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KISSsoft Tutorial: Sizing of helical gears

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1 Example problem, starting KISSsoft

1.1 Example problem

A helical gear pair is to be designed such that it has a lifetime of 5'000h when transmitting 5kW at 400Rpm (Application factor = 1.25). The ratio shall be 1:4 (reducing speed), the gear material is 18CrNiMo7-6. The gear pair is to be optimized in terms of noise/contact ratio. The lifetime calculation is to be performed according to ISO 6336, method B.

1.2 Starting gear pair calculation

After having installed and released KISSsoft as test or commercial version (see installation instructions), start KISSsoft using „Start/Program Files/KISSsoft 10-2008/KISSsoft“. The following window will appear:

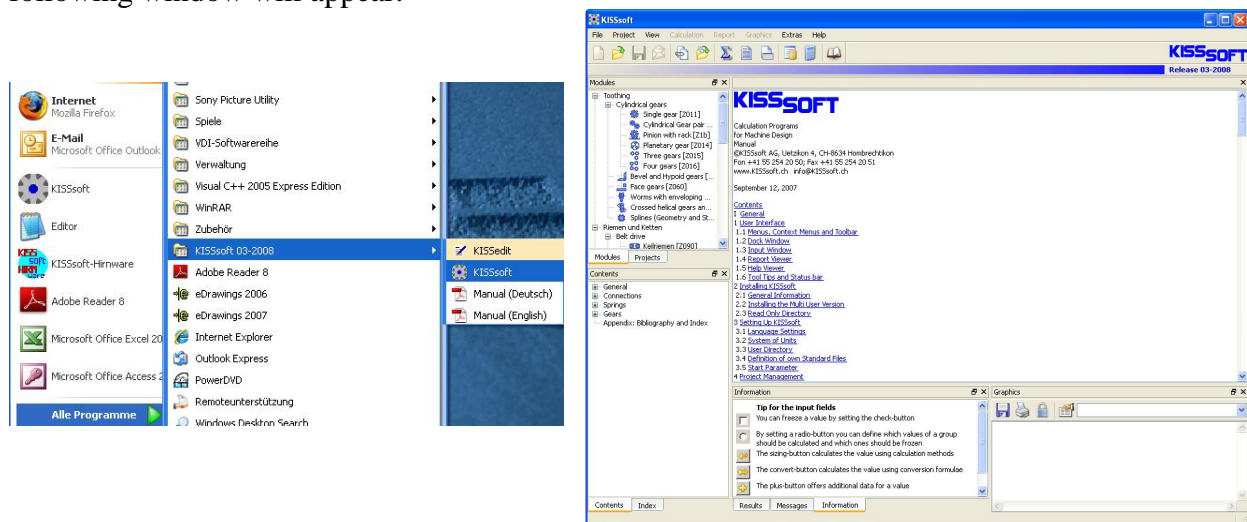


Figure 1.2-1: Start KISSsoft, KISSsoft main window.



Figure 1.2-2: Selecting cylindrical Gear pair.

The example used in this tutorial can be opened using “File/Open” and selecting „Tutorial-009-Step1“ (to “Tutorial-009-Step5”), see figure below or using the Module tree window Tab “Modules”, select the Cylindrical Gear pair calculation. In each of the different sections of this tutorial, it will be indicated which step should be opened.

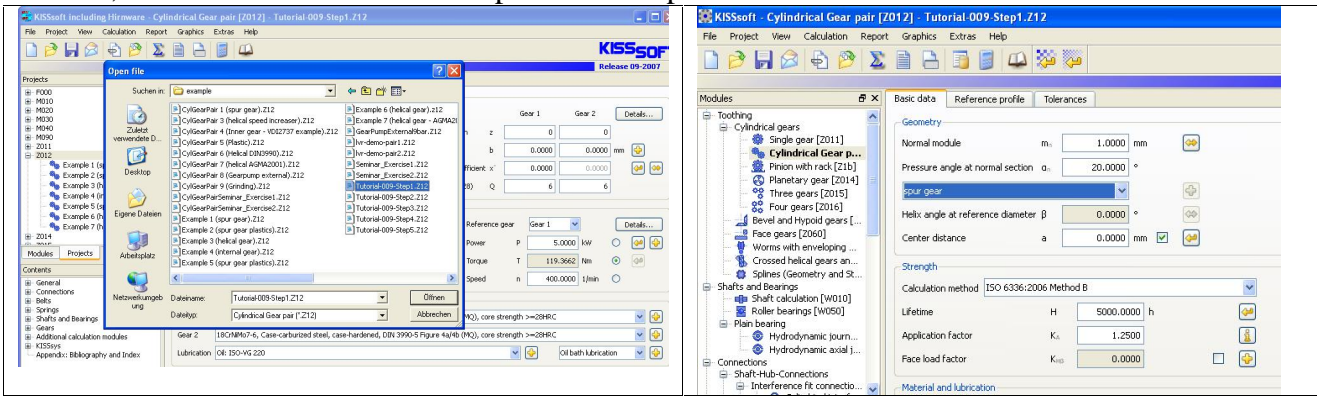
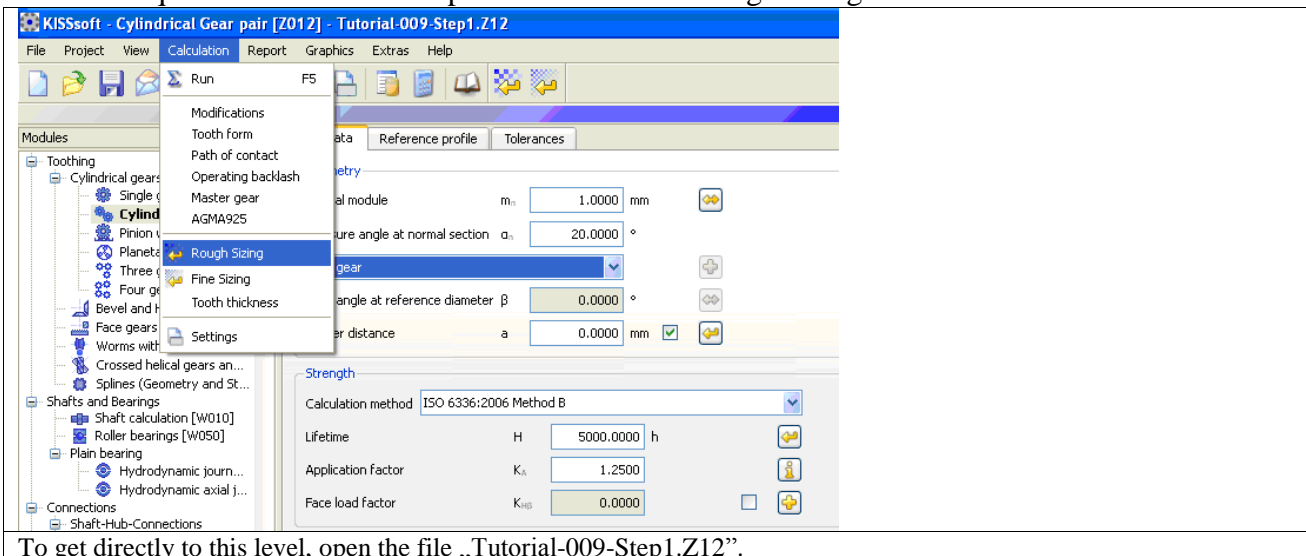


Figure 1.2-3: Options to opening the example problem files at different stages of progress.

