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KISSsoft Tutorial: Cylindrical Gear Pair

Für Release 10/2008
kisssoft-tut-008-E-CylindricalGearPair.doc
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1 Problem

This tutorial explains how to introduce data of a cylindrical gear pair into KISSsoft.

The following steps are carried out for a given cylindrical gear pair:

1. Enter data into KISSsoft
2. Calculate safeties according to ISO 6336:2006 Method B
3. Document the results

1.1 Input Data

The values shown below parameterize the cylindrical gear pair

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

Table 1.1-1: Strength.

Normal module [m_n]	1.5	mm
Helix angle at reference diameter [β]	25	° (right hand)
Pressure angle at normal section [α_n]	20	°
Number of teeth [z] *Gear 1 / Gear 2*	16 / 43	
Facewidth [b] *Gear 1 / Gear 2*	14 / 14.5	mm
Center distance [a]	48.9 ±0.03	mm
Profile shift coefficient [x*] *Gear 1 (pinion)*	0.3215	

Table 1.1-2: Geometry.

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

Table 1.1-3. Reference profile.

	Material	*Data on hardness*	σ_{Flim}	σ_{Hlim}	*Lub.*
Gear 1 (pinion)	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2	Grease, Microlube GB00, 80 °C
Gear 2	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2	

Table 1.1-4. Material and Lubrication.

	No. of teeth spanned [k]	*Max. base tangent length* [$W_{k,max}$]	*Min. base tangent length* [$W_{k,min}$]
Gear 1 (pinion)	3	11.782 mm	11.758 mm
Gear 2	6	25.214 mm	25.183 mm

Table 1.1-5. Tolerances.

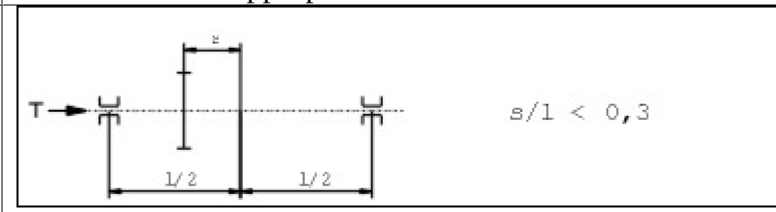
Quality [Q]	8 / 8 (DIN 3961)
Lead correction	End relief
Position of contact pattern	not verified or inappropriate
Type of pinion shaft	 **Fig. 1.1-1. Load case of pinion shaft (see ISO 6336:2006, Fig. 13a)** l = 53 mm; s = 5.9 mm; d_{sh} = 14 mm no support effect

Table 1.1-6. Specifications.

2 Solution

2.1 Starting the Program

Upon installation and activation of the license KISSsoft is started via „Start”->”Programs”->”KISSsoft 10-2008/KISSsoft”. The main window opens (see Fig. 2.1-1).

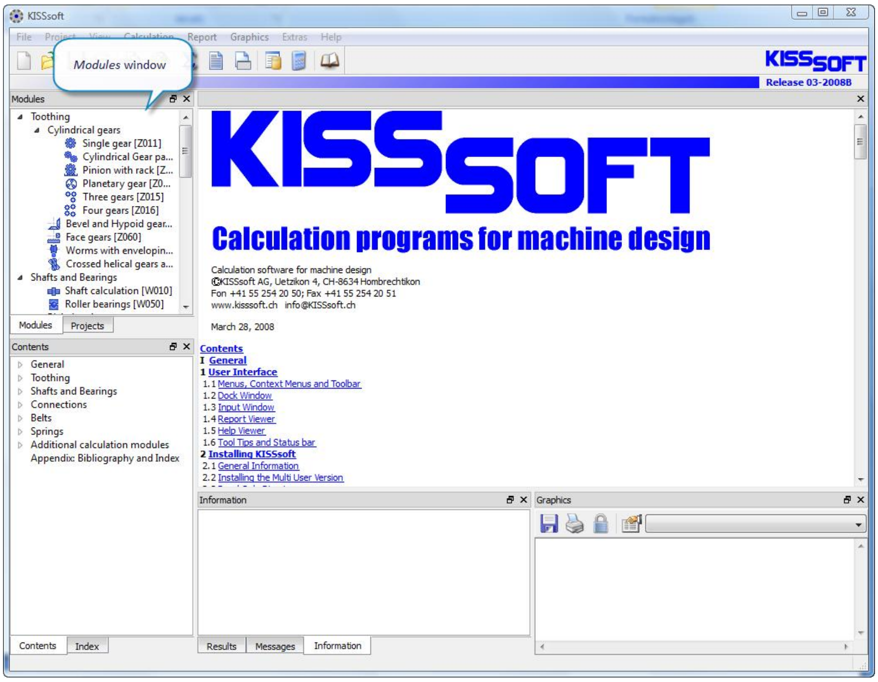


Fig. 2.1-1: KISSsoft main window.

