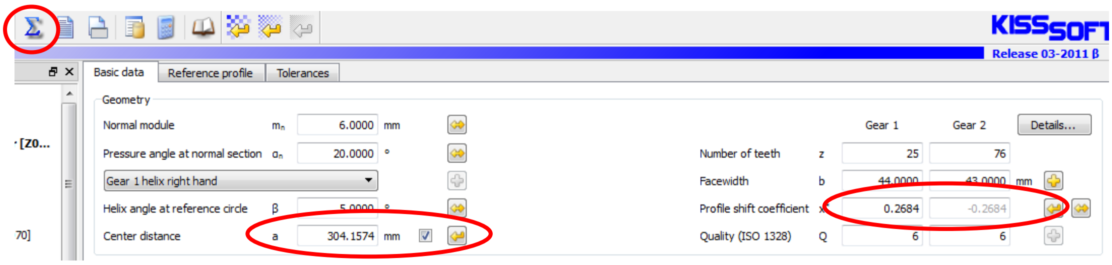


Figure 3.12 Calculated profile shift coefficients

The center distance is a theoretical value. It is set to 304.2mm (overwrite the value directly in the screen). To make the required changes to the profile shift coefficients, click **"Σ"** (Calculate). This is a minor change that does not affect specific sliding. When you perform the analysis, the system also defines the safety factors for the specified nominal load. The results then appear in the lower part of the window.

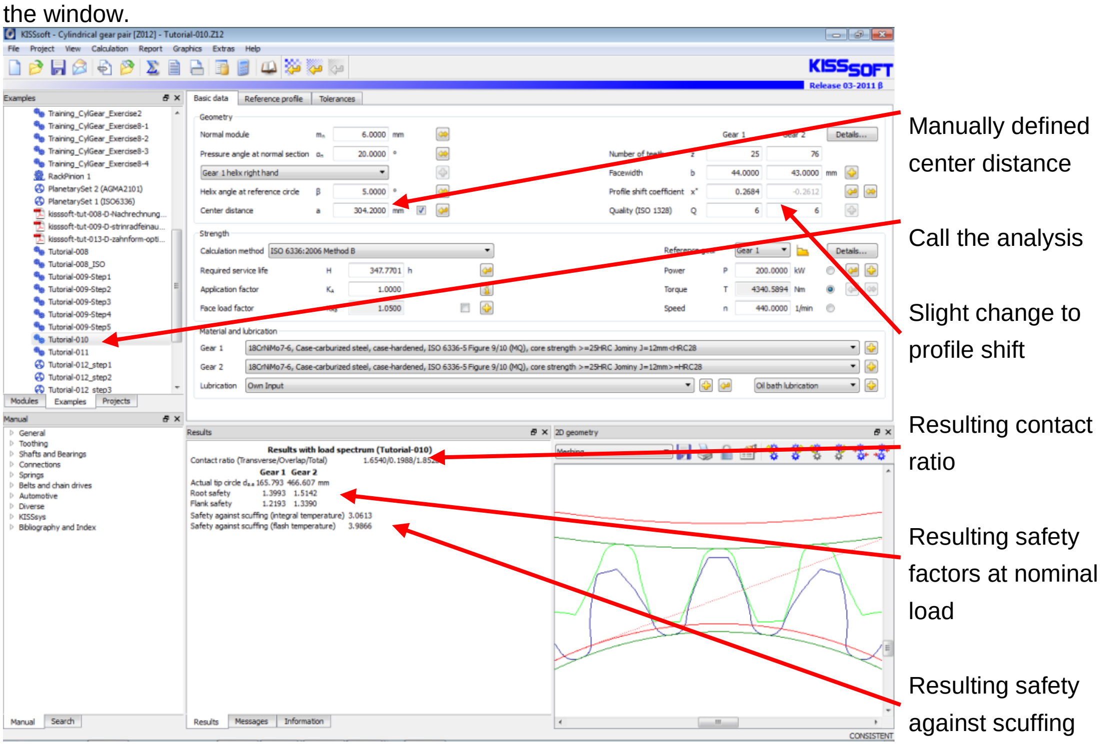


Figure 3.13 Gear pair with a sensible center distance, profile shift coefficients and first results under nominal load

You can now observe specific sliding by clicking **"Graphics"→ "Evaluation" →"Specific sliding"**:

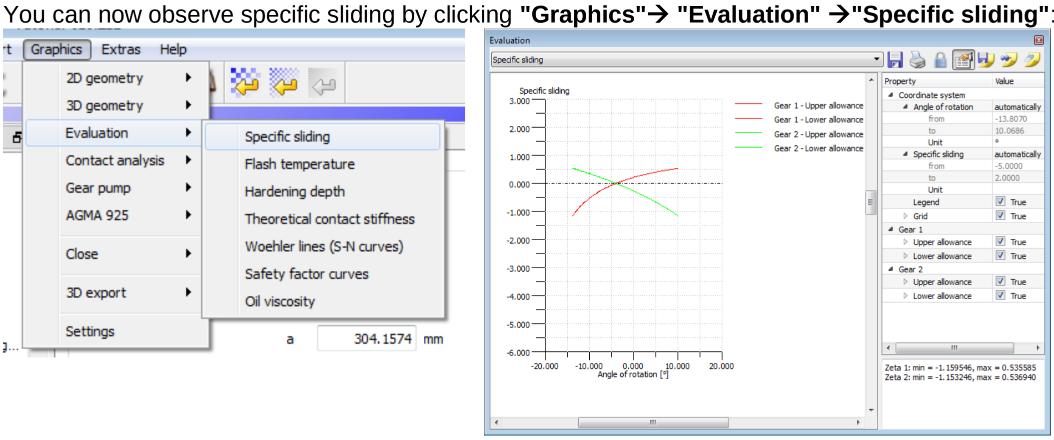


Figure 3.14 Call to display specific sliding, graphic

3.3.3 Lubrication

You can select the lubrication type and lubricant directly in the main screen. To specify the lubricant temperature, click the plus button to the right of the lubrication type. You can also input data about the ambient temperature in the **"Operating backlash"** tab.