2 Rough sizing of gear pair

2.1 Executing rough sizing function

KISSsoft offers a function where a sensible gear pair is proposed based on the power rating and lifetime required alone. For this operation is used the rough sizing function.



To get directly to this level, open the file „Tutorial-009-Step1.Z12”.

Figure 2.1-1: Start Rough Sizing

The power rating can be defined. Furthermore, the analysis method and the gear materials should be selected from the drop down list (press small vertical arrow). Of particular importance is the required ratio including the definition of a permissible ratio error (*here 5%*). Other parameters such as helix angle or centre distance may also be pre-defined. In the input window „Rough Sizing“ group ‚geometry‘ it is possible to make some further inputs for example number of teeth, geometry proportion, centre distance.

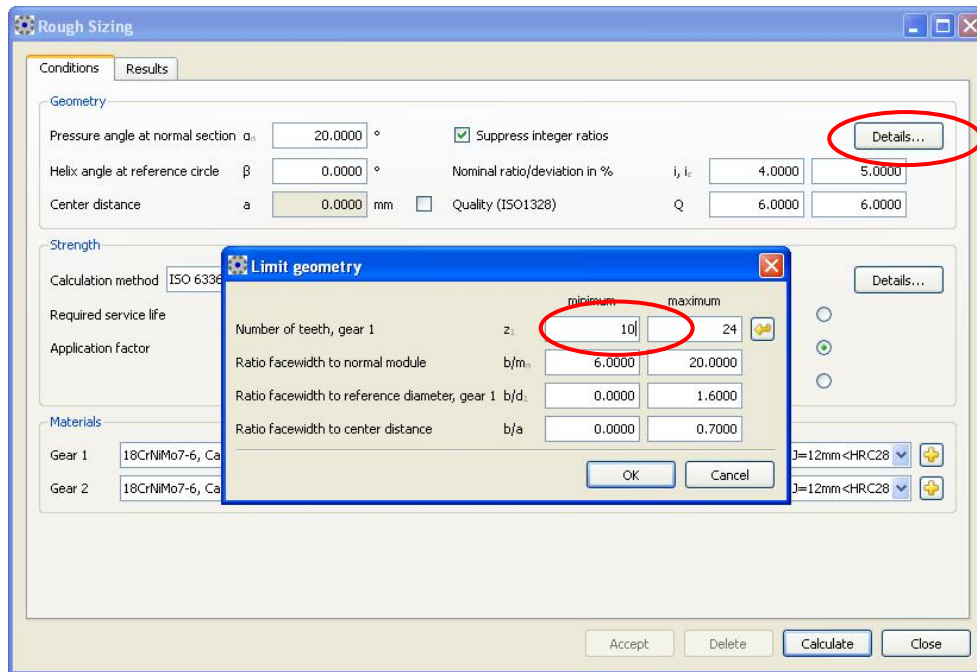


Figure 2.1-2: Input window “Rough sizing”, group ‘Geometry’ - Condition number of teeth, gear 1.

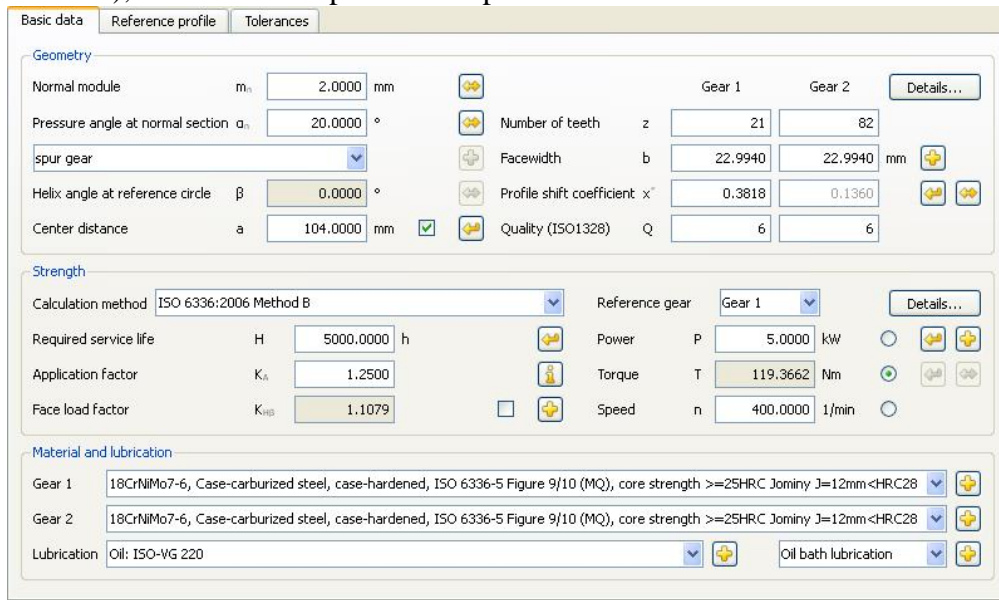
Take the button “Condition” in the input window “Rough sizing” group: ‘Strength’ and the desired size of safety can be inputted.

a [mm]	b [mm]	b ₁ [mm]	m [mm]	β [°]	z ₁	z ₂	x ₁	x ₂	ε _α	ε _β	ε _γ
83.500	49.665	49.665	2.500	0.000	13	51	0.610	0.993	1.201	0.000	
83.500	45.679	45.679	2.750	0.000	12	47	0.497	0.454	1.305	0.000	
93.500	30.311	30.311	1.750	0.000	21	83	0.607	0.957	1.367	0.000	
93.500	33.131	33.131	2.000	0.000	18	73	0.588	0.781	1.353	0.000	
104.000	22.493	22.493	1.750	0.000	24	94	0.351	0.089	1.600	0.000	
104.000	22.994	22.994	2.000	0.000	21	82	0.332	0.153	1.551	0.000	
114.000	19.173	19.173	2.000	0.000	23	90	0.367	0.149	1.578	0.000	
114.000	20.328	20.328	2.250	0.000	20	81	0.321	-0.152	1.597	0.000	
124.000	16.100	16.100	2.250	0.000	22	87	0.390	0.246	1.548	0.000	
134.000	14.702	14.702	2.250	0.000	23	94	0.453	0.671	1.489	0.000	

The data displayed in the columns can be changed using right mouseclick.

Figure 2.1-3: Helical gear pair rough sizing, Defining power rating, required lifetime, analysis method and material.

Using the button “Calculate”, KISSsoft will calculate different possible gear pairs meeting the requirements. These solutions are shown in a list. To select a solution (here with centre distance of 104 mm), click on it and press “Accept”. The data will be visible in the main window:



- To get directly to this level, open the file „Tutorial-009-Step2.Z12“.

Figure 2.1-4: Module, number of teeth, width and profile shift coefficient as proposed by KISSsoft.

2.2 Modifications

The theoretical values calculated, e.g. for the width b of the gears, can now be modified manually. Change the width of gear 1 to 28mm, gear 2 to 27mm (type values into respective fields).

The following window will show, giving information about the reference profile and the profile shift coefficient:

With Tab „Reference profile“ can the reference profile now be modified with the Drop-down list.