2.2 Starting the Calculation Module

Start the „Cylindrical Gear pair" calculation module by double-clicking the appropriate entry within the window "Modules" in the upper left corner of the main window.

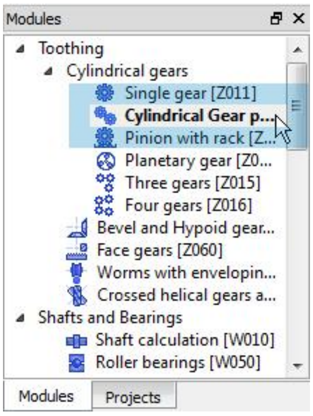


Fig. 2.2-1: Select "Cylindrical Gear pair" calculation module from window "Modules".

The input window tab "Basic data" opens (see Fig. 2.2-2).

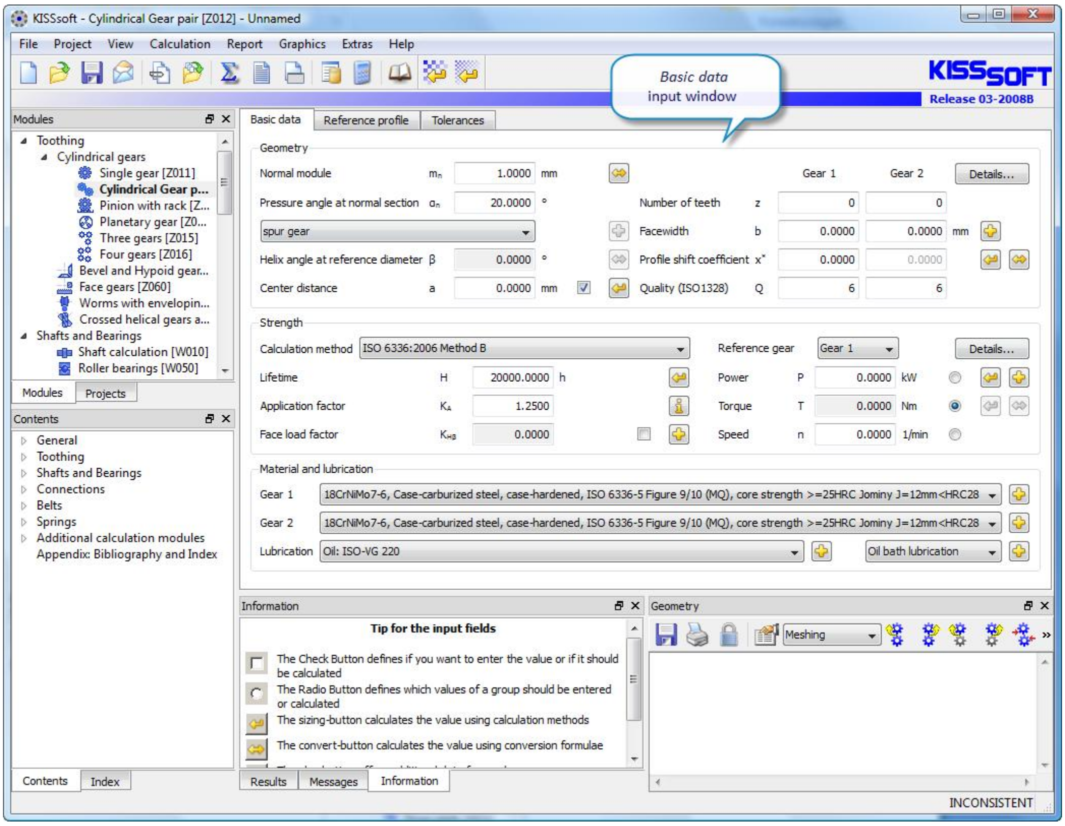
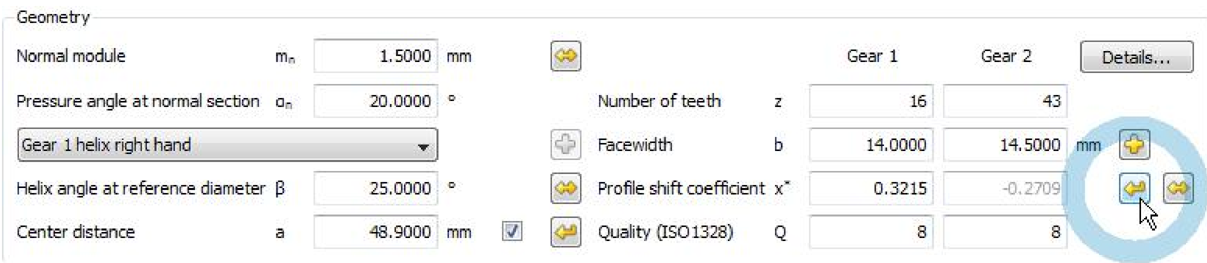