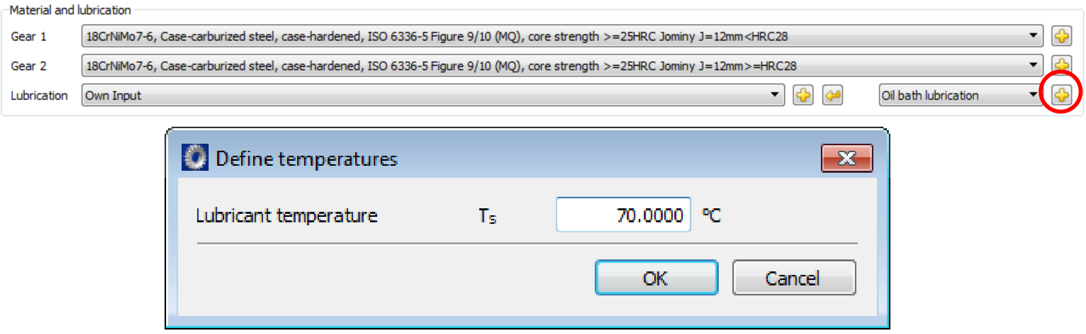


Figure 3.15 Details about lubrication

4 Strength analysis with load spectra

4.1 Resulting service life with required safety factors

In the first step, you must define the service life in hours, taking into account a required safety factor. The required safety factors for different settings and modules are interpolated automatically by the software. In module-specific settings these safety factors are predefined for each specific module and can differ according to whether metal (as stated in DIN, ISO and AGMA) or plastic materials are used.

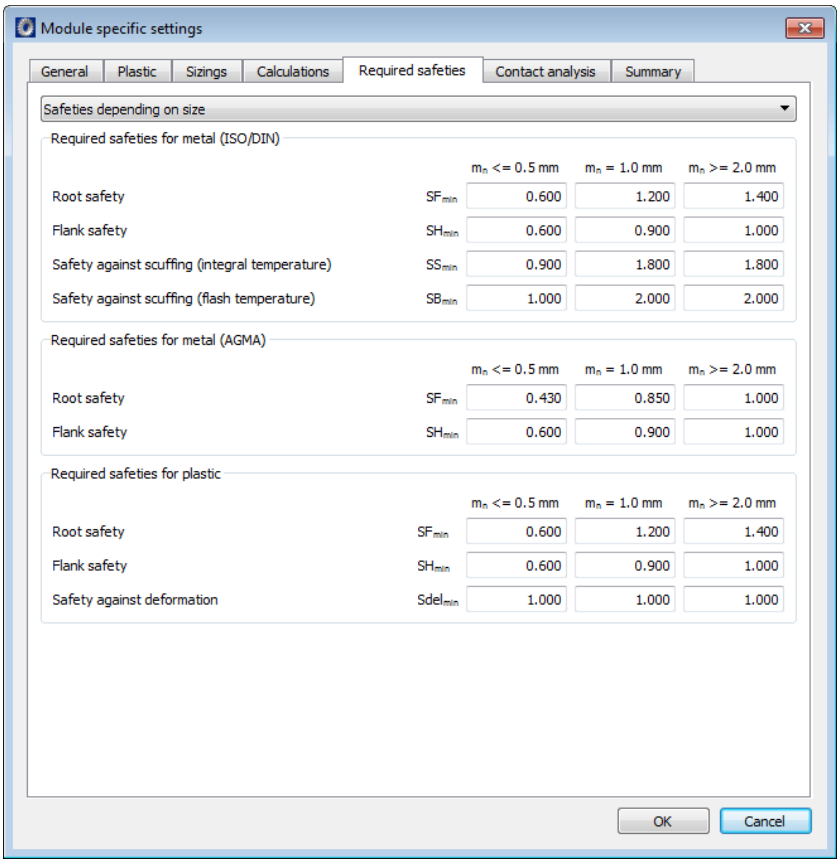


Figure 4.1 Predefined setting for the required safety factors

You can also input your own values in the **"Required safeties"** tab.

