KISSsoft AG - +41 55 254 20 50
Uetzikon 4 - +41 55 254 20 51
8634 Hombrechtikon - info@KISSsoft. AG
Switzerland - www. KISSsoft. AG

KISSsoft Tutorial: Cylindrical Gear Pairs

1 Task

This tutorial explains how to input data you already know for cylindrical gear pairs in the KISSsoft system.

You must therefore perform the following steps for an existing cylindrical gear pair:

1) Input the necessary data in KISSsoft
2) Verify it in accordance with ISO 6336
3) Document the results

1.1 Input data

The method you use to input the following data is described at the end of section 2 in this tutorial:

1.1.1 Power data

Power [P]	3.5	kW
Speed [n] at drive	2500	1/min (Gear1 driving)
Application factor [K_A]	1.35	
Service life [H]	750	h

1.1.2 Geometry

Normal module [m_n]	1.5	mm
Helix angle at reference diameter[ß]	25	°
Pressure angle at normal section [α_n]	20	°
Number of teeth [z] Gear1/Gear2	16/43	
Face width [b] Gear1/Gear2	14/14.5	mm
Center distance [a]	48.9 ±0.03	mm
Profile shift coefficient [x] Gear 1 (pinion)	0.3215	

1.1.3 Reference profile

	Dedendum coefficient [h^*_{fP}]	Root radius coefficient [ρ^*_{fP}]	Addendum coefficient [h^*_{aP}]
Gear 1 (pinion)	1.25	0.3	1.0
Gear 2	1.25	0.3	1.0

1.1.4 Additional data

Material:

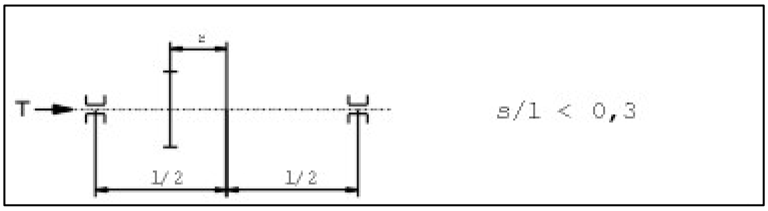
	Material	Hardness data	σFlim	σHlim
Gear 1 (pinion)	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2
Gear 2	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2

Lubrication:

Grease lubrication	Microlube GB 00	80 °C

Base tangent length allowances

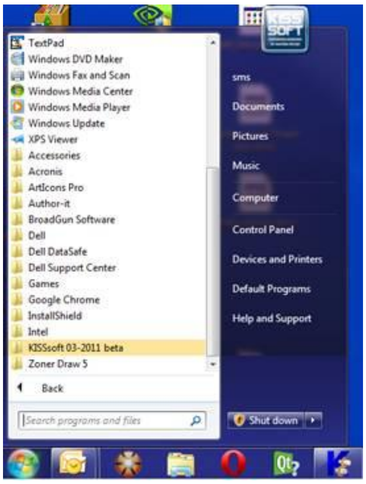
	No. of teeth spanned [k]	Max. base tangent length [Wkmax]	Min. base tangent length [Wkmin]
Gear 1 (pinion)	3	11.782 mm	11.758 mm
Gear 2	6	25.214 mm	25.183 mm

Quality [Q] (ISO 6363)	8/8
Lead correction factor	end relief
Contact pattern	not verified or inappropriate
Type of pinion shaft	 Figure 1.1 **Load case for the pinion shaft** ISO 6336 Picture 13a; l = 53 mm; s = 5.9 mm; dsh = 14 mm

2 Solution

2.1 Starting the software

Once you have installed and activated KISSsoft either as a test or licensed version, follow these steps to call the KISSsoft system. Usually you start the program by clicking "Start→Program Files→KISSsoft 03-2011→KISSsoft". This opens the following KISSsoft user interface:



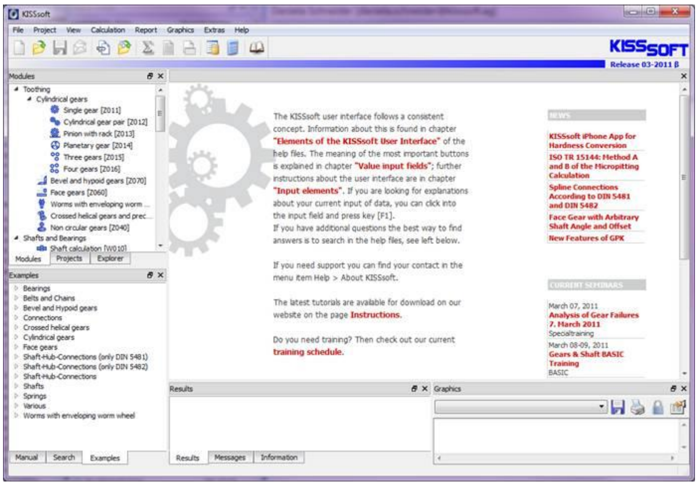


Figure 2.1 Starting KISSsoft, initial window

2.2 Selecting a calculation

In the Modules tree window, select the **"Modules"** tab to call the calculation for cylindrical gear pairs:

Figure 2.2 Calling cylindrical gear calculation

The KISSsoft input window then opens:

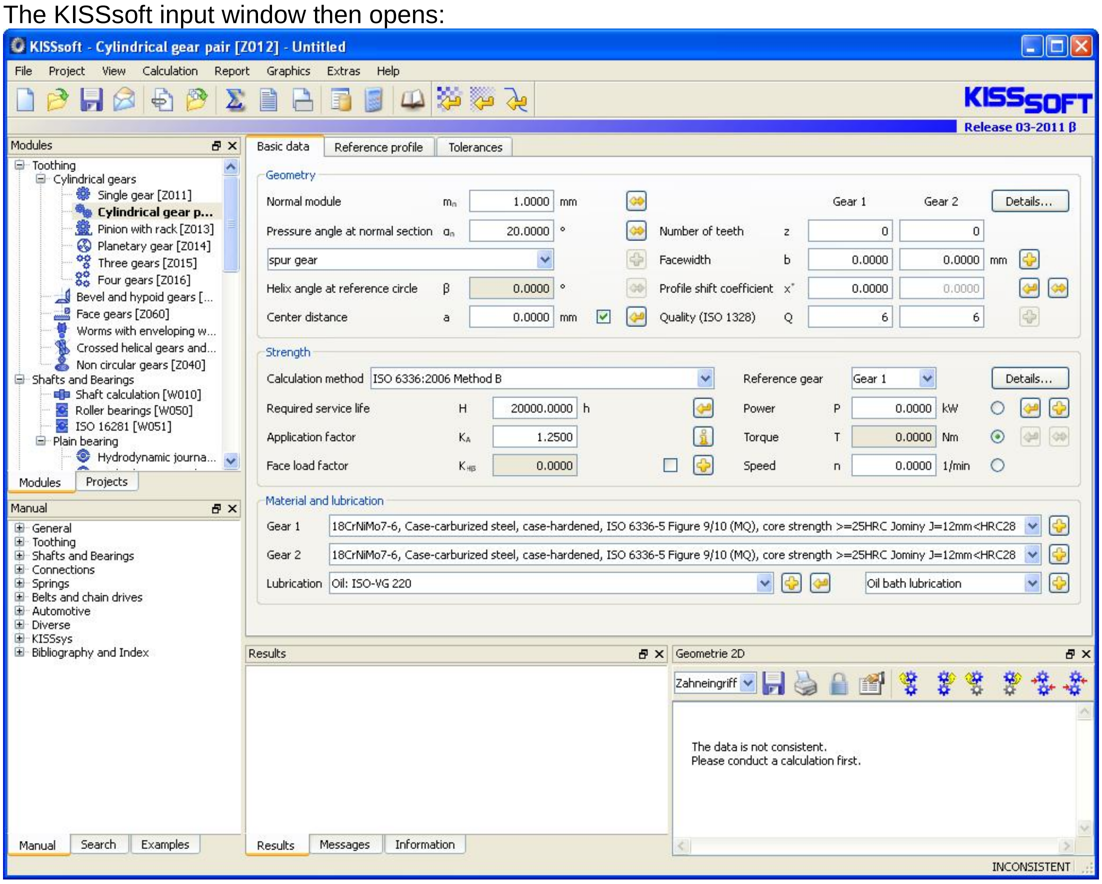


Figure 2.3 Input window: KISSsoft Cylindrical gear calculation

The following sections describe how to input parameters for the gear pair.