Fig. 2.2-2. input window tab "Basic data" of "Cylindrical Gear pair" calculation module.

The following sections deal with parameterizing the gear pair.

2.3 Geometry of the Gear Pair

The data (given in Table 1.1-1: Strength.
) along with the value for Quality in Table 1.1-6 is entered into group 'Geometry' of tab "Basic data". Since the profile shift coefficient of gear 2 is computed from center distance and profile shift coefficient of gear 1 it cannot be entered into the input field. Clicking the  button right next to the "Profile shift coefficient" input field opens the "Sizing of profile shift coefficient" window which enables you to have the profile shift coefficients calculated according to a given criterion, e.g. "For optimum specific sliding".



According to Table 1.1-6 the Quality value refers to DIN 3961. By default, if the calculation method is set to ISO the Quality value refers to ISO, too. Likewise, if the calculation method is set to DIN the Quality value refers to DIN. The problem that we face here is that a strength calculation method according to ISO has to be combined with a quality value according to DIN. We can bypass the standard mapping by clicking the menu „Calculation"->"Settings" in the menu bar. The "Module specific settings" window opens (see Fig. 2.3-1). Choose the option „DIN3961-3963" from the "drop-down list" for Input of quality according to and have KISSsoft map the Quality value according to DIN while the strength calculation is carried out according to ISO.

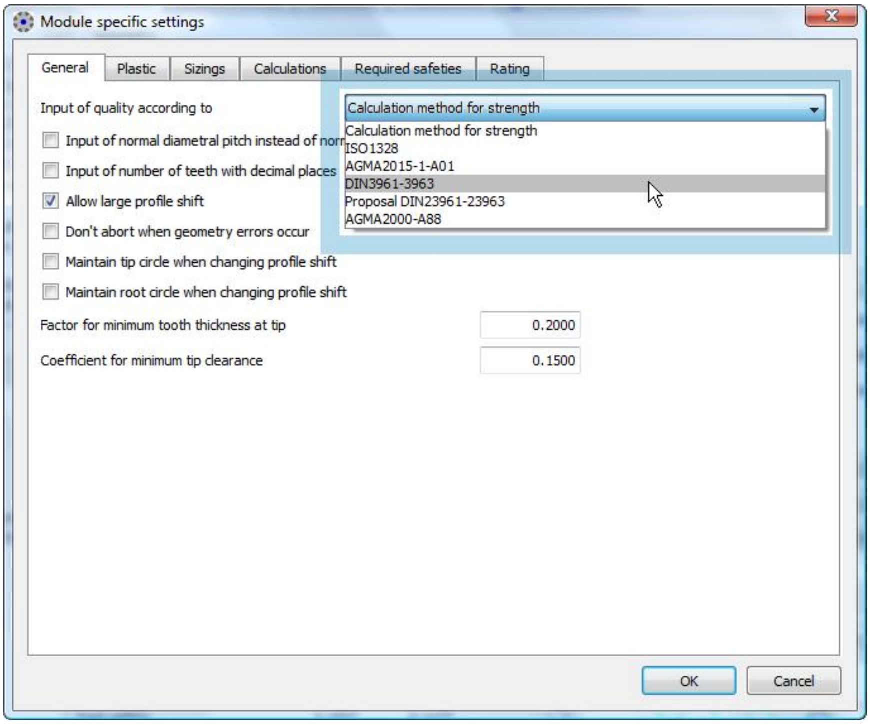


Fig. 2.3-1: Quality mapping in “Module specific settings” window.