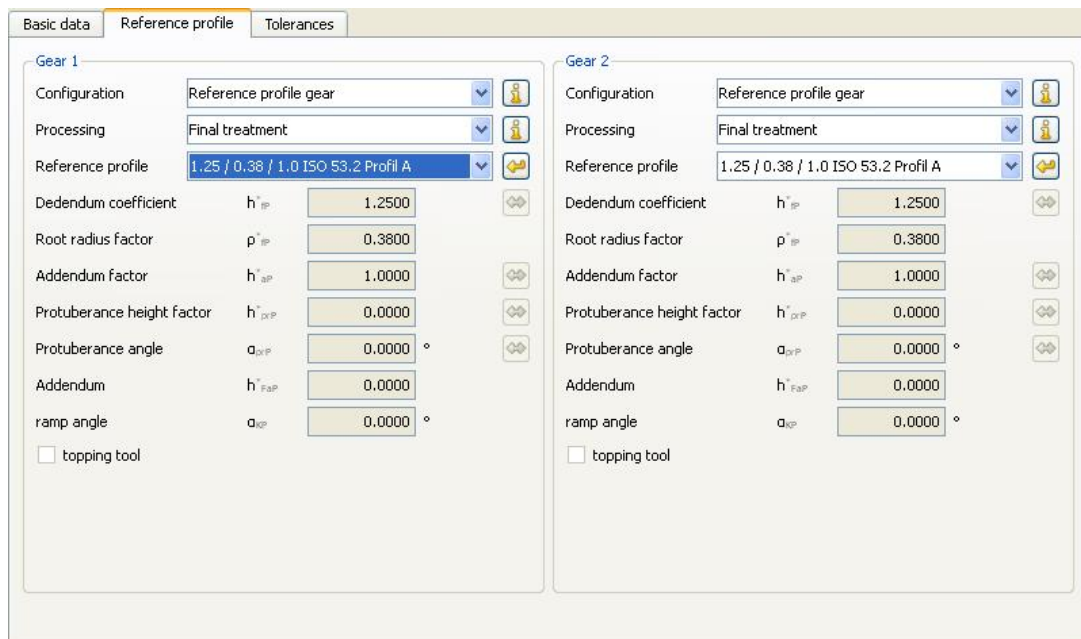


Figure 2.2-1: Tab "Reference profile" information on reference profile.

To the right of the profile shift coefficient, a sizing button is available. Using this button, KISSsoft will propose a sensible profile shift coefficient according to different criteria. In this example, the profile shift coefficient should result in balanced specific sliding. For this, press the “Size button”, see marking in the below window and the window as seen in Figure 2.2-2: is shown. By selecting

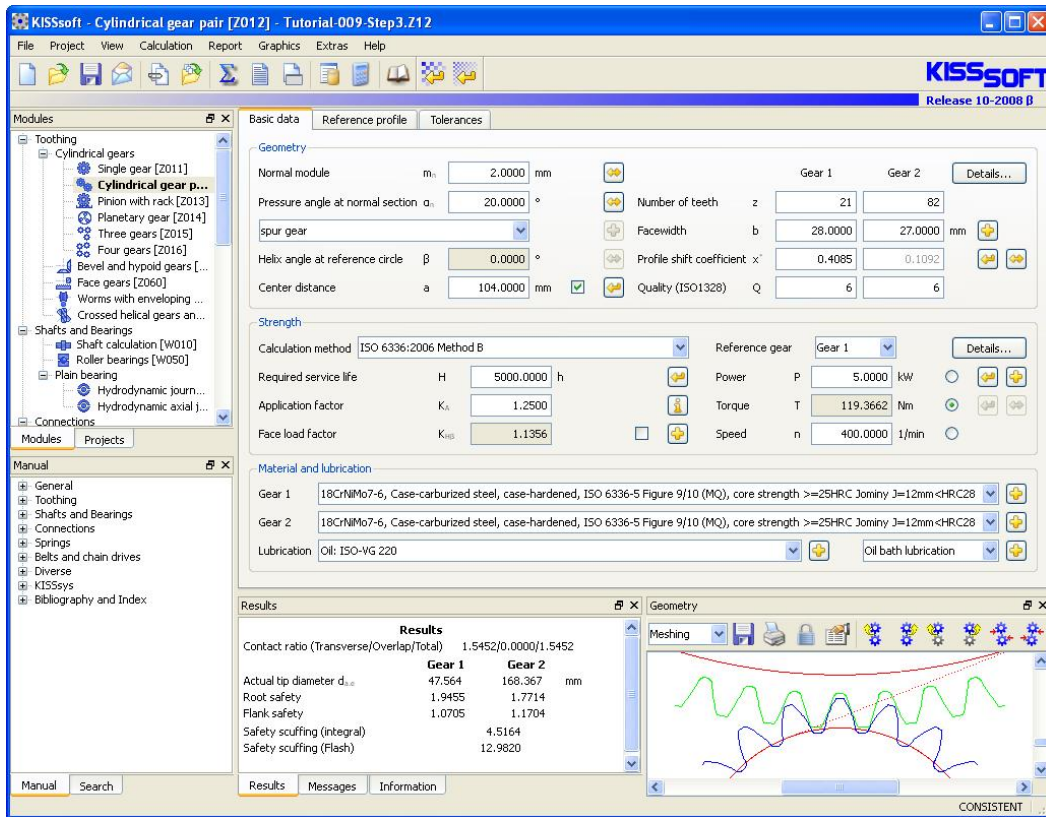
the “Radio button” and pressing “OK”, the respective profile shift coefficient will be used and the window will close.

	Gear 1	Gear 2	
For optimum specific sliding	0.4085	0.1092	<input checked="" type="radio"/>
For minimum sliding velocity	0.1857	0.3320	<input type="radio"/>
For maximum root safety	0.0760	0.4417	<input type="radio"/>
For maximum flank safety	0.5190	-0.0013	<input type="radio"/>
For maximum scuffing safety	0.3910	0.1267	<input type="radio"/>
For gear 1 without undercut and point at tip (min)	-0.2283	0.7460	<input type="radio"/>
For gear 1 without undercut and point at tip (max)	0.9621	-0.4444	<input checked="" type="radio"/>
For undercut boundary per gear	-0.2283	-3.7961	<input type="radio"/>
For minimum topland per gear	0.9621	2.3742	<input type="radio"/>

- Different methods for defining a sensible profile shift coefficient are available
- Resulting / proposed profile shift coefficient
- Maximum and minimum values (pointed tooth / undercut)

Figure 2.2-2: dialog window; Sizing of profile shift coefficient

The profile shift coefficient is now available in the main window. Pressing in the Tool bar the icon “Σ” (or the button “F5”) in the main window it will start the analysis. The safety factors for tooth root and flank, the safety against scuffing (flash and integral temperature criterion) and the contact ratio are calculated (s. Figure 2.2-3: **adapted profile shift coefficient, Execution of calculation, results**). The main mask should now look as follows (there may be small differences in e.g. the profile shift coefficient):



• To get directly to this level, open the file „Tutorial-009-Step3.Z12“.

Figure 2.2-3: adapted profile shift coefficient, Execution of calculation, results.

3 Fine sizing of gear pair

3.1 Starting the fine sizing function

Now that a gear pair meeting the requirements has been defined using the rough sizing function, this gear pair should be optimised. The objective is to get a gear pair with an optimal contact ratio. Open the “Fine Sizing” go to “calculation” Fine Sizing and a window “Fine Sizing” will appear.