2.3 Gear Pair Geometry

In the **"Basic data"** tab, "Geometry" group, input the normal module (1.5 mm), pressure angle (20°), helix angle (25°), center distance (48.9 mm), number of teeth (16/43), tooth widths (14/14.5 mm), profile shift coefficient (0.3215/. ..) and the quality (8/8). You cannot input a value for the profile shift of gear 2 directly because this value is calculated from the center distance and profile shift of the first gear.

However, you can click the Sizing button  to size the value to match your requirements. You can set the quality to suit you, no matter which calculation method is in use.

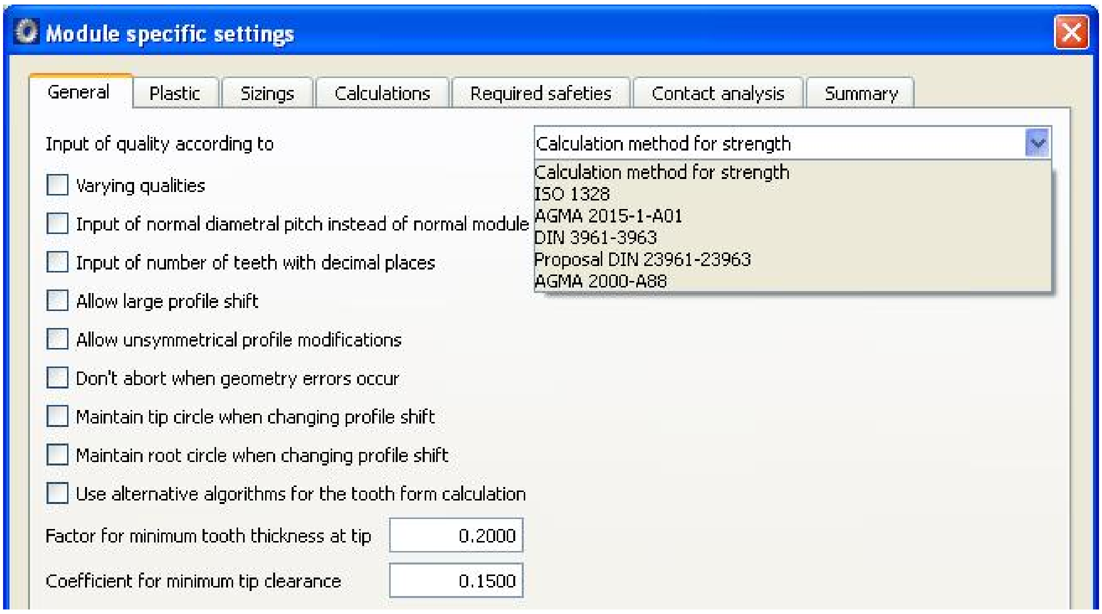


Figure 2.4 Module-specific settings. Quality does not depend on calculation method

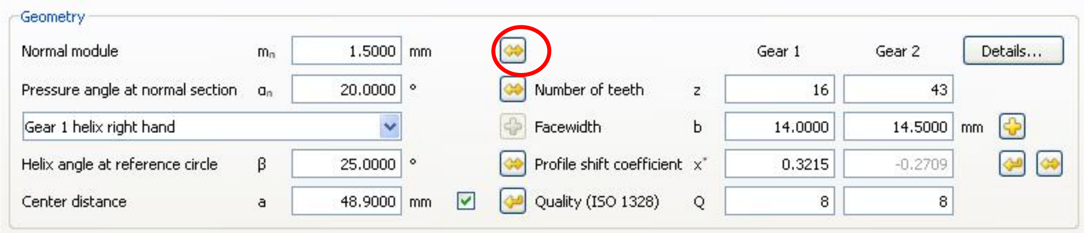


Figure 2.5: Input window – "Basic data" tab, "Geometry" group

Click the Convert button  to the right of the input fields to enter additional data for each field, or to input other data for these particular values. If you need to input an angle, right-click in the input field to open another window in which you can enter the angle, minutes and seconds:

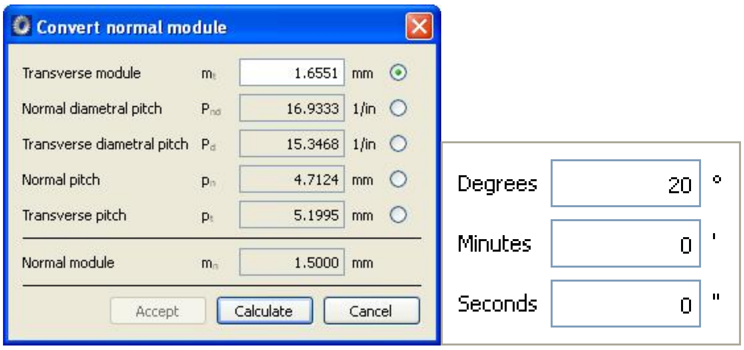


Figure 2.6 Additional entries, normal module, angle details

2.4 Defining power data and calculation method

In the "Strength" group, in the **"Basic data"** tab input window, you can now define the kinematics, the required service life (750 h) and the application factor (1.35). In this example, the torque is defined by inputting the power (3.5 kW) and speed (2500 1/min). However, in a different example, if you want to input the torque and calculate the power, simply set the **"Selection"** button to the right of the input field from torque to power. Under Details you can now input even more parameters about strength.

It is also important that you set the reference gear correctly (first gear - Gear 1) for the load.

Select the calculation method in the drop-down list you see on the right. In this case, you must also switch to ISO 6363:2006 Method B.

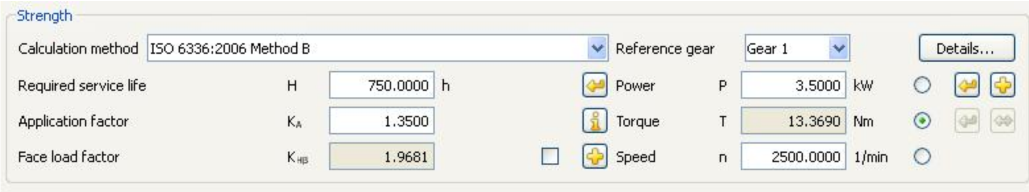


Figure 2.7 Input window – "Basic data" tab, Strength group

You can input face load factor $K_{Hß}$ either directly (to do this, set the flag in the checkbox) or define it by clicking the Plus button next to the input field.