Note that some of the input fields come with the “convert button” (). Clicking this button opens a dialog window which enables you to calculate the respective value based on one or more other values. Take the input field “Normal module”, for example. If the only thing you know is the value for the Transverse diametral pitch you may click the button. The “Convert normal module window” opens and offers you a list of alternative values to choose from. Select the desired value by placing a checkmark in the checkbox adjacent to the input field and enter your digits. Click the “Calculate” button to convert the given value into normal module and confirm with “Accept” afterwards. The result is taken over into the “Normale module” input field.

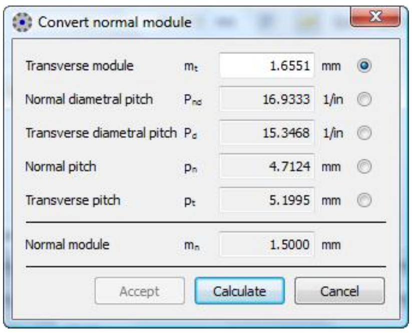


Fig. 2.3-2: “Convert normal module” window.

There are some input fields that expect values which refer to angles, e.g. “Pressure angle at normal section”. Right-clicking these input fields opens a dialog which allows the definition of degree-minutes and degree-seconds instead of decimals (see Fig. 2.3-3).

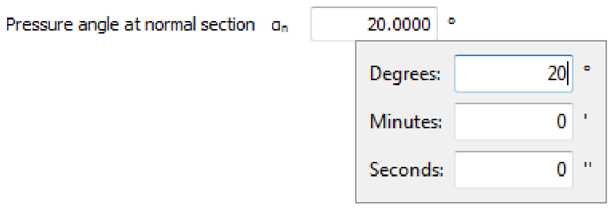


Fig. 2.3-3: Dialog window for definition of angle decimals.

2.4 Definition of Power Data and Calculation Method

In the input window tab “Basic data” you can find the group ‘Strength’. Therein, define required Lifetime (H = 750h), Application factor (K_A = 1.35) and kinematics: torque is defined via Power (P = 3.5kW) and Speed (n = 2500 1/min). If, for any reason, torque was known instead of power the radio button next to the input field Power must be activated. An active radio button marks the respective value to be evaluated from the two others. Tell KISSsoft which gear you are refering the power data to by choosing the appropriate index from the drop-down list Reference gear. Here it is Gear 1 (pinion).

The problem description requires the calculation carried out according to ISO. Therefore choose ISO 6336:2006 Method B from the “drop-down list” for Calculation method.

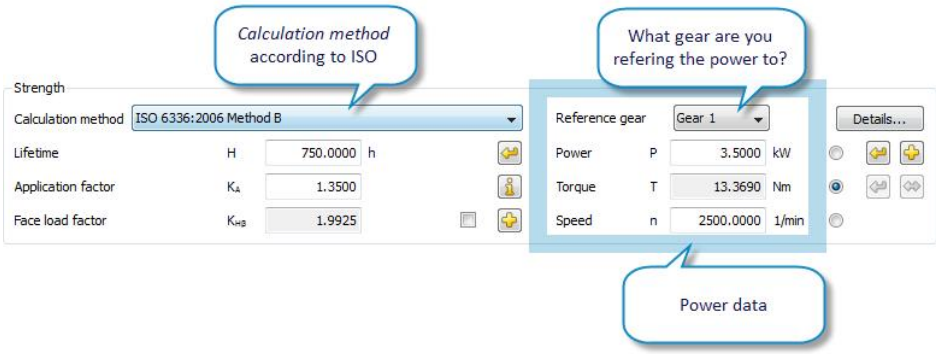


Fig. 2.4-1: Group ‘Strength’ in tab “Basic data”.

If you know the value for the Face load factor $K_{H\beta}$[1] you may enter it directly in the respective input field. Before doing so you have to activate it by placing a checkmark into the checkbox right next to the input field. Generally, however, the face load factor is not known and must be evaluated from other parameters: open the “Define face load factor” window by clicking the button right next to the input field “Face load factor” and parameterize the dialog window as follows:

1. The “drop-down list” for Lead correction has to be set to “End relief” according to Table 1.1-6.
2. Choose the option “ISO6336 picture 13a” from the “drop-down list” for Type of pinion shaft.
3. Enter the values Bearing span (l=53mm), Span[2] (s=5.9mm) and Outside diameter (d_{sh}=14mm) in group ‘Pinion shaft’ according to Table 1.1-6.
4. Since the pinion has no support effect and position of contact pattern is not verified or inappropriate the respective drop-down lists have to be chosen accordingly.

The readily parameterized dialog window is shown in Fig. 2.4-2.

[1] The face load factor $K_{H\beta}$ is a measure for non-linearity of load distribution along the face width.
[2] Activate this input field by first placing a checkmark into the checkbox next to it.