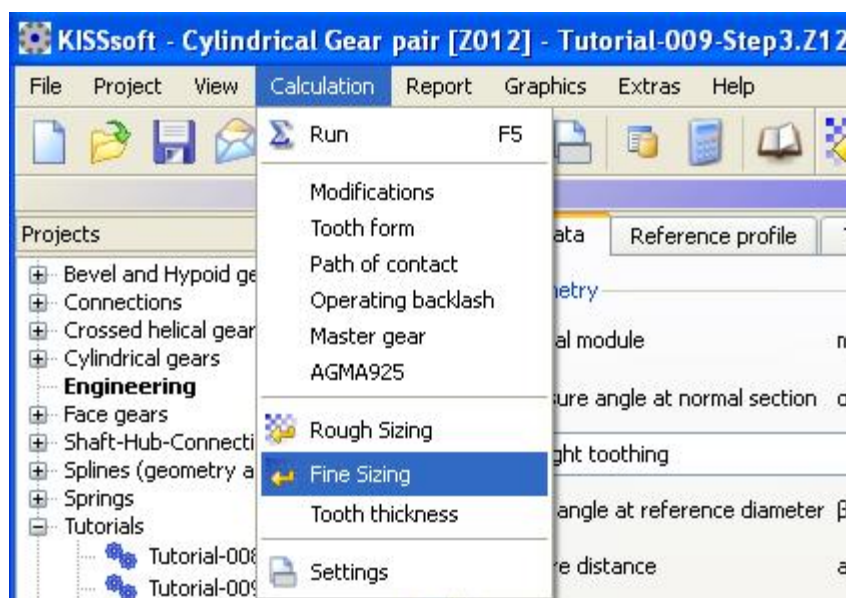


Figure 3.1-1: Start “Fine Sizing”.

In this window, parameter ranges and step sizes can be defined. KISSsoft will then search for a suitable gear pair solution within these parameter ranges:

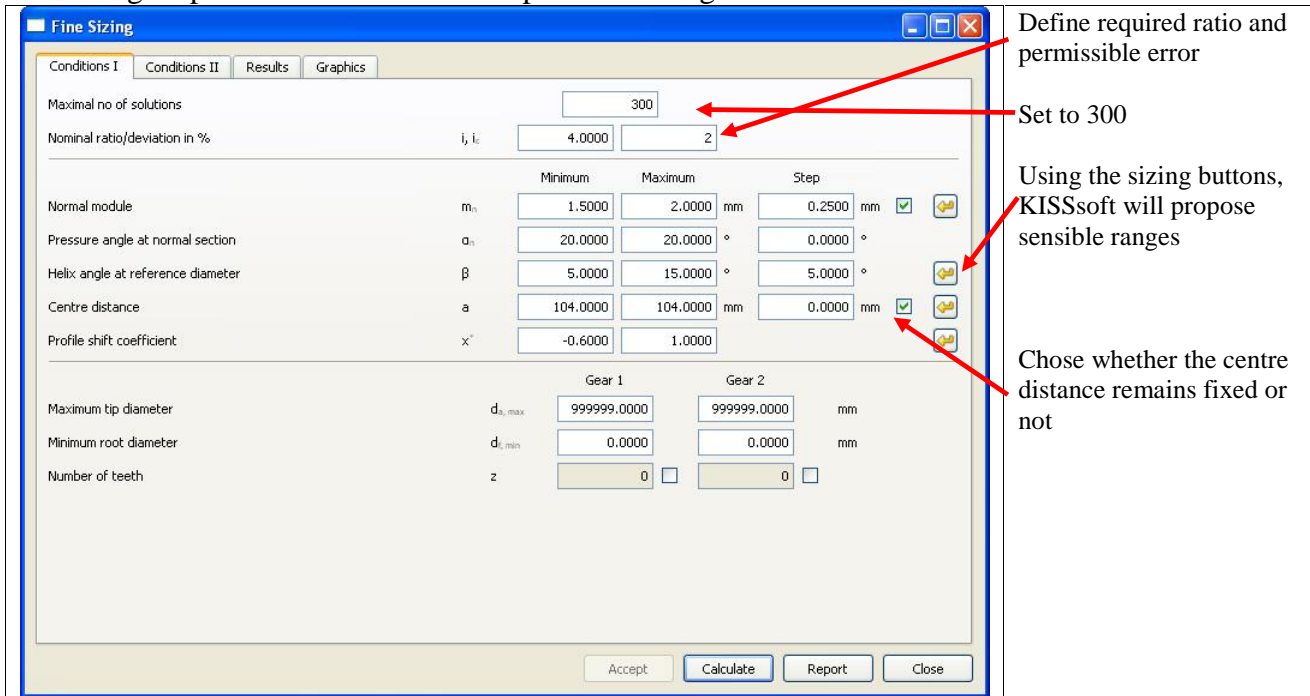


Figure 3.1-2: Fine Sizing window, definition of parameters.

- Range for module
- Range for helix angle
- Range for centre distance (to activate, set flag „Variable centre distance“)

In addition to this, the following can be defined

- Upper limit for the tip diameter
- Lower limit for the root diameter
- Number of teeth (if 0 is used, the number of teeth will be defined by KISSsoft automatically)

For this example, the settings should be chosen as shown in Figure 3.1-2: Fine Sizing window, definition of parameters. The sizing is executed by pressing „Calculate“. A list is shown, where all solutions are compiled (see Figure 3.1-3: Result, List of solutions found). In this example, the objective is to get a gear pair with low noise. For this, see the report as shown in Figure 3.1-3: Result, List of solutions found, where the variants are rated according to different criteria. (e.g. Δc). A suitable solution, which we use, is No. 31 (see marking).

The variant can be selected with double click or using the button „Accept“.

Nr.	a [mm]	m [mm]	α [°]	β [°]	z_1	z_2	x_1	x_2	ϵ_α	ϵ_β
19	104.000	1.500	20.000	10.000	27	109	0.317	-0.029	1.615	0.995
20	104.000	1.500	20.000	10.000	27	110	0.043	-0.263	1.718	0.995
21	104.000	1.500	20.000	10.000	27	110	0.143	-0.363	1.697	0.995
22	104.000	1.500	20.000	10.000	27	110	0.243	-0.463	1.673	0.995
23	104.000	1.500	20.000	15.000	26	106	0.241	0.814	1.498	1.483
24	104.000	1.500	20.000	15.000	26	106	0.341	0.714	1.484	1.483
25	104.000	1.500	20.000	15.000	26	106	0.441	0.614	1.468	1.483
26	104.000	1.500	20.000	15.000	27	106	0.140	0.359	1.582	1.483
27	104.000	1.500	20.000	15.000	27	106	0.240	0.259	1.566	1.483
28	104.000	1.500	20.000	15.000	27	106	0.340	0.159	1.548	1.483
29	104.000	1.500	20.000	15.000	27	107	0.056	-0.086	1.649	1.483
30	104.000	1.500	20.000	15.000	27	107	0.156	-0.186	1.631	1.483
31	104.000	1.500	20.000	15.000	27	107	0.256	-0.286	1.610	1.483
32	104.000	1.500	20.000	15.000	27	108	-0.016	-0.516	1.704	1.483
33	104.000	1.750	20.000	5.000	23	93	0.315	0.979	1.478	0.428
34	104.000	1.750	20.000	5.000	23	93	0.415	0.879	1.463	0.428
35	104.000	1.750	20.000	5.000	23	93	0.515	0.779	1.445	0.428
36	104.000	1.750	20.000	5.000	24	95	0.067	-0.360	1.732	0.428
37	104.000	1.750	20.000	5.000	24	95	0.167	-0.460	1.707	0.428
38	104.000	1.750	20.000	5.000	24	95	0.267	-0.560	1.680	0.428
39	104.000	1.750	20.000	10.000	23	92	0.279	0.827	1.489	0.853
40	104.000	1.750	20.000	10.000	23	92	0.379	0.727	1.474	0.853
41	104.000	1.750	20.000	10.000	23	92	0.479	0.627	1.456	0.853
42	104.000	1.750	20.000	10.000	23	93	0.189	0.362	1.578	0.853
43	104.000	1.750	20.000	10.000	23	93	0.289	0.262	1.559	0.853
44	104.000	1.750	20.000	10.000	23	93	0.389	0.162	1.538	0.853
45	104.000	1.750	20.000	15.000	23	91	0.159	0.269	1.556	1.271
46	104.000	1.750	20.000	15.000	23	91	0.259	0.169	1.538	1.271
47	104.000	1.750	20.000	15.000	23	91	0.359	0.069	1.518	1.271

Figure 3.1-3: Result, List of solutions found.