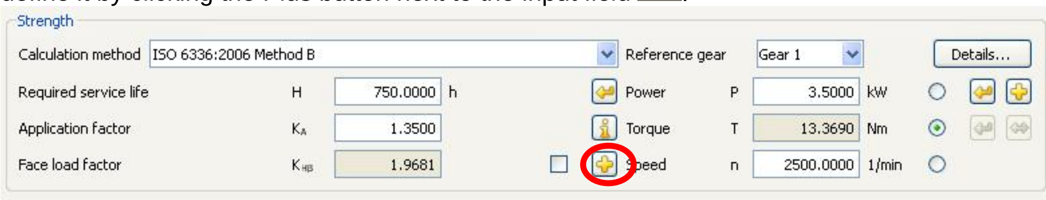


Figure 2.8 Defining the face load factor

To calculate the load coefficients, you must enter:

- The lead correction (in this case **"End relief" Figure 2.9**).
- Possible shaft configurations. To do this, click the Info button to the right of the **"Type of pinion shaft"** field in the **"Info window"**. See the selection on the right-hand side of the next figure. This example corresponds to Figure A in **Figure 2.9**. You can then input the distances l and s as soon as the flag is set in the checkbox behind the corresponding input fields.
- You must also select the Position of contact pattern, which is not verified, from the appropriate drop-down list.

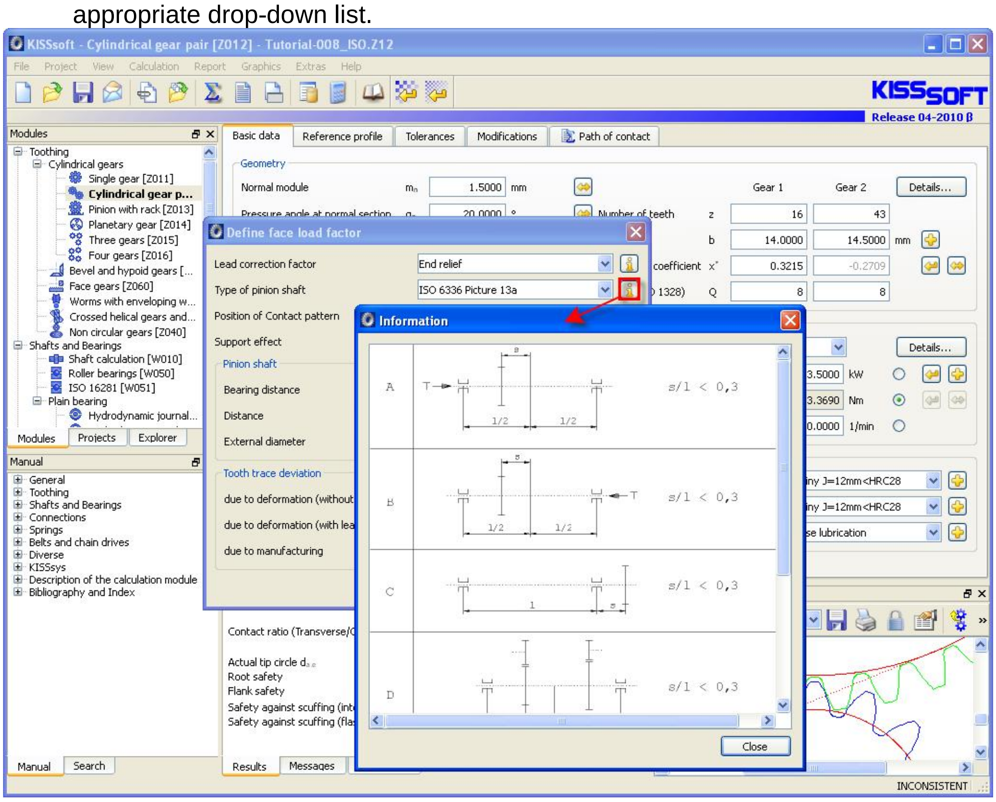


Figure 2.9 Defining the face load factor

Note:
You need the shaft configuration to calculate face load factor $K_{Hß}$. ISO 6336 (or DIN 3990) provides 5 different configurations from which you can select the one you require. These examples are listed A to E in the previous figure.
Face load factor $K_{Hß}$ shows the non-linear distribution of the load across the face width. You can request separate instructions about this from KISSsoft AG: see document: "kisssoft-anl-002-D-Eingabe-des-Breitenlastfaktors-KHß.doc".

2.5 Material and lubrication

In the **"Basic data"**, "Material and lubrication" group, you will see drop-down lists from which you can select the materials used to form the gears. 15 Cr Ni 6, case-carburized steel is used in this example.
You can also select the individual lubricant as well as the lubrication type.

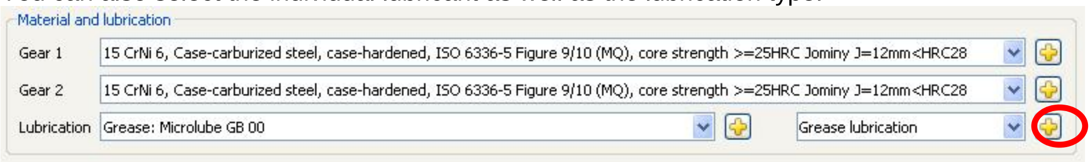
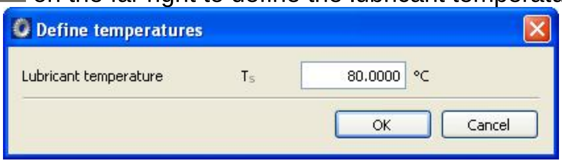


Figure 2.10 Input window – "Basic data" tab, Material and lubrication group

Click the plus button on the far right to define the lubricant temperature.



2.6 Reference profile

In the **"Reference profile"** tab you can now input further data, such as the reference profile, the dedendum coefficient, the root radius factor and the addendum coefficient for Gear 1 and Gear 2.

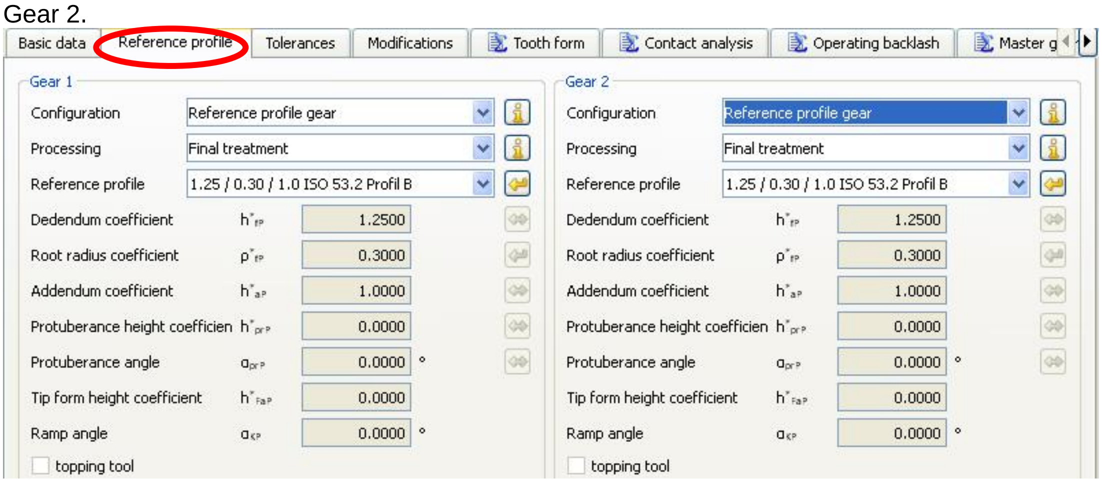


Figure 2.11 Input window – "Reference profile" tab

2.7 Tolerances

Define the tooth thickness deviation in the **"Tolerances"** tab. In a verification example, it is often the case that only the effective tolerances of base tangent length and the number of teeth spanned are specified. If you input these values, the KISSsoft system will then calculate the correct tooth thickness tolerances for the tooth form.
In this case, you can also input the center distance tolerances either by selecting them from the drop-down list or by inputting your own values as shown in the example.