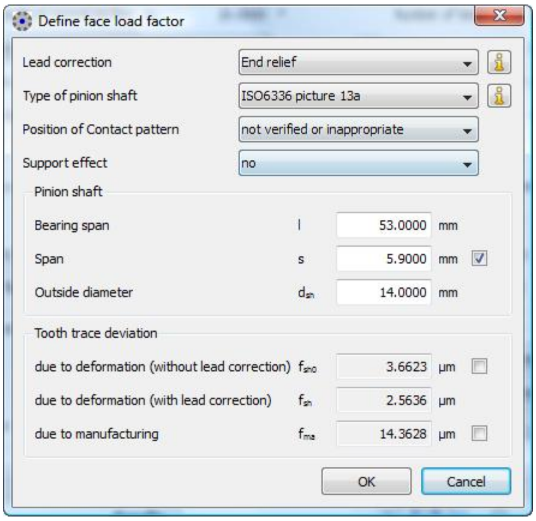


Fig. 2.4-2. Definition of face load factor.

Hint:
According to ISO 6336:2006 there are five different contact patterns to be distinguished. Clicking the  button displays them in the Information window.

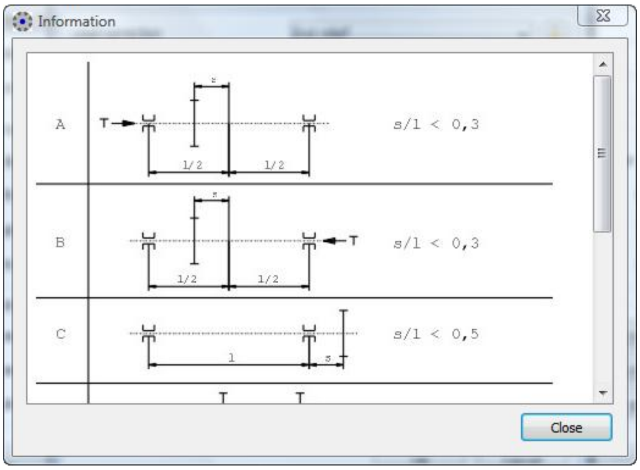


Fig. 2.4-3: window “Information” on contact patterns.

2.5 Material and Lubrication

From the “drop-down lists” for Gear 1 and Gear 2 in group ‘Material and lubrication’ in tab “Basic data” choose the same material 15 CrNi 6. Lubricant is required to be Grease: Microlube GB 00. Choose it from the “drop-down lists” for Lubrication. The  button next to the right-hand “drop-down list” enables you to define the lubricant temperature which equals the operating temperature of the gear. Lubricant temperature has a major effect on effective viscosity where in case of grease and oil lubrication the ambient temperature is of no interest. Note that in case of plastic gears the choice of lubricant temperature has an effect on the strength of the material.

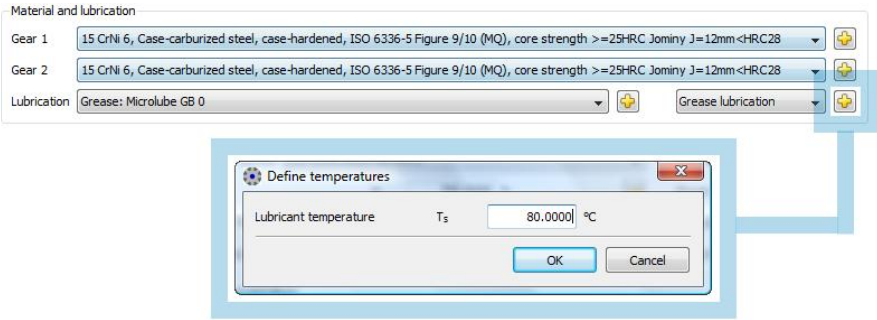


Fig. 2.5-1: Definition of material, lubrication and lubricant temperature.

2.6 Reference Profile

Reference profile data as seen in Table 1.1-2: Geometry.
 can be entered into the input window tab “Reference profile”. Choose it from the tabs at top of the input window.

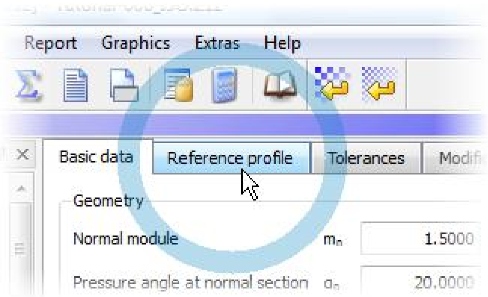


Fig. 2.6-1: Tab “Reference profile” at top of the input window.