To do this, select **"Safeties are not depending on size"** from the drop-down list and input your own values:

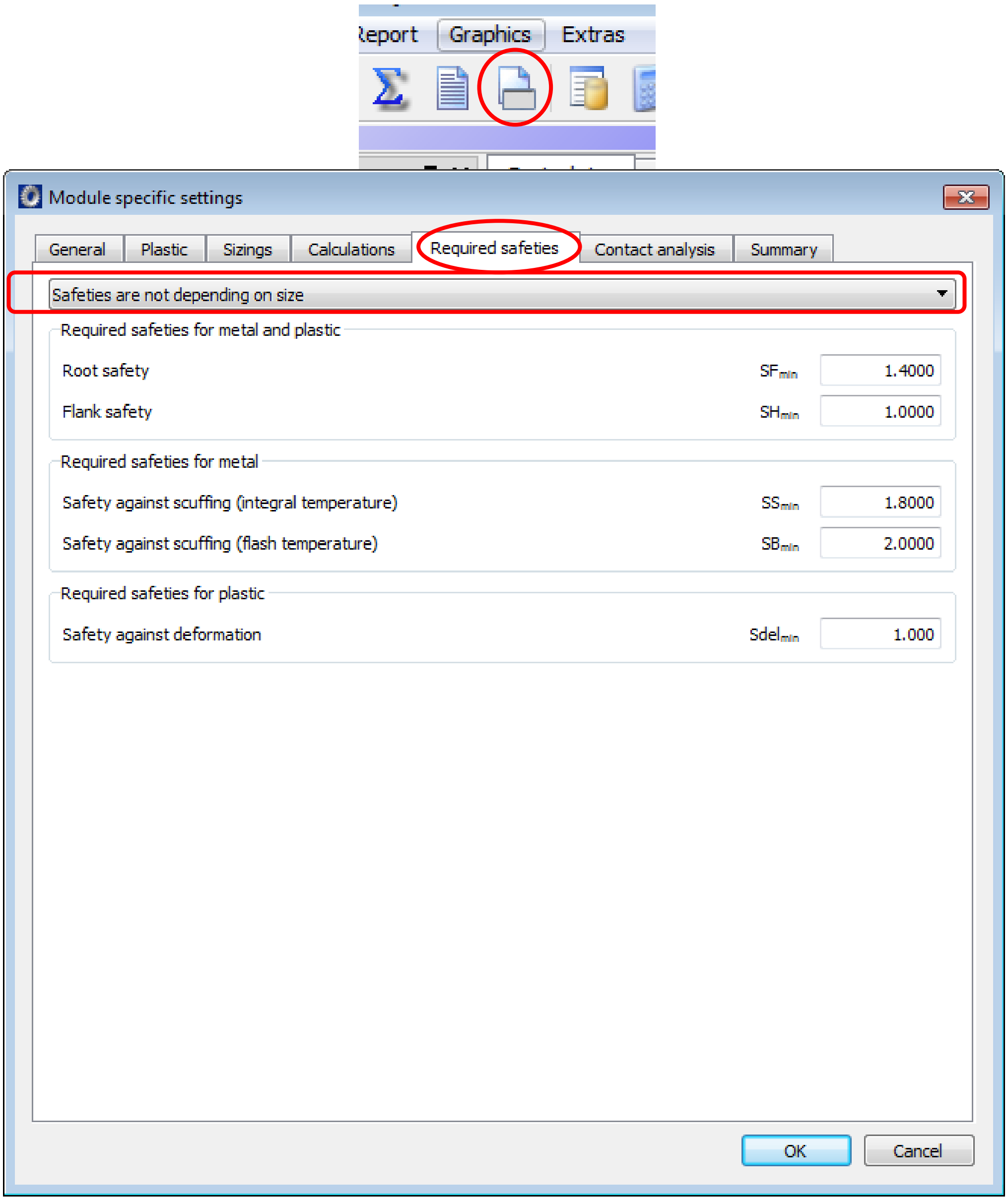


Figure 4.2 Setting the required safety factors

Now click the plus button  next to the power input field to calculate the resulting service life:

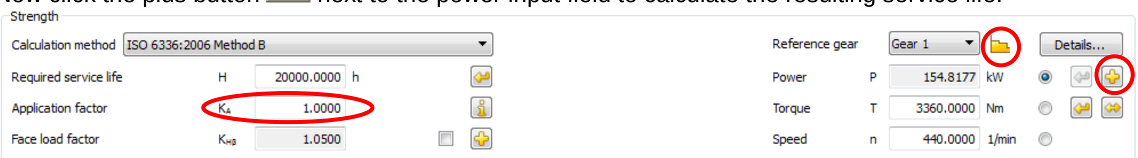


Figure 4.3 Calling the service life calculation with load spectra

In the next screen, **"Define load spectrum"**, the appropriate load spectrum from the drop-down list is assigned. For more information see Figure 4.4. Once you have selected a load spectrum, you will see a small icon next to the reference gear (upper marking in Figure 4.3). Now set the application factor to 1.00, which is the usual setting when you are working with load spectra (however, this value can be greater than 1.00 depending on which application/defaults are being used). In addition, you can apply different modifications of the endurance limit range. Press "F1" to call the online help for more information about this. The calculation is then performed when you click **"Σ"** (Calculate) or press F5.