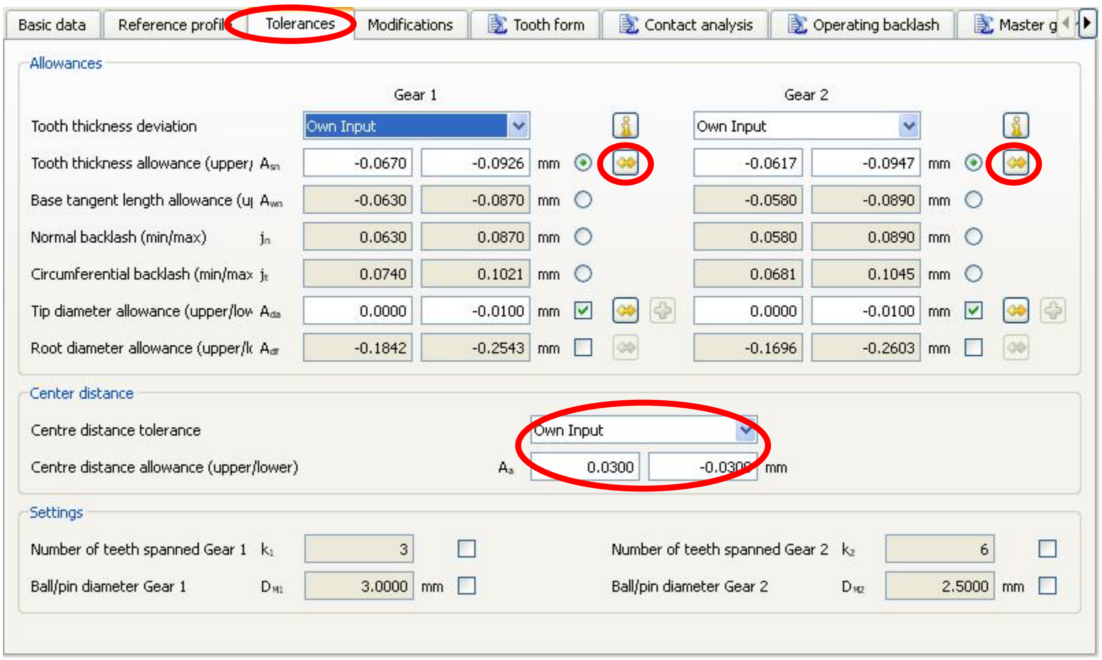


Figure 2.12 Input window – "Tolerances" tab

To input the base tangent lengths, click the **"Tolerances"** tab, "Deviation" group, and then click the Sizing button next to the tooth thickness deviation input window (middle markings).

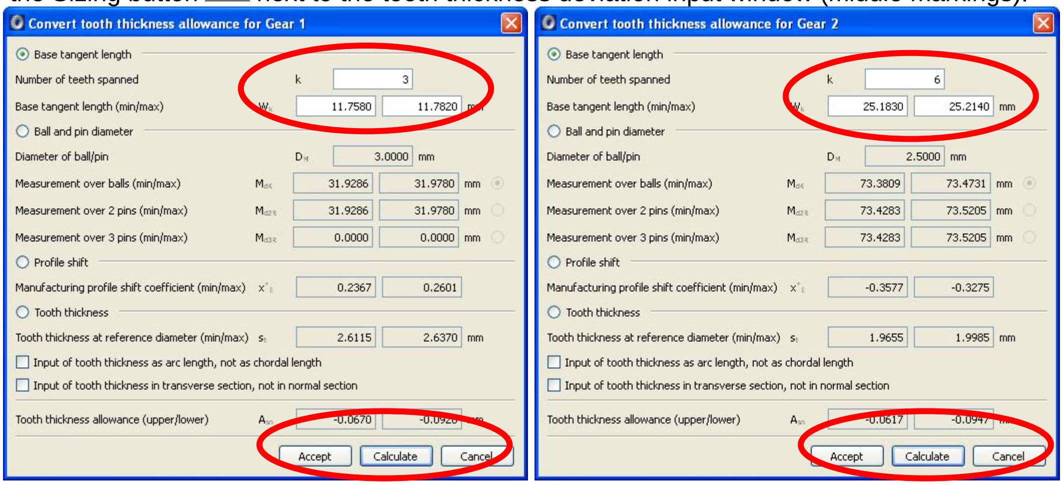


Figure 2.13 Calculating the base tangent lengths

You can now input the number of teeth spanned and the base tangent length (min/max). Then click Calculate . Then click **"Accept"** to transfer the values to the main screen.

Warning: you cannot input a deviation until profile shifts have been determined for both gears. Otherwise you will receive incorrect values and you must repeat the sizing process.

Note: You can change the Number of teeth spanned between steps 2 and 3. To do this, set the flag in the "checkbox" next to the "Number of teeth spanned" field in the input window: select the "Tolerances" tab, "Settings" group, and then change the Number of teeth spanned either in the "Settings" group or in the calculation screen.

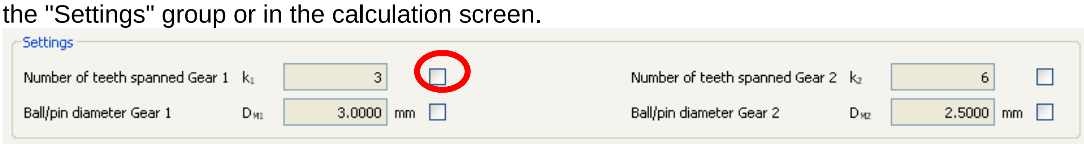


Figure 2.14 Input window – "Tolerances" tab, "Settings" group

2.8 Lubrication

The input window for the **"Basic data"** tab, "Material and lubrication" group, is only designed to hold the input value for lubricant temperature for the various types of lubricant that can be used. You can select other lubrication types and grease types in the appropriate drop-down list when you input the temperature as a numerical value.

The **"Lubricant temperature"** input field for oil or grease lubrication defines the basic temperature of the gear body. For this reason, the **"Lubricant temperature"** is also important for calculating effective lubricant viscosity. However, the **"Ambient temperature"** has no effect on the calculation (see also 2.5 Material and lubrication).

The **"Ambient temperature"** field only defines the base temperature during a dry run. In this case, the temperature of the gear body does influence the calculation.

Exceptions:

- Worm gears: the **"Ambient temperature"** is an input value used to calculate the temperature safety coefficient.
- Plastic gears: as the strength values of plastic gears depend greatly on the temperature of the gear body you must input the corresponding temperatures here.