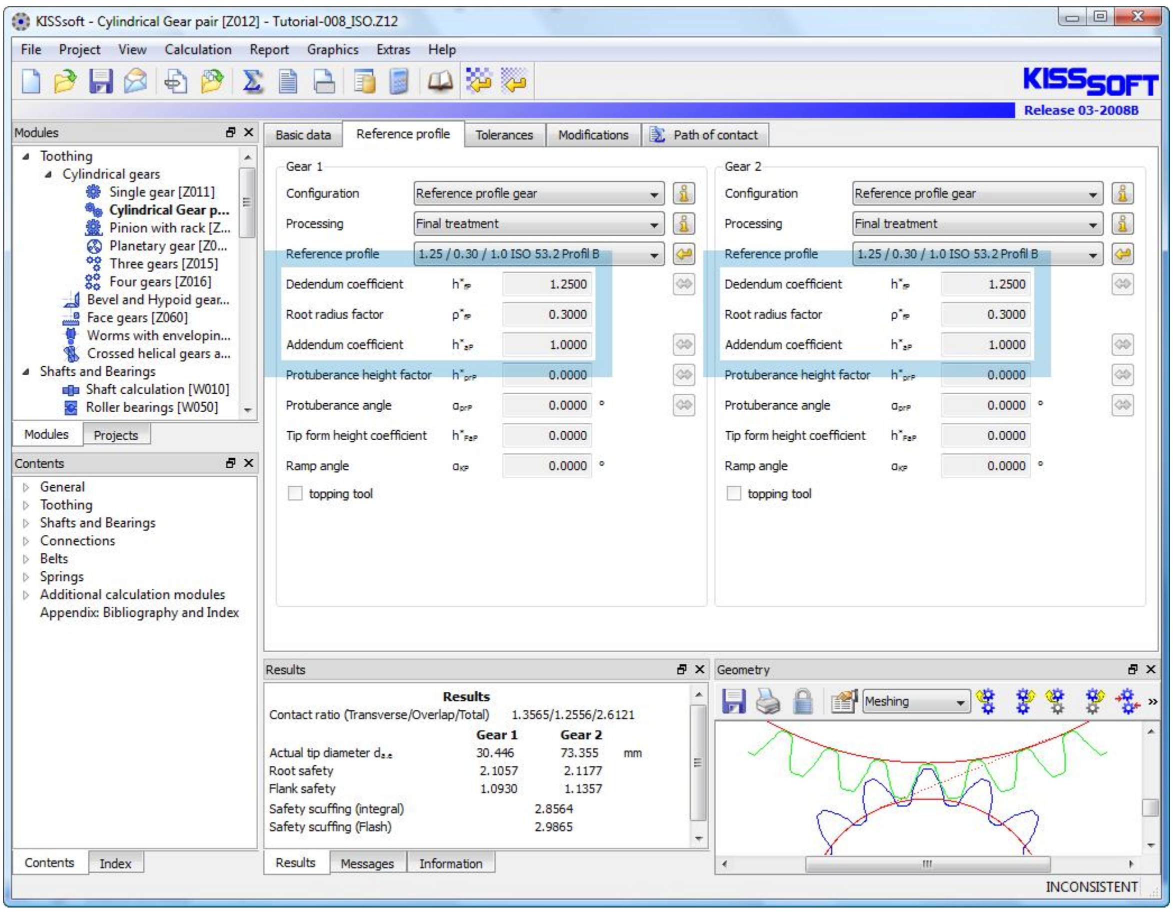


Fig. 2.6-2: Input window tab “Reference profile”.

2.7 Tolerances

Tooth thickness deviations are defined in the tab “Tolerances” (Fig. 2.7-1). It is activated in the same manner as the tab “Reference profile” described in the previous section.