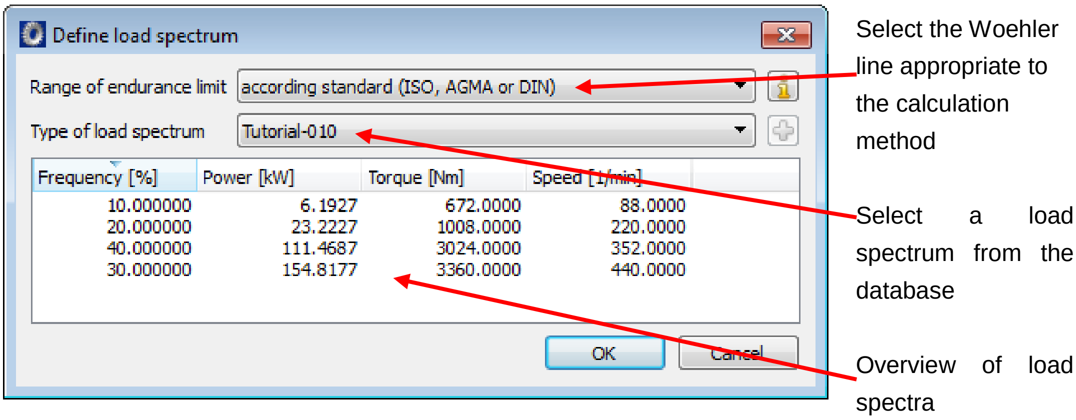


Figure 4.4 Selecting and displaying the load spectrum defined in section**3.1**

Then perform the analysis with **200 kW**. Click **"Report"→"Service life"** to display the results in a report.

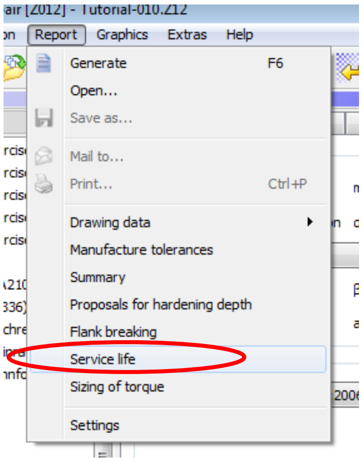
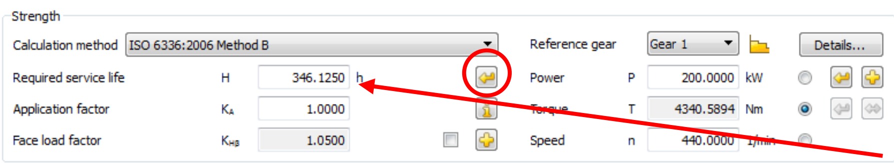


Figure 4.5 Service life report

```
—————————————————————— KISSsoft - Release 03-2011
KISSsoft Calculation programs for machine design

——————————————————————————————— File
Name        : Tutorial-010
Description: KISSsoft Data Set
Changed by : bm          on: 03.02.2011         at: 14:11:43



Calculation of service life

Load spectrum

Nominal Power             [P]           200.0000     kW
Application factor         [KA]                       1.00

Load spectrum     : Tutorial-010
Number of element in the Load spectrum: 4
Reference gear: 1

Element Frequency (%)    Power (kW)  Nominal Speed  (1/min)  Torque (Nm)
    1      10.00000         8.00        88.00                  868.12
    2      20.00000        30.00       220.00                 1302.18
    3      40.00000       144.00       352.00                 3906.53
    4      30.00000       200.00       440.00                 4340.59

Woehler line (S-N curve) at the fatigue stress according:  Miner

Notice:
 Calculation-method according to:
 - ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Notice:
Calculation with methods ISO6336 and AGMA 2001 results in a reduction
 of resistance in the domain of fatigue resistance
(from circa 10^7 to 10^10 cycles with a reduction of circa 15 %%).
The lifetime calculation takes this into account
(also with the S-N curve (Woehler Curve) of the Miner type).


Required safety root:                   1.400
Required safety flank:                  1.000

Results
                                           Gear 1         Gear 2
Service life (h) root         :         346.125       895.807
Service life (h) flank        :        5411.706     18750.234

Service life (h) system:       346.125

Element no.   Damage(%)
    1      0.0000e+000
    2      0.0000e+000
    3          0.7249
    4         99.2751


Safety scuffing (Integral)                          3.06
Safety scuffing (Flash)                             3.99
(Safety against scuffing/micropitting is indicated for the weakest element of the load spectrum.)

End report                                                    lines:   65
```

Figure 4.6 Calculation report for load spectrum calculation



System's service life (minimum of the achieved service lives)