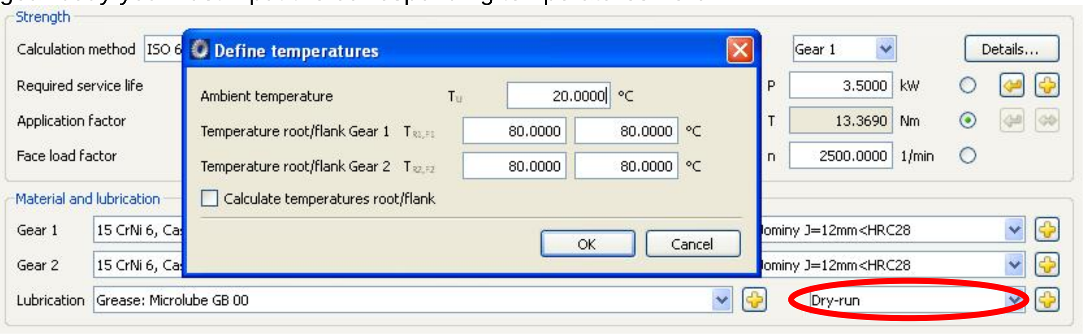


Figure 2.15 Inputting the temperature for a dry run

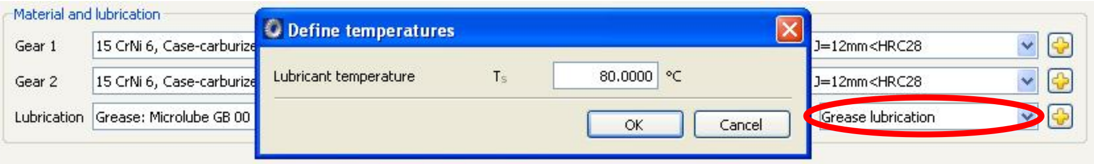


Figure 2.16 Inputting the temperature for grease lubrication

2.9 Calculate

Click  in the tool bar or press "F5" to calculate the strength results. As the proof of the contact pattern is missing, this message appears to tell you the $K_{Hß}$ value is too high.

Figure 2.17 Information window after "Calculation"

This means that the calculation for the value $K_{Hß}$ was performed with an unrealistic contact pattern. When you test the contact pattern in the workshop, you can see whether this assumption was conservative or realistic.

If you have worked through this tutorial correctly, the highlighted strength values should agree with **Figure 2.18**:

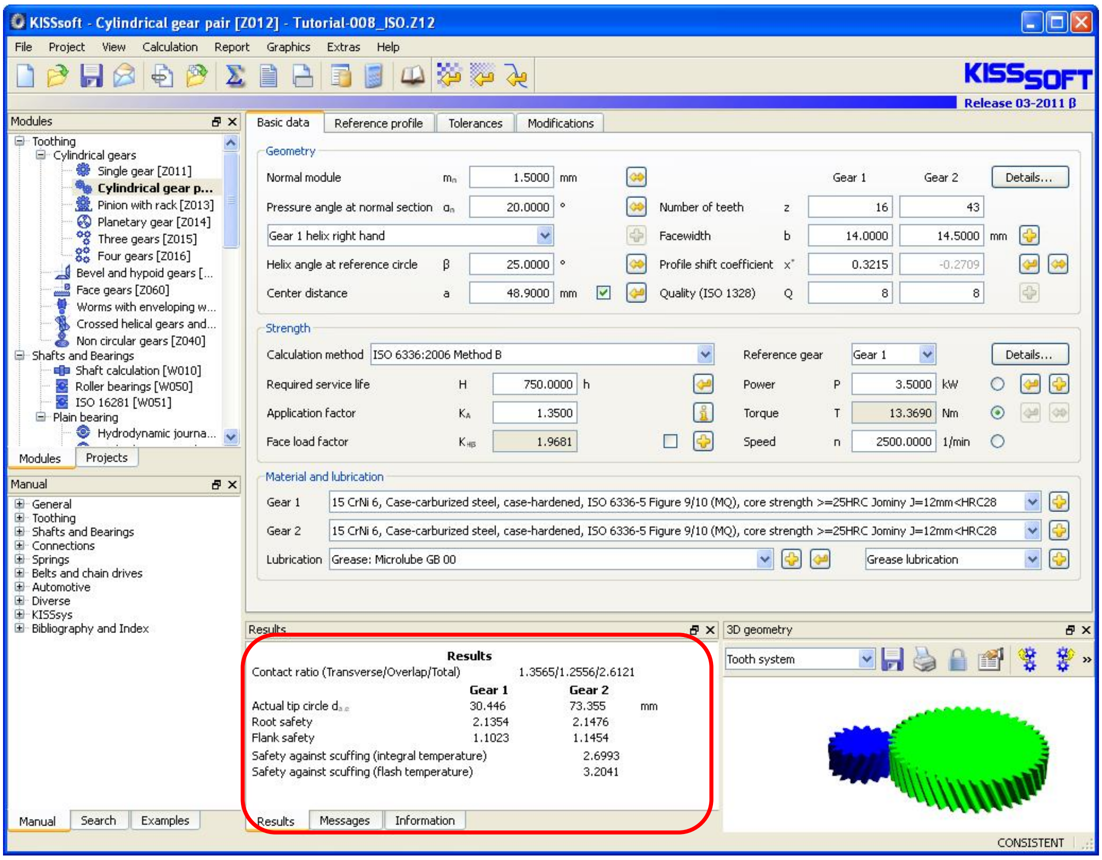


Figure 2.18 End results for tutorial

2.10 Report

```
———————————————————————— KISSsoft - Release 03-2011
KISSsoft-Entwicklungs-Version       KISSsoft AG      CH-8634 HOMBRECHTIKON

——————————————————————————————————— File
Name       : Tutorial-008_ISO
Description: KISSsoft example
Changed by : ho          on: 11.02.2011         at: 08:42:49


Important hint: At least one warning has occurred during the calculation:
1-> Indication:
With the setting 'Position of the contact pattern: unfavorable'
unrealistic high face load coefficient KHb is given for gears with tooth trace modifications.



CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1:    0.000.0
Gear 2:    0.000.0

Calculation method  ISO 6336:2006 Method B

                                                   ------- GEAR 1 -------- GEAR 2 --

Power (kW)                              [P]                        3.500
Speed (1/min)                           [n]             2500.0              930.2
Torque (Nm)                             [T]               13.4               35.9
Application factor                      [KA]                        1.35
Required service life                   [H]                       750.00
Gear driving (+) / driven (-)                              +                   -

1. TOOTH GEOMETRY AND MATERIAL

   (Geometry calculation according ISO 21771)
                                                   ------- GEAR 1 -------- GEAR 2 --
Center distance (mm)                    [a]                       48.900
Centre distance allowances (mm)         [Aa.e/i]             0.030 / -0.030
Normal module (mm)                      [mn]                      1.5000
Pressure angle at normal section (°)    [alfn]                   20.0000
Helix angle at reference circle (°)     [beta]                   25.0000
Number of teeth                         [z]                 16                 43
Facewidth (mm)                          [b]              14.00              14.50
Hand of gear                                             right               left
Accuracy grade                          [Q-ISO1328]          8                  8
Inner diameter (mm)                     [di]              0.00               0.00
Inner diameter of gear rim (mm)         [dbi]             0.00               0.00

Material
Gear 1:                    15 CrNi 6, Case-carburized steel, case-hardened
                           ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28
Gear 2:                    15 CrNi 6, Case-carburized steel, case-hardened
                           ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28

                                                   ------- GEAR 1 -------- GEAR 2 --
Surface hardness                                        HRC 60             HRC 60
Material quality according to ISO6336:  Normal (Life factors ZNT and YNT >=0.85)
Fatigue strength. tooth root stress (N/mm²)
                                        [sigFlim]       430.00             430.00
Fatigue strength for Hertzian pressure (N/mm²)
                                        [sigHlim]      1500.00            1500.00
Tensile strength (N/mm²)                [Rm]           1000.00            1000.00
Yield point (N/mm²)                     [Rp]            685.00             685.00
Young's modulus (N/mm²)                 [E]             206000             206000
Poisson's ratio                         [ny]             0.300              0.300
Average roughness, Ra, tooth flank (µm) [RAH]             0.60               0.60
Mean roughness height, Rz, flank (µm)   [RZH]             4.80               4.80
Mean roughness height, Rz, root (µm)    [RZF]            20.00              20.00

Tool or reference profile of gear  1 :
Reference profile 1.25 / 0.30 / 1.0 ISO 53.2 Profil B
Addendum coefficient                        [haP*]                    1.000
Dedendum coefficient                        [hfP*]                    1.250
Tip radius factor                           [rhoaP*]                  0.000
Root radius factor                          [rhofP*]                  0.300
Tip form height coefficient                 [hFaP*]                   0.000
Protuberance height factor                  [hprP*]                   0.000
Protuberance angle                          [alfprP]                  0.000
Ramp angle                                  [alfKP]                   0.000
                                                               not topping

Tool or reference profile of gear  2 :
Reference profile 1.25 / 0.30 / 1.0 ISO 53.2 Profil B
Addendum coefficient                        [haP*]                    1.000
Dedendum coefficient                        [hfP*]                    1.250
Tip radius factor                           [rhoaP*]                  0.000
Root radius factor                          [rhofP*]                  0.300
Tip form height coefficient                 [hFaP*]                   0.000
```