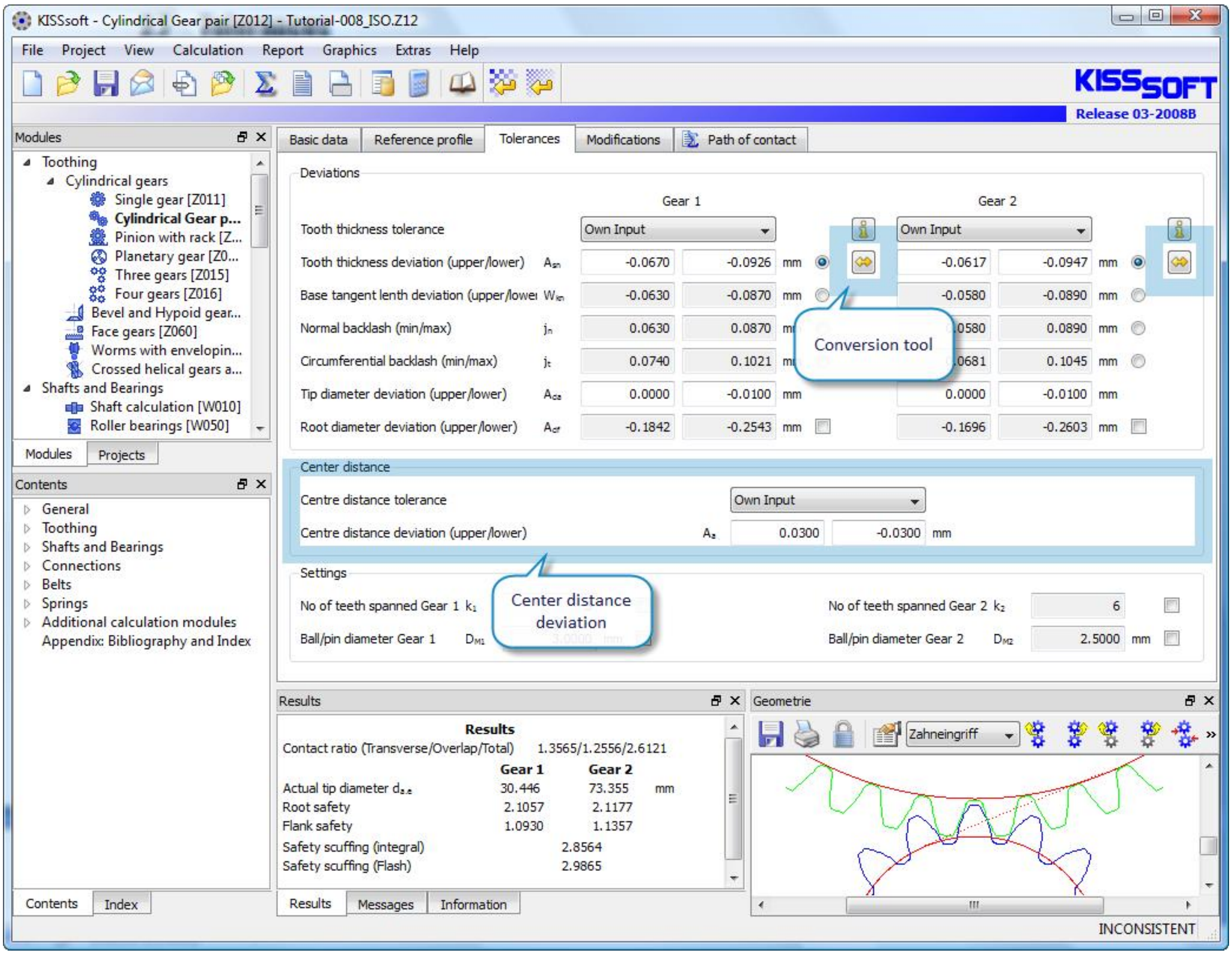


Fig. 2.7-1: Input window “Tolerances”.

In the majority of cases only the effective base tangent length deviations and number of teeth spanned are given. That is why KISSsoft offers the conversion tool “Convert tooth thickness deviations for Gear 1 (2)”. Activate it by clicking the  button on the right-hand side of the input field “Tooth thickness deviation (upper/lower)” as shown in Fig. 2.7-2. Enter number of teeth spanned and upper and lower limits of base tangent length. Click “Calculate” and then “Accept” to take over the results for the tooth thickness tolerances.

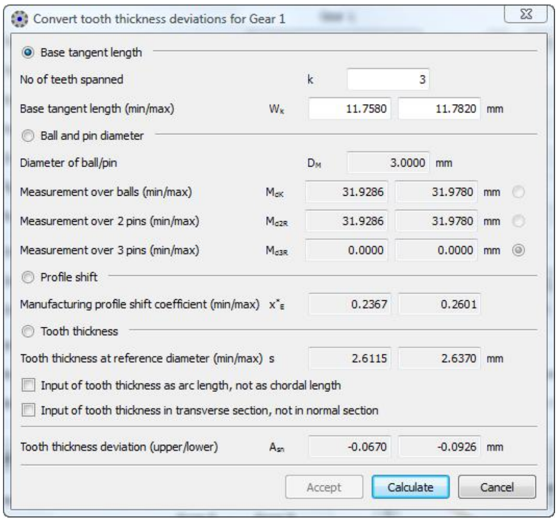


Fig. 2.7-2: Conversion tool "Convert tooth thickness deviations for Gear 1(2)".