Figure 4.7 Displaying the minimum service life

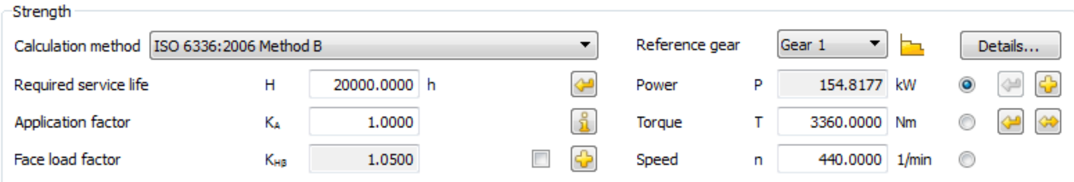
The interim values for, for example, K.Hb are stored in the Z18-H1.tmp file, for example in directory C:\Documents and settings\User\Local settings\TMP\KISS_???.

```
Results (for check only):
 P =        8.0008 kW
Element no. 1 (h =10.00%)
 n1  88.000 (rpm), T1 868.205 (Nm),  L1   8.001 (kW)
 Pair[1-2] K.A   1.000, K.V   1.008, K.Hb   1.177, K.Fb   1.123, K.Ha   1.126, K.Fa   1.126
 SB  24.223, SSInt   4.674
  NL.F[1]=    1e+010; NL.F[2]=    1e+010;  NL.H[1]=    1e+010; NL.H[2]=    1e+010;
 H[No.1] at 100% =10000000000000000000.000 (h)
  {H.F[1] > 1e6  H.F[2] > 1e6  (h)}
  {H.H[1] > 1e6  H.H[2] > 1e6  (h)}

Element no. 2 (h =20.00%)
 n1 220.000 (rpm), T1 1302.307 (Nm),  L1  30.003 (kW)
 Pair[1-2] K.A   1.000, K.V   1.016, K.Hb   1.102, K.Fb   1.071, K.Ha   1.040, K.Fa   1.040
 SB  14.258, SSInt   4.363
  NL.F[1]=    1e+010; NL.F[2]=    1e+010;  NL.H[1]=    1e+010; NL.H[2]=    1e+010;
 H[No.2] at 100% =10000000000000000000.000 (h)
  {H.F[1] > 1e6  H.F[2] > 1e6  (h)}
  {H.H[1] > 1e6  H.H[2] > 1e6  (h)}

Element no. 3 (h =40.00%)
 n1 352.000 (rpm), T1 3906.921 (Nm),  L1 144.014 (kW)
 Pair[1-2] K.A   1.000, K.V   1.017, K.Hb   1.050, K.Fb   1.035, K.Ha   1.000, K.Fa   1.000
 SB   4.728, SSInt   3.273
  NL.F[1]= 4.03e+008; NL.F[2]= 1.71e+008;  NL.H[1]= 2.65e+008; NL.H[2]= 3.02e+008;
 H[No.3] at 100% = 12533.257 (h)
  {H.F[1]= 19099.970  H.F[2]= 24577.146  (h)}
  {H.H[1]= 12533.257  H.H[2]= 43425.499  (h)}

Element no. 4 (h =30.00%)
 n1 440.000 (rpm), T1 4341.023 (Nm),  L1 200.020 (kW)
 Pair[1-2] K.A   1.000, K.V   1.021, K.Hb   1.050, K.Fb   1.035, K.Ha   1.000, K.Fa   1.000
 SB   3.986, SSInt   3.061
  NL.F[1]= 2.76e+006; NL.F[2]= 2.37e+006;  NL.H[1]= 5.18e+007; NL.H[2]=  5.9e+007;
 H[No.4] at 100% =   104.596 (h)
  {H.F[1]=   104.596  H.F[2]=   272.718  (h)}
  {H.H[1]=  1962.458  H.H[2]=  6799.408  (h)}


  Foot: H[1]=      346.125 (h); H[2]=      895.8072 (h);
  Flanc: H[1]=     5411.706 (h);   H[2]=      18750.23 (h);

Damage(%) - refering to required life time  20000.000 h
Element no.    Damage(%) (F1, F2,...   H1, H2,...)
    1            0.0000       0.0000      0.0000      0.0000
    2            0.0000       0.0000      0.0000      0.0000
    3           41.8849      32.5506     63.8302     18.4224
    4         5736.3748    2200.0726    305.7391     88.2430

 Sum          5778.2597    2232.6232    369.5692    106.6653

Damage(%) - refering to total life time    346.125 h
Element no.    Damage(%) (F1, F2,...   H1, H2,...)
    1            0.0000       0.0000      0.0000      0.0000
    2            0.0000       0.0000      0.0000      0.0000
    3            0.7249       0.5633      1.1047      0.3188
    4           99.2751      38.0750      5.2912      1.5272

 Sum           100.0000      38.6383      6.3959      1.8460
```

Figure 4.8 Display showing interim calculations for each step etc.

4.2 Resulting safety factors for a required service life

After you have specified a required service life in the "Strength" group, this analysis is performed simultaneously when you run the **"Calculations with load spectra"**. The calculation is performed with an iteration. The results are displayed in the **"Results"** window.



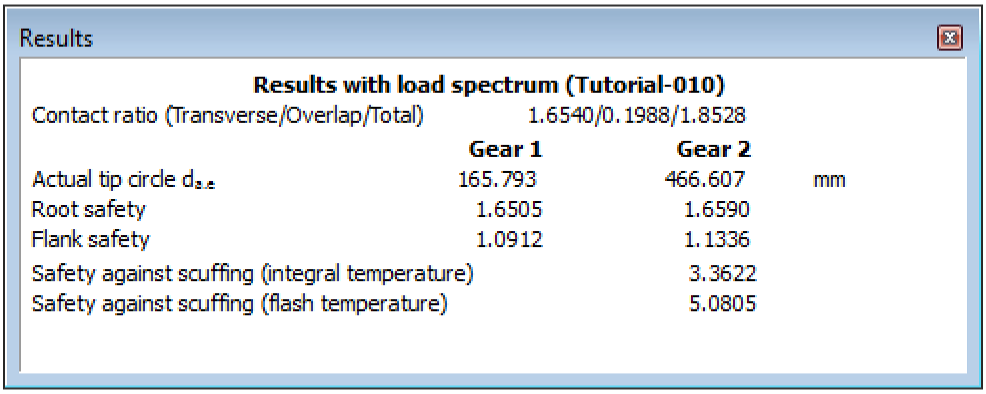


Figure 4.9 Results of safety factors with load spectra for the required service life

4.3 Calculating maximum permissible torque

Similarly, click the Sizing button to define the maximum transmissible power. In this case, the specified speed, required service life and the necessary safety factors are taken into account.