Protuberance height factor	[hprP*]	0.000	
Protuberance angle	[alfprP]	0.000	
Ramp angle	[alfKP]	0.000	
		not topping	

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofP*]	0.300	0.300
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Buckling root flank height (module)	[hFaP*]	0.000	0.000
Buckling root flank angle (°)	[alfKP]	0.000	0.000

Type of profile modification:
none (only running-in)

Tip relief (µm)	[Ca]	2.00	2.00

Lubrication type		Grease lubrication
Type of grease		Grease: Microlube GB 00
Lubricant base		Mineral-oil base
Kinem. viscosity base oil at 40 °C (mm^2/s)	[nu40]	700.00
Kinem. viscosity base oil at 100 °C (mm^2/s)	[nu100]	35.00
FZG-Test A/8.3/90 step	[FZGtestA]	12
Specific density at 15 °C (kg/dm^3)	[roOil]	0.900
Grease temperature (°C)	[TS]	80.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-2.688	
Gear ratio	[u]	2.688	
Transverse module (mm)	[mt]	1.655	
Pressure angle at Pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.100	
	[alfwt.e/i]	22.186 / 22.013	
Working pressure angle at normal section (°)	[alfwn]	20.199	
Helix angle at operating pitch circle (°)	[betaw]	25.034	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	48.824	
Sum of profile shift coefficients	[Summexi]	0.0506	
Profile shift coefficient	[x]	0.3215	-0.2709
Tooth thickness (Arc) (module)	[sn*]	1.8048	1.3736
Tip alteration (mm)	[k*mn]	0.000	0.000
Reference diameter (mm)	[d]	26.481	71.168
Base diameter (mm)	[db]	24.573	66.041
Tip diameter (mm)	[da]	30.446	73.355
(mm)	[da.e/i]	30.446 / 30.436	73.355 / 73.345
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	30.446	73.355
(mm)	[dFa.e/i]	30.446 / 30.436	73.355 / 73.345
Operating pitch diameter (mm)	[dw]	26.522	71.278
(mm)	[dw.e/i]	26.538 / 26.506	71.322 / 71.234
Root diameter (mm)	[df]	23.696	66.605
Generating Profile shift coefficient	[xE.e/i]	0.2601 / 0.2367	-0.3275 / -0.3577
Manufactured root diameter with xE (mm)	[df.e/i]	23.511 / 23.441	66.436 / 66.345
Theoretical tip clearance (mm)	[c]	0.375	0.375
Effective tip clearance (mm)	[c.e/i]	0.540 / 0.429	0.537 / 0.437
Active root diameter (mm)	[dNf]	25.050	68.670
(mm)	[dNf.e/i]	25.086 / 25.020	68.719 / 68.627
Root form diameter (mm)	[dFf]	24.894	67.921
(mm)	[dFf.e/i]	24.820 / 24.794	67.816 / 67.761
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.146 / 0.100	0.479 / 0.405
Addendum (mm)	[ha = mn * (haP*+x)]	1.982	1.094
(mm)	[ha.e/i]	1.982 / 1.977	1.094 / 1.089
Dedendum (mm)	[hf = mn * (hfP*-x)]	1.393	2.281
(mm)	[hf.e/i]	1.485 / 1.520	2.366 / 2.411
Roll angle at dFa (°)	[xsi_dFa.e/i]	41.909 / 41.870	27.702 / 27.682
Roll angle to dNa (°)	[xsi_dNa.e/i]	41.909 / 41.870	27.702 / 27.682
Roll angle to dNf (°)	[xsi_dNf.e/i]	11.766 / 10.969	16.480 / 16.189
Roll angle at dFf (°)	[xsi_dFf.e/i]	8.135 / 7.696	13.371 / 13.160
Tooth height (mm)	[H]	3.375	3.375
Virtual gear no. of teeth	[zn]	20.960	56.329
Normal Tooth thickness at Tip cyl. (mm)	[san]	0.874	1.225
(mm)	[san.e/i]	0.806 / 0.771	1.166 / 1.127
Normal space width at tip cylinder (mm)	[efn]	0.000	1.352
(mm)	[efn.e/i]	0.000 / 0.000	1.388 / 1.409
Max. sliding velocity at tip (m/s)	[vga]	1.436	0.919
Specific sliding at the tip	[zetaa]	0.610	0.591
Specific sliding at the root	[zetaf]	-1.443	-1.567
Sliding factor on tip	[Kga]	0.414	0.265
Sliding factor on root	[Kgf]	-0.265	-0.414
Pitch on reference circle (mm)	[pt]	5.200	
Base pitch (mm)	[pbt]	4.825	
Transverse pitch on contact-path (mm)	[pet]	4.825	
Lead height (mm)	[pz]	178.408	479.470
Axial pitch (mm)	[px]	11.150	
Length of path of contact (mm)	[ga, e/i]	6.555 (6.635 / 6.456)	
Length T1-A, T2-A (mm)	[T1A, T2A]	2.432(2.352/ 2.523)	15.965(15.965/15.954)
Length T1-B (mm)	[T1B, T2B]	4.162(4.162/ 4.154)	14.235(14.155/14.323)
Length T1-C (mm)	[T1C, T2C]	4.989(4.967/ 5.011)	13.408(13.350/13.466)