Analysis of the results (Assessment of important characteristics)

Comment:

- No. = Number of the variant
- diff_i = Deviation from the nominal ratio in %
- kg = Weight in kg
- Slide = Specific sliding (maximum value)
- v.Slide = Sliding velocity (m/s, maximum value)
- AC/AE = Begin working depth AC / working depth AE (Friction)
- s_Rig = Variant on the stiffness during rolling (N/mm/mym) (Calculation WITHOUT taking into account the exact tooth-shape)
- 1-eta = Losses in % (1.0-total efficiency)
- Safety = Safety (Tooth root and flank, 0 = high, 1 = medium, 2 = low) (SF-min: 0.60/ 1.20/ 1.40 SH-min: 0.60/ 0.90/ 1.00)
- Summary = Overall assessment (weighted) (50.0%:s_Rig 20.0%:diff_i 10.0%:kg 35.0%:Slide 0.0%:v.Slide 0.0%:AC/AE 10.0%:1-eta 100.0%:Safety)

(For this table it can be said in general: the smaller the value the better!)

No.	diff_i	kg	Slide	v.Slide	AC/AE	s_Rig	1-eta	Safety	Summary
1	0.926	4.969	1.041	0.187	0.517	1.903	1.077	1.362	0.663
2	0.926	4.957	0.863	0.190	0.470	1.904	1.068	1.387	0.672
3	0.926	4.945	0.709	0.205	0.421	1.973	1.093	1.400	0.677
...									
68	1.250	5.026	2.518	0.272	0.473	0.135	1.643	0.748	0.410
69	1.250	5.010	1.826	0.291	0.426	0.130	1.664	0.768	0.414
70	1.250	4.994	1.344	0.310	0.379	0.123	1.733	0.778	0.416

Analysis of the results (with the variant index in decreasing order)

Analysis of the results (with the variant index in decreasing order)

Best variant for accurate ratio: 14 15 16 32 39 40 41 48 49 50 ...

Best solutions for weight: 9 28 13 8 31 27 11 12 7 30 ...

Best variants relative to friction (AC/AE): 55 70 38 67 50 61 22 64 44 ...

Best solution for stiffness: 17 18 13 15 19 14 16 20 21 22 ...

Best variant for strength: 65 68 48 66 69 63 67 70 62 64 ...

Best overall variants (summary) : 65 48 66 67 49 68 50 63 69 64 ...

Figure 3.1-4: report of solutions found, rating of solutions.

Note: the procedure has been described here only briefly. In reality, a careful investigation of the solutions as listed under “Geometry” should be done. It may well be that another solution is to be preferred due to other considerations. Use the “Graphic” button to compare the solutions graphically:

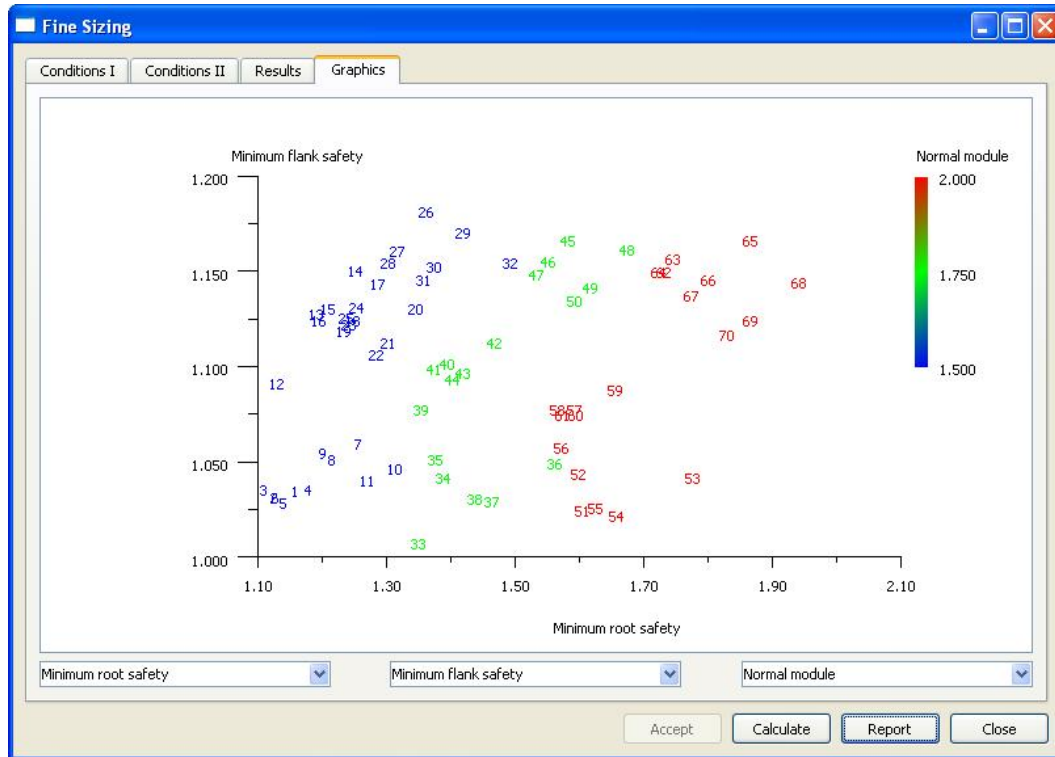
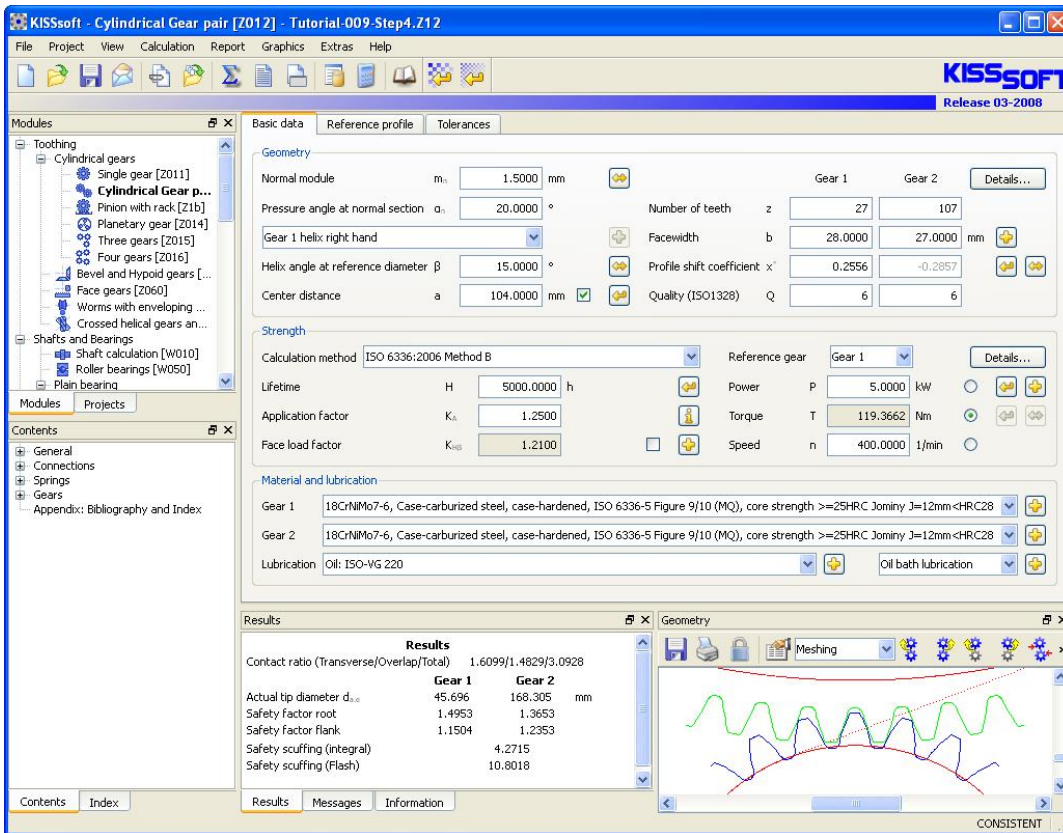