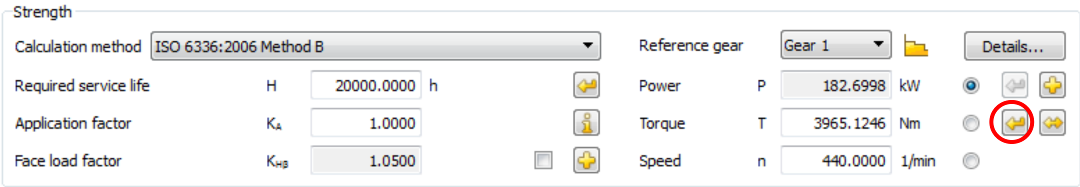


Figure 4.10 Calculating maximum transmissible torque

5 Additional calculations

5.1 Safety against scuffing

In the lower part of the main window, you can also see safeties against scuffing for flash or integral temperature criteria:

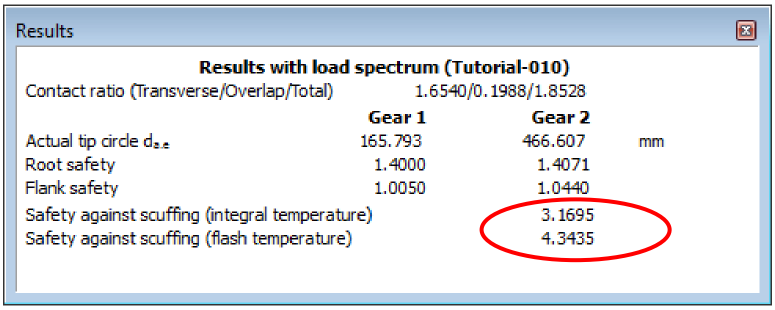


Figure 5. 1 Safety factors against scuffing

You can show the progression of the flash temperature across the contact by clicking **"Graphics"→"Evaluation"→"Flash temperature"**, see Figure 5.2. If you now click **"Calculation"→ "Modifications"** (see Figure 5.3) e.g. the program sizes a tip relief (here optimized for 75% nominal load and 50% manufacturing tolerance) and transfers the changed tooth form [Accept data] (this is shown in the message displayed in Figure 5.4). You can therefore change the progression of flash temperature in the tip area.