Length T1-D (mm)	[T1D, T2D]	7.257(7.177/ 7.348)	11.140(11.140/11.129)
Length T1-E (mm)	[T1E, T2E]	8.987(8.987/ 8.979)	9.410(9.330/ 9.498)
Length T1-T2 (mm)	[T1T2]	18.397 (18.317 / 18.477)	
Diameter of single contact point B (mm)	[d-B]	25.945(25.945/25.940)	71.916(71.853/71.986)
Diameter of single contact point D (mm)	[d-D]	28.540(28.459/28.633)	69.698(69.698/69.691)
Addendum contact ratio	[eps]	0.829(0.833/ 0.822)	0.530(0.542/ 0.516)
Minimal length of contact line (mm)	[Lmin]	19.611	

Transverse contact ratio	[eps_a]	1.359
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.375 / 1.357 / 1.338
Overlap ratio	[eps_b]	1.256
Total contact ratio	[eps_g]	2.614
Total contact ratio with allowances	[eps_g.e/m/i]	2.631 / 2.612 / 2.594

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	1009.7	
Axial force (N)	[Fa]	470.8	
Radial force (N)	[Fr]	405.5	
Normal force (N)	[Fnorm]	1185.6	
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	72.12	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	1008.1	
Axial force (N)	[Faw]	470.8	
Radial force (N)	[Frw]	409.4	
Circumferential speed pitch d.. (m/sec)	[v]	3.47	
Running-in value (µm)	[yp]	1.1	
Running-in value (µm)	[yf]	1.0	
Correction coefficient	[CM]	0.800	
Gear body coefficient	[CR]	1.000	
Reference profile coefficient	[CBS]	0.975	
Material coefficient	[E/Est]	1.000	
Singular tooth stiffness (N/mm/µm)	[c']	12.156	
Meshing stiffness (N/mm/µm)	[cgalf]	15.426	
Meshing stiffness (N/mm/µm)	[cgbet]	13.112	
Reduced mass (kg/mm)	[mRed]	0.00235	
Resonance speed (min-1)	[nE1]	48315	
Nominal speed (-)	[N]	0.052	
Subcritical range			
Running-in value (µm)	[ya]	1.1	
Bearing distance l of pinion shaft (mm)	[l]	53.000	
Distance s of pinion shaft (mm)	[s]	5.900	
Outside diameter of pinion shaft (mm)	[dsh]	14.000	
load according ISO 6336/1 Diagram 16 0:a), 1:b), 2:c), 3:d), 4:e)	[-]	0	
coefficient K' following ISO 6336/1 Diagram 13	[K']	0.80	
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]	15.11	
from deformation of shaft (µm)	[fsh*B1]	2.56	
Tooth trace: with end relief			
Position of Contact pattern: not verified or inappropriate			
from production tolerances (µm)	[fma*B2]	14.36	
Tooth trace deviation, theoretical (µm)	[Fbx]	17.77	
Running-in value (µm)	[yb]	2.7	
Dynamic factor	[KV]	1.051	
Width factor - flank	[KHb]	1.968	
- Tooth root	[KFb]	1.676	
- Scuffing	[KBb]	1.968	
Transverse coefficient - flank	[KHa]	1.341	
- Tooth root	[KFa]	1.341	
- Scuffing	[KBa]	1.341	
Helix angle coefficient scuffing	[Kbg]	1.242	
Number of load changes (in mio.)	[NL]	112.500	41.860

3. TOOTH ROOT STRENGTH

		------- GEAR 1	-------- GEAR 2 --
Calculation of Tooth form coefficients according method: B			
(Calculate tooth form factor YF with manufacturing addendum mod. xE.e)			
Tooth form factor	[YF]	1.37	1.67
Stress correction factor	[YS]	2.15	1.84
Working angle (°)	[alfen]	21.64	18.97
Bending lever arm (mm)	[hF]	1.52	1.84
Tooth thickness at root (mm)	[sFn]	3.14	3.15
Tooth root radius (mm)	[roF]	0.65	0.82

(hF* = 1.012/1.225 sFn* = 2.093/2.102 roF* = 0.431/0.545 dsFn = 24.00/67.03 alfsFn = 30.00/30.00)

Contact ratio factor	[Yeps]	1.000
Helix angle factor	[Ybet]	0.792

```
Deep tooth factor                     [YDT]                          1.000
Gear rim factor                       [YB]              1.000                 1.000
Effective facewidth (mm)              [beff]           14.00                 14.50
Nominal shear stress at tooth root (N/mm²)
                                      [sigF0]         112.30                113.33
Tooth root stress (N/mm²)             [sigF]          358.07                361.35

Permissible bending stress at root of Test-gear
Support factor                        [YdrelT]          0.999                 0.994
Surface factor                        [YRrelT]          0.957                 0.957
Size coefficient (Tooth root)         [YX]              1.000                 1.000
Finite life factor                    [YNT]             0.930                 0.949
                        [YdrelT*YRrelT*YX*YNT]          0.889                 0.902
Alternating bending coefficient       [YM]              1.000                 1.000
Stress correction factor              [Yst]                          2.00
Limit strength tooth root (N/mm²)     [sigFG]         764.63                776.06
Permissible tooth root stress (N/mm²)
                                  [sigFP=sigFG/SFmin]  588.17                596.97
Required safety                       [SFmin]           1.30                  1.30
Safety for Tooth root stress          [SF=sigFG/sigF]   2.14                  2.15
Transmittable power (kW)              [kWRating]        5.75                  5.78
```

4. SAFETY AGAINST PITTING (TOOTH FLANK)

```
                                                   ------- GEAR 1 -------- GEAR 2 --
Zone factor                           [ZH]                           2.291
Elasticity coefficient (N^.5/mm)      [ZE]                         189.812
Contact ratio factor                  [Zeps]                         0.858
Helix angle factor                    [Zbet]                         0.952
Effective facewidth (mm)              [beff]                        14.00
Nominal flank pressure (N/mm²)        [sigH0]                      686.65
Surface pressure at Operating pitch circle (N/mm²)
                                      [sigHw]                     1328.53
Single tooth contact factor           [ZB,ZD]           1.00                  1.00
Flank pressure (N/mm²)                [sigH]         1328.53               1328.53

Lubrication factor                    [ZL]              1.096                 1.093
Speed factor                          [ZV]              0.974                 0.975
Roughness factor                      [ZR]              0.937                 0.939
Material mating factor                [ZW]              1.000                 1.000
Finite life factor                    [ZNT]             0.975                 1.014
                              [ZL*ZV*ZR*ZNT]            0.976                 1.014
Small amount of pitting permissible (0=no, 1=yes)       0                     0
Size coefficient (flank)              [ZX]              1.000                 1.000
Limit strength pitting (N/mm²)        [sigHG]        1464.48               1521.64
Permissible surface pressure (N/mm²) [sigHP=sigHG/SHmin]  1541.56          1601.73

Safety for surface pressure at operating pitch circle
                                      [SHw]             1.10                  1.15
Required safety                       [SHmin]           0.95                  0.95
Transmittable power (kW)              [kWRating]        4.71                  5.09
Safety for stress at single tooth contact
                                      [SHBD=sigHG/sigH]  1.10                 1.15
(Safety regarding nominal torque)     [(SHBD)^2]        1.22                  1.31
```