Figure 3.1-5: Graphical comparison of solutions.

3.2 Results of the fine sizing function

The contact ratio is now slightly above 3.1 (see Figure 3.2-1: **Results and data as defined by the fine sizing function**), which means that the variation of the contact stiffness is small during the meshing and vibrations will be minimal.



- To get directly to this level, open the file „Tutorial-009-Step4.Z12“.

Figure 3.2-1: Results and data as defined by the fine sizing function.

The resulting gear geometry is shown in a graphic window. It may be made a floating window by dragging it from using the right mouse button.

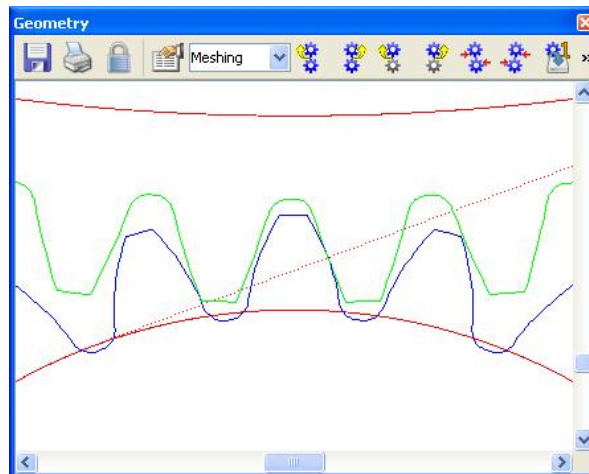


Figure 3.2-2: Resulting tooth form (base circle and line of action are shown in red)

The contact stiffness can be shown using “Graphics/ Evaluation/ Theoretical contact stiffness”:

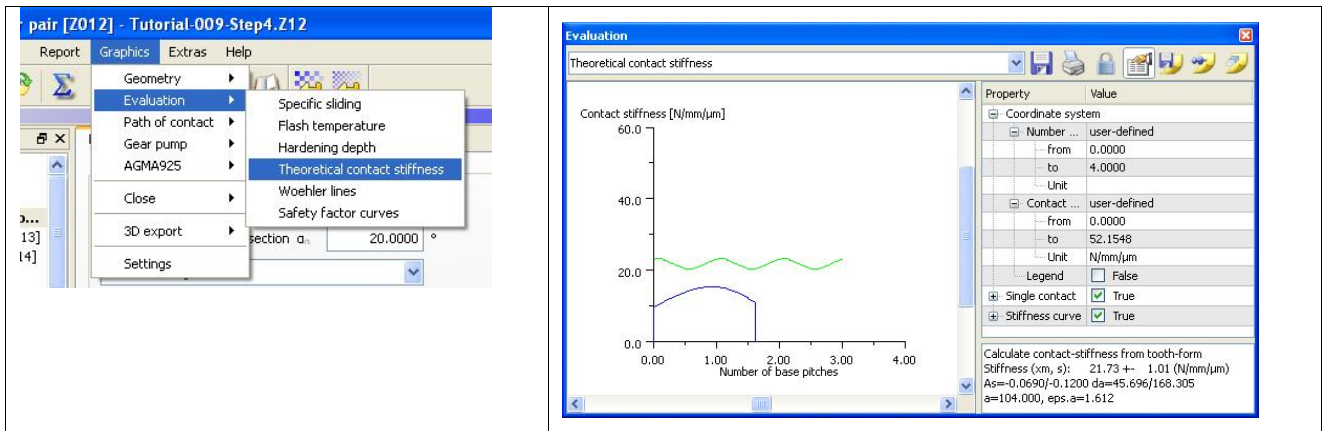


Figure 3.2-3: Theoretical contact stiffness.

3.3 Dimensioning of a deep tooth form

In the next step the existing solution is more improved. The transverse contact ratio ϵ_a should now be increased to 2, by using a deep tooth form (target size can be define under “Module specific settings” Tab “Sizing”). Again, an optimised tooth form should be proposed by KISSsoft.

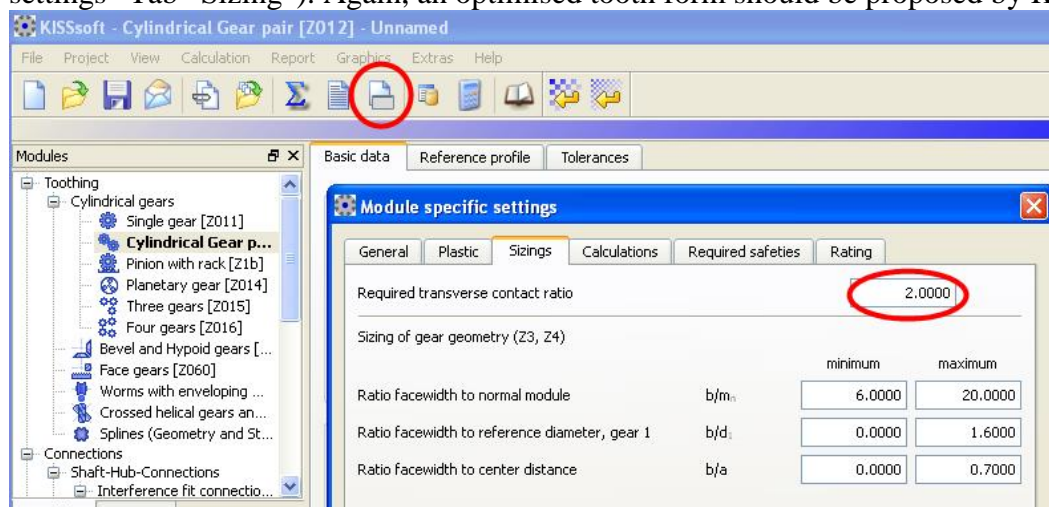


Figure 3.3-1; Modul specific settings

For this, the fine sizing function is used again. In the fine sizing window, select „Conditions II” and set the flag „Sizing of Deep tooth form“ and execute the fine sizing again using “Calculate”.