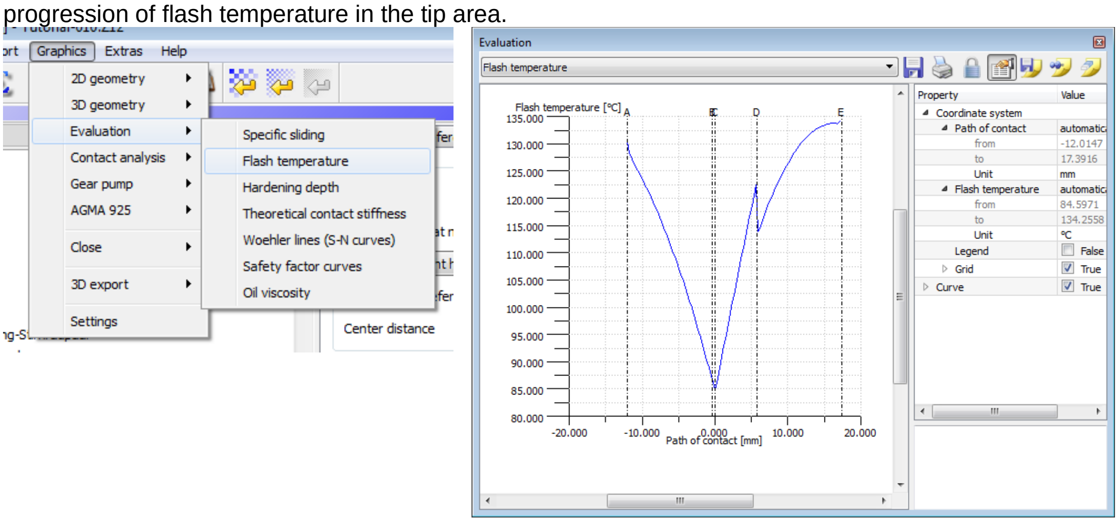


Figure 5.2 Flash temperature progression over the unmodified tooth form

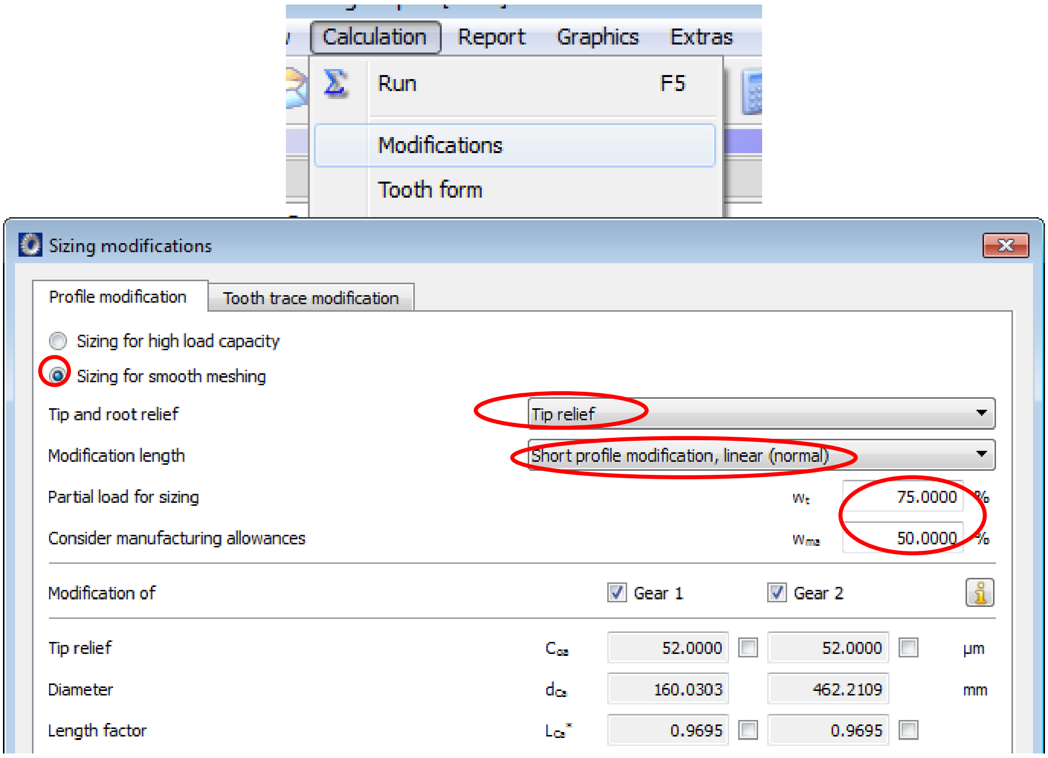


Figure 5.3 Calling the profile correction screen, sizing a tip relief for 75% nominal load etc.

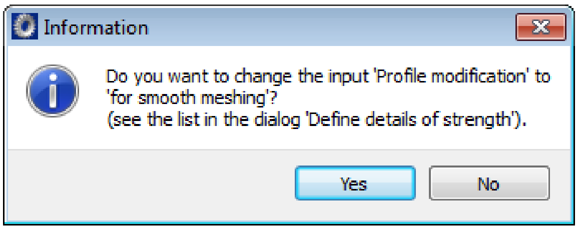
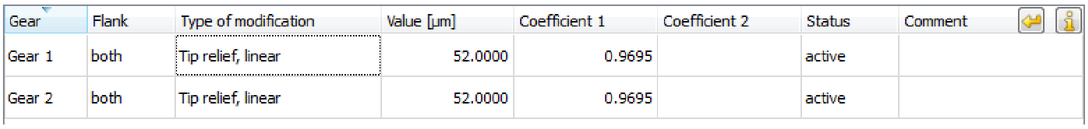


Figure 5.4 Message you see after clicking the [Accept] button



Gear	Flank	Type of modification	Value [µm]	Coefficient 1	Coefficient 2	Status	Comment
Gear 1	both	Tip relief, linear	52.0000	0.9695		active	
Gear 2	both	Tip relief, linear	52.0000	0.9695		active	

Figure 5.5 Inputting the correction

If you now click **"Calculation"** again in the cylindrical gear main screen (F5), the system defines the safety factor against scuffing using the predefined nominal load. Here you should note that these factors are now higher than previously. Compare these values with Figure 5. 1 and Figure 5.6.

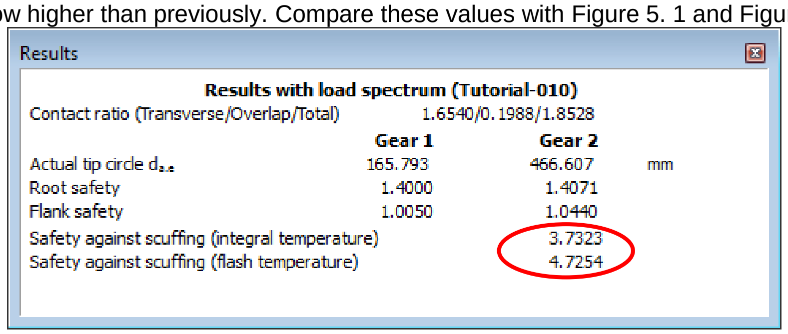


Figure 5.6 Scuffing safeties, integral and flash temperature criterion

If you now calculate the flash temperature progression again by clicking **"Graphics"→"Evaluation"→"Flash temperature"**, you will see that the flash temperature has reduced at the tooth tip to the gear tooth mass temperature.