5. STRENGTH AGAINST SCUFFING

```
Calculation method according to ISO/TR 13989

The calculation of load capacity for scuffing does not cover grease.
The FZG-Test stage [FZGtestA] is only estimated for grease.
The calculation can only serve as a rough guide.!

Lubrication coefficient (for lubrication type)
                                      [XS]                         1.200
Lubricant factor                      [XL]                         1.000
Multiple meshing factor               [Xmp]                        1.0
Relative structure coefficient (Scoring) [XWrelT]                  1.000
Thermal contact factor (N/mm/s^.5/K)  [BM]             13.795                13.795
Relevant tip relief (µm)              [Ca]              2.00                  2.00
Optimal  tip relief (µm)              [Ceff]                       6.31
Effective facewidth (mm)              [beff]                      14.000
Applicable circumferential force/tooth width (N/mm)
                                          [wBt]                  269.984
 (Kbg =   1.242, wBt*Kbg = 335.345)
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)   [XM]                      1.581
Pressure angle factor (eps1:
                   0.990, eps2: 0.829)  [Xalfbet]                  0.530

Flash temperature-criteria
Tooth mass temperature (°C)           [theMi]                     93.52
 theM = theoil + XS*0.47*Xmp*theflm   [theflm]                    23.97
Scuffing temperature (°C)             [theS]                     343.25
Coordinate gamma (point of highest temp.) [Gamma]                  0.788
 [Gamma.A]= -0.513 [Gamma.E]= 0.801
Highest contact temp. (°C)            [theB]                     162.16
Approach factor                       [XJ]                         1.000
Load sharing factor                   [XGam]                       1.151
Dynamic viscosity (mPa*s)             [etaM]                      63.62
Coefficient of friction               [mym]                        0.073
Required safety                       [SBmin]                      2.000
Safety factor for scuffing (flash-temp)  [SB]                      3.204
```

Integral temperature-criteria

Tooth mass temperature (°C)	[theM-C]	98.78
theM-C = theoil + XS*0.70*theflaint	[theflaint]	22.36
Integral scuffing temperature (°C)	[theSint]	357.16
Running-in factor (well run in)	[XE]	1.000
Contact ratio factor	[Xeps]	0.282
Dynamic viscosity (mPa*s)	[etaOil]	63.62
Averaged coefficient of friction	[mym]	0.101
Geometry factor	[XBE]	0.364
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.261
Integral tooth flank temperature (°C)	[theint]	132.32
Required safety	[SSmin]	1.800
Safety factor for scuffing (intg.-temp.)	[SSint]	2.699
Safety referring to transferred torque	[SSL]	5.298

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1	-------- GEAR 2 --
Tooth thickness deviation		Own Input	Own Input
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.067 / -0.093	-0.062 / -0.095
Number of teeth spanned	[k]	3.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	11.845	25.272
Actual base tangent length ('span') (mm)	[Wk.e/i]	11.782 / 11.758	25.214 / 25.183
Diameter of contact point (mm)	[dMWk.m]	26.843	69.973
Theoretical diameter of ball/pin (mm)	[DM]	2.789	2.496
Eff. Diameter of ball/pin (mm)	[DMeff]	3.000	2.500
Theor. dim. centre to ball (mm)	[MrK]	16.053	36.846
Actual dimension centre to ball (mm)	[MrK.e/i]	15.989 / 15.964	36.760 / 36.714
Diameter of contact point (mm)	[dMMr.m]	27.596	70.166
Diametral measurement over two balls without clearance (mm)	[MdK]	32.107	73.644
Actual dimension over balls (mm)	[MdK.e/i]	31.978 / 31.929	73.473 / 73.381
Theor. dimension over two pins (mm)	[MdR]	32.107	73.691
Actual dimension over rolls (mm)	[MdR.e/i]	31.978 / 31.929	73.520 / 73.428
Dimensions over 3 pins without clearance (mm)	[Md3R]	0.000	73.691
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	73.520 / 73.428
Chordal tooth thickness (no backlash) (mm)	['sn]	2.704	2.060
Actual chordal tooth thickness (mm)	['sn.e/i]	2.637 / 2.611	1.998 / 1.965
Reference chordal height from da.m (mm)	[ha]	2.037	1.103
Tooth thickness (Arc) (mm)	[sn]	2.707	2.060
(mm)	[sn.e/i]	2.640 / 2.615	1.999 / 1.966

Backlash free center distance (mm)	[aControl.e/i]	48.725 / 48.646
Backlash free center distance, allowances (mm)	[jta]	-0.175 / -0.254
Centre distance allowances (mm)	[Aa.e/i]	0.030 / -0.030
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.024 / -0.024
Radial clearance (mm)	[jr]	0.284 / 0.145
Circumferential backlash (transverse section) (mm)	[jt]	0.231 / 0.118
Torsional angle using fixed values gear 1 (°)		0.3725 /0.1899
Normal backlash (mm)	[jn]	0.197 / 0.100

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According ISO 1328:			
Accuracy grade	[Q-ISO1328]	8	8
Single pitch deviation (μm)	[fpt]	14.00	15.00
Base circle pitch deviation (μm)	[fpb]	13.00	14.00
Cumulative circular pitch deviation over k/8 pitches (μm)	[Fpk/8]	19.00	24.00
Profile form deviation (μm)	[ffa]	11.00	13.00
Profile slope deviation (μm)	[fHa]	9.50	11.00
Total profile deviation (μm)	[Fa]	15.00	17.00
Helix form deviation (μm)	[ffb]	14.00	15.00
Helix slope deviation (μm)	[fHb]	14.00	15.00
Total helix deviation (μm)	[Fb]	20.00	21.00
Total cumulative pitch deviation (μm)	[Fp]	41.00	52.00
Concentricity deviation (μm)	[Fr]	32.00	42.00
Total radial composite deviation (μm)	[Fi"]	45.00	55.00
Radial tooth-to-tooth composite deviation (μm)	[fi"]	13.00	13.00
Total tangential composite deviation (μm)	[Fi']	61.00	74.00
Tangential tooth-to-tooth composite deviation (μm)	[fi']	21.00	22.00

Tolerance for alignment of axes (recommendation acc. ISO/TR 10064, Quality 8)

Maximum value for deviation error of axis (μm)	[fSigbet]	39.62
Maximum value for inclination error of axes (μm)	[fSigdel]	79.25

8. ADDITIONAL DATA

Maximal possible centre distance (eps_a=1.0)			
	[aMAX]	49.577	
Torsional stiffness (MNm/rad)	[cr]	0.0	0.2
Mean coeff. of friction (acc. Niemann)	[mum]	0.098	
Wear sliding coef. by Niemann	[zetw]	0.819	
Power loss from gear load (kW)	[PVZ]	0.061	
(Meshing efficiency (%)	[etaz]	98.253)	
Weight - calculated with da (g)	[Mass]	79.80	479.82
Moment of inertia (System referenced to wheel 1):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kgm²)	[TraeghMom]	5.684e-006	0.0002656
System ((da+df)/2...di) (kgm²)	[TraeghMom]	4.246e-005	

Indications for the manufacturing by wire cutting:			
Deviation from theoretical tooth trace (μm)	[WireErr]	400.3	149.6
Permissible deviation (μm)	[Fb/2]	10.0	10.5

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :

Calculation of Gear 1
Tooth form, Gear 1, Step 1 (automatic (final treatment))
haP*= 1.071, hfP*= 1.250, rofP*= 0.300

Calculation of Gear 2
Tooth form, Gear 2, Step 1 (automatic (final treatment))
haP*= 1.070, hfP*= 1.250, rofP*= 0.300

REMARKS:
- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  fma following equation (64), fsh following (57/58), Fbx following (52/53/57)
  KHa, KFa according to method B

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