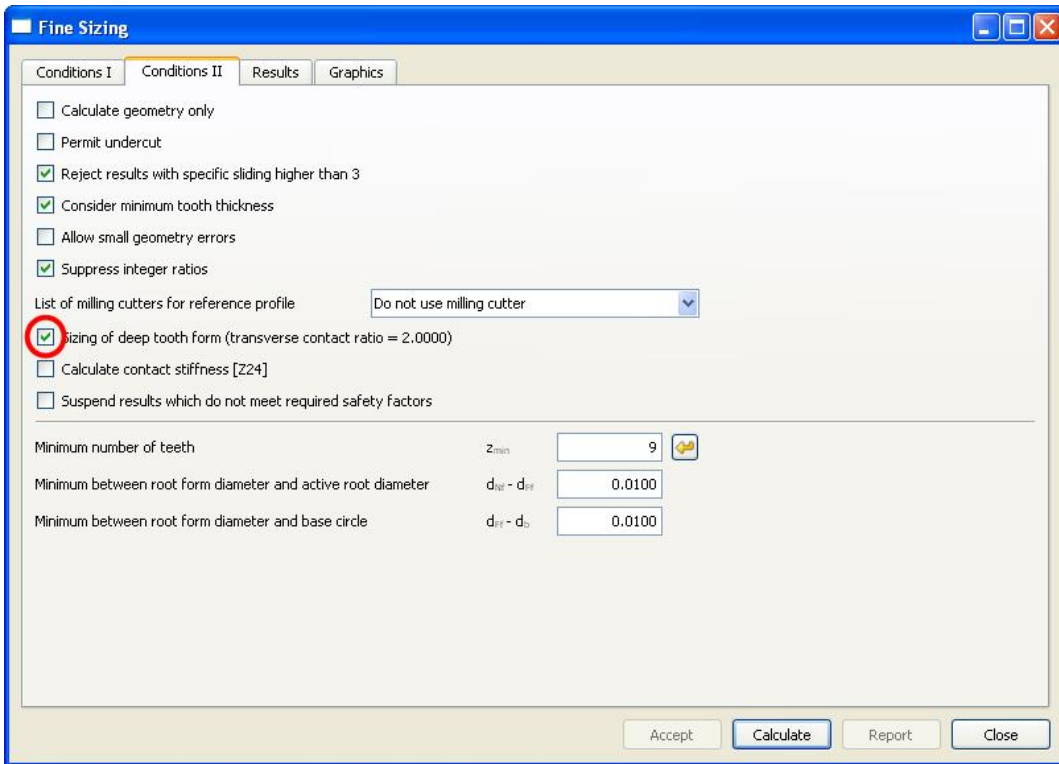
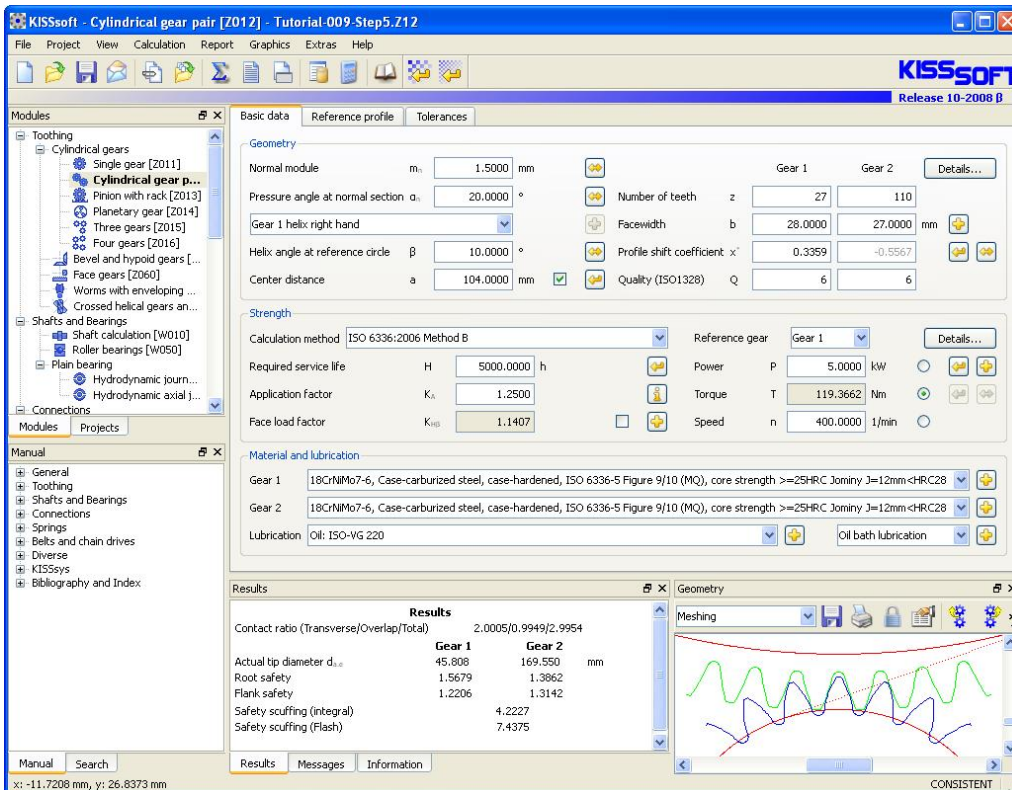


Figure 3.3-2; Fine Sizing; Condition II select „Sizing of Deep tooth form“

The best solution in terms of noise now is solution No. 23. After than the variant can be selected with double click or using the button „Accept“.

The respective gear data is made available in the main window of the gear pair analysis module: Since the reference profile has been changed.

The new gear data is now available (changes in number of teeth, helix angle and profile shift coefficient), the calculation of the contact ratio is executed:



- To get directly to this level, open the file „Tutorial-009-Step5.Z12“.

Figure 3.3-3: new gear data and results, in particular Contact ratio.

The resulting gear geometry is shown in a graphic window.

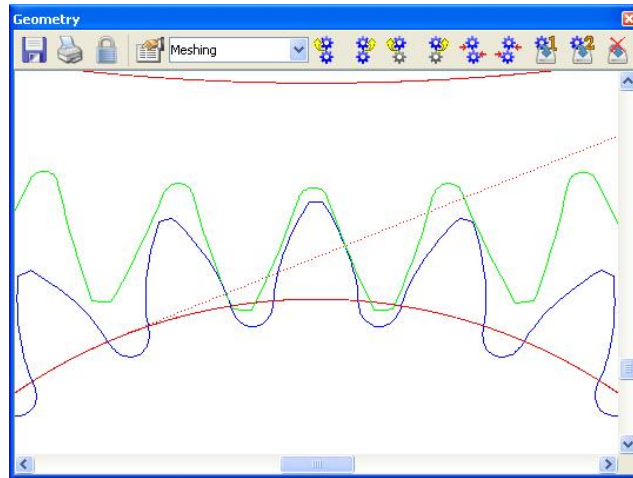


Figure 3.3-4: resulting gear geometry.