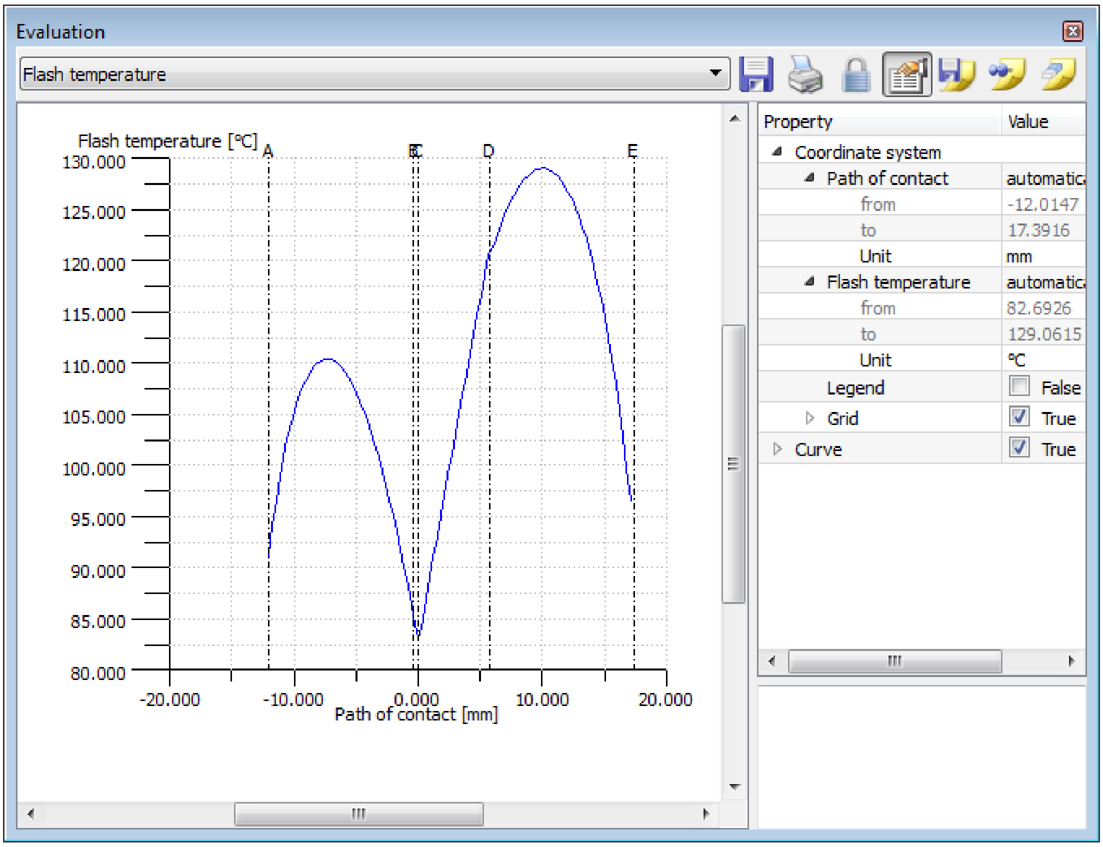


Figure 5.7 Flash temperature progression after tip relief

5.2 Necessary hardening depth

To estimate the necessary hardening depth, use the progression of the shear stress level as the result of Hertzian contact stress. Click **"Graphics"→"Evaluation"→"Hardening depth"** to get the stress distribution. We recommend you try to achieve a hardening depth that is twice the depth of the shear stress maximum. If the gear is ground after implementation/hardening, you must add the grinding depth to the recommended hardening depth.

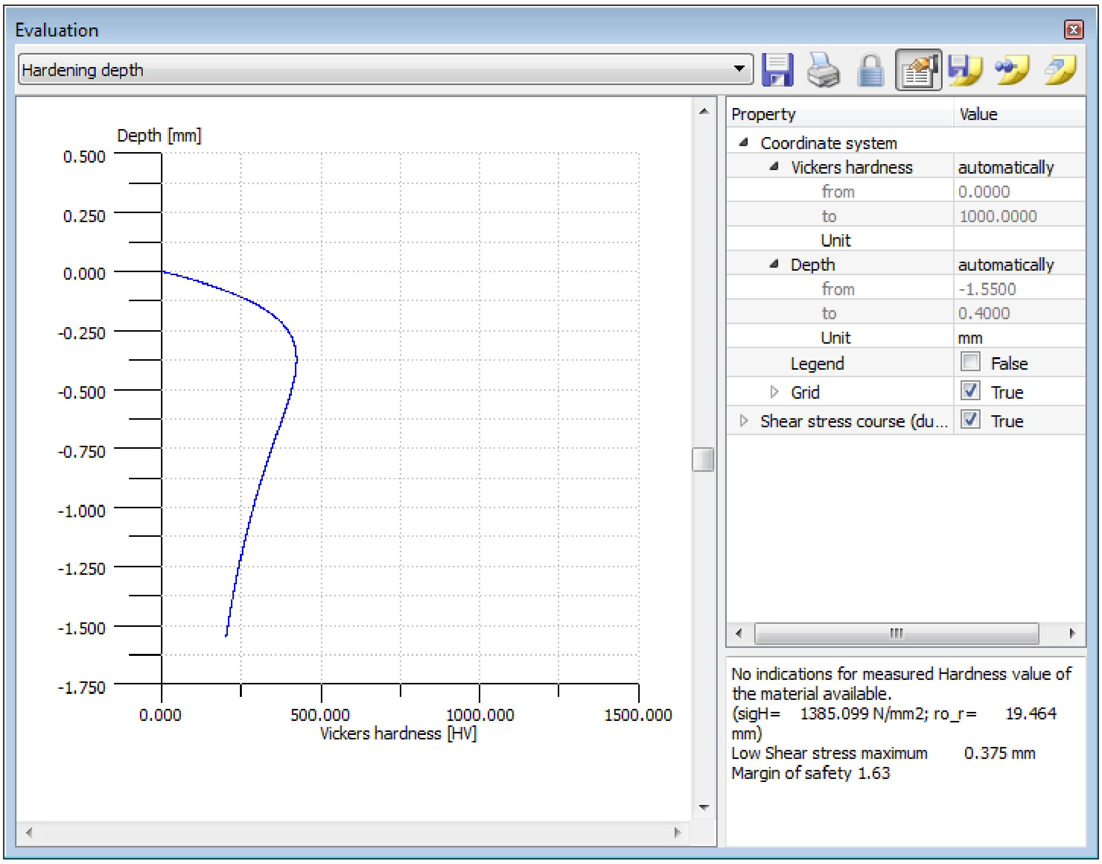


Figure 5.8 Display showing shear stress across the tooth depth, recommended hardening depth