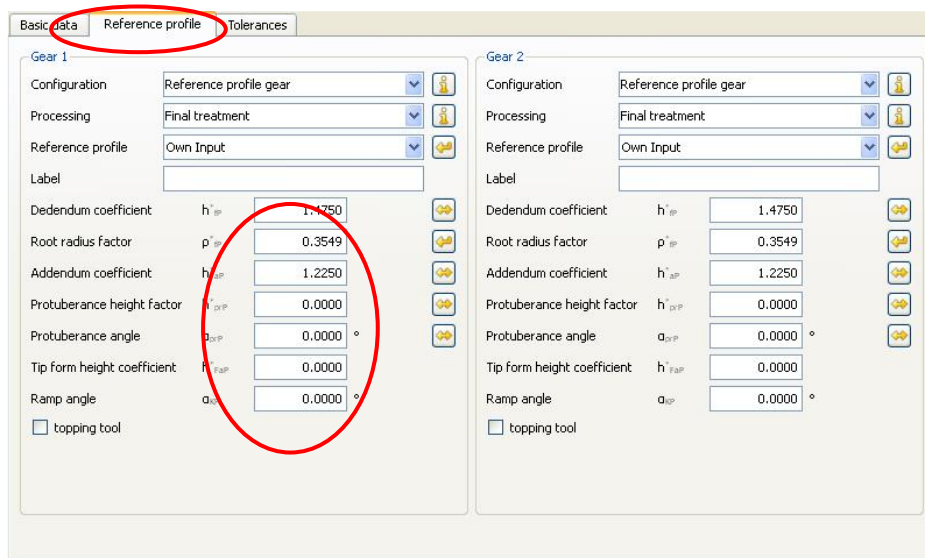


Figure 3.3-5: view the deep tooth form in the tab „Reference profile“.

The contact ratio is now very close to 3 (see results in Figure 3.3-3: **new gear data and results, in particular Contact ratio**), resulting in a very even contact stiffness:

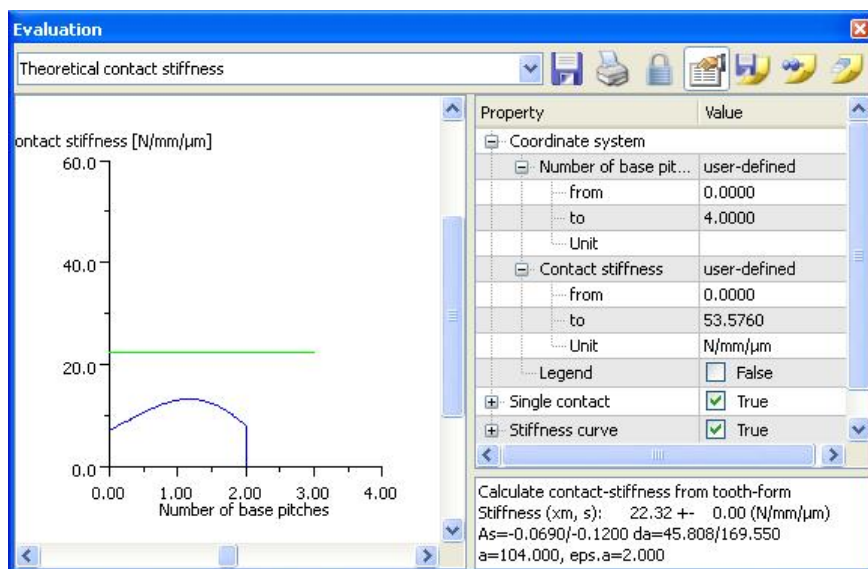


Figure 3.3-6: Theoretical contact stiffness.

3.4 Further details to the strength analysis

For the final strength analysis, information on the lubrication and face load coefficient is required.

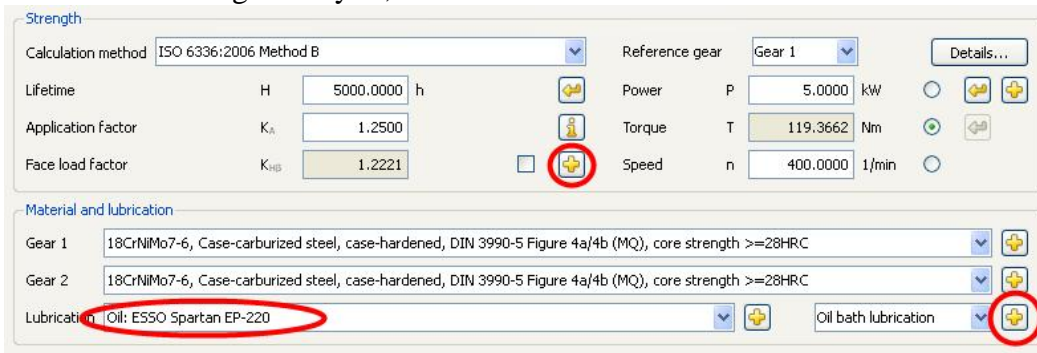


Figure 3.4-1; input lubrication and call for define of Face load factor

Define the kind and the type of lubrication in the main window (see the left and right marker):

The list of lubricant type can be extended with the Dada base tool.

The lubricant temperature is defined with the „Plus button“ (right marking).

The input of ambient temperature or temperature of housing may be defined with the Tab “Operating backlash“. See the marking in the below window.

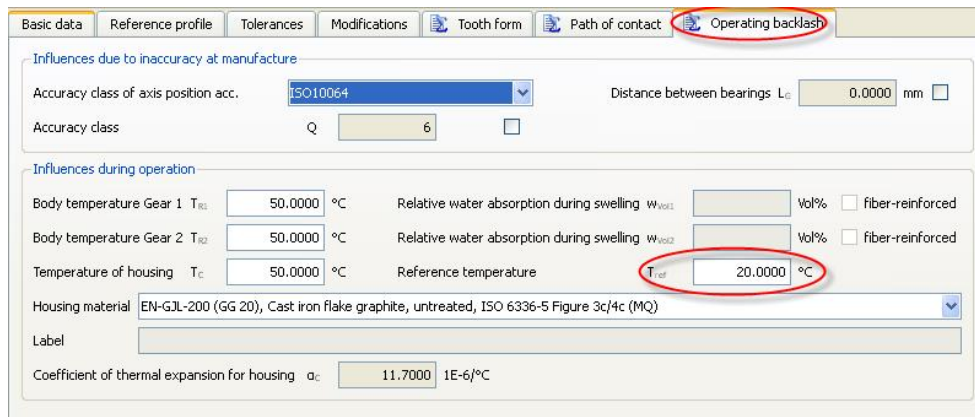
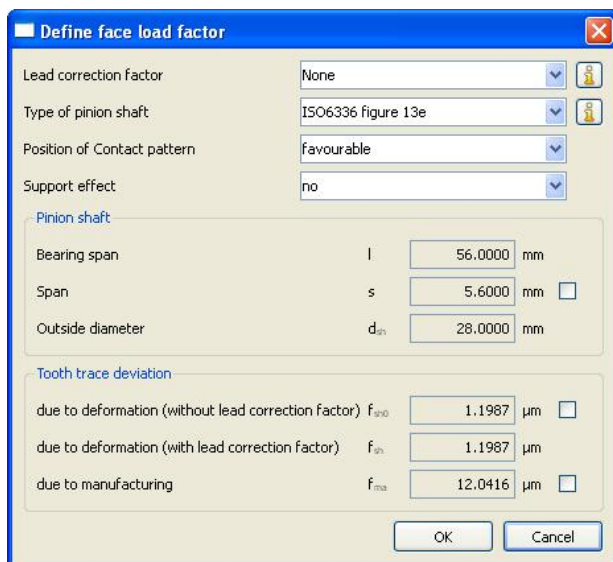


Figure 3.4-2: Operating backlash.



- The face load coefficient can be define according to methods A, B or C (see DIN 3990 or ISO 6336)
- For instructions on the face load coefficient, see „kisssoft-anl-002-D-Eingabe-des-Breitenlastfaktors-KHβ.doc “ which is available from the KISSsoft customer support
- Normal case no changes are here necessary.

Figure 3.4-3: Define further parameters, especially face load coefficient.

Important remark:

If the strength analysis and life time calculation important for the evaluation of Gear fine sizing, you must define the input data, before the gear fine sizing is done.