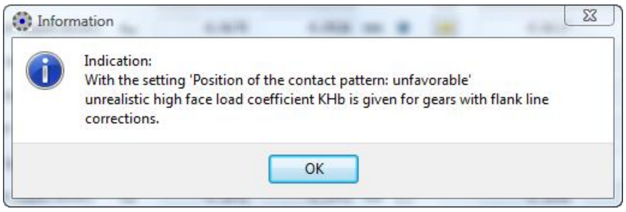
The tab "Tolerances" is also used for defining deviations of center distance in group 'Center distance'. You may either choose deviations by category via the "drop-down list" for Center distance tolerance or define your own limits. Choose "Own Input" from the "drop-down list" therefore.

Remarks:

1. Set deviations after definition of the profile shift coefficients for both gears. Otherwise sizing has to be redone.
2. Change the number of spanned teeth by placing a checkmark into the checkbox next to the input field "No of spanned teeth" in group 'Settings' and entering the new value.

2.8 Calculation

Click Σ in the tool bar or press "F5" to carry out the strength calculation. For the given scenario an Information window opens with following message:



If necessary, test if this is actually the case. The final results for strength calculation are given in Fig. 2.8-1.

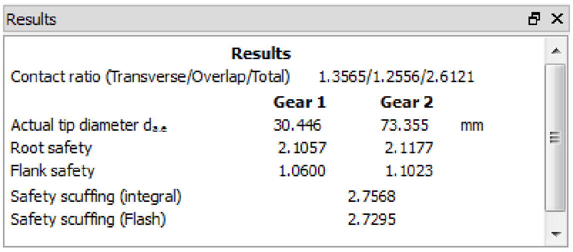


Fig. 2.8-1: Final results.

2.9 Report

Clicking the button or pressing *F6* creates a report of the calculation:

```
───────────────────────── KISSsoft - Release 03-2008
KISSsoft Evaluationsversion

─────────────────────────────────── File
Name       : Tutorial-008_ISO
Changed by : mh          on: 14.06.2008         at: 00:03:26



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 flank line corrections.



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 --

Nominal 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
Service life in hours                  [H]                       750.00
Gear driving (+) / driven (-)                                +                  -

1. TOOTH GEOMETRY AND MATERIAL

   (Geometry calculation according ISO 21771)
                                                        ------- GEAR 1 -------- GEAR 2 --
Centre distance (mm)                   [a]                       48.900
Centre distance tolerances                                ISO 286 Measure js9
Normal module (mm)                     [mn]                      1.5000
Pressure angle at normal section (°)   [alfn]                   20.0000
Helix angle at Pitch diameter (°)      [beta]                   25.0000
Number of teeth                        [z]                    16                 43
Facewidth (mm)                         [b]                 14.00              14.50
Helix                                                      right               left
Accuracy grade                         [Q-ISO1328]             8                  8
Inner diameter of ring (mm)            [dRing]              0.00               0.00
Internal diameter gearbody (mm)        [di]                 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 treatment according to ISO 6336: Normal (Life faktors ZNT and YNT >=0.85)
Fatigue str. tooth root tension (N/mm²)  [sigFlim]         430.00             430.00
Fatigue str. Hertzian stress (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
Youngs 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 factor                            [haP*]                      1.000
Dedendum coefficient                       [hfP*]                      1.250
```

Tip radius factor	[rhoaP*]	0.000
Root radius factor	[rhofP*]	0.300
Addendum form factor	[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 factor	[haP*]	1.000
Dedendum coefficient	[hfP*]	1.250
Tip radius factor	[rhoaP*]	0.000
Root radius factor	[rhofP*]	0.300
Addendum form factor	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
		not topping

Sum 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)	[hk*]	0.000	0.000
Protuberance angle (°)	[alfPro]	0.000	0.000
Buckling root flank height (module)	[hko*]	0.000	0.000
Buckling root flank angle (°)	[alfnk]	0.000	0.000

Type of profile modification:

		No	
Tip relief (µm)	[Ca]	2.00	2.00

Type of lubrication	Grease lubrication	
Grease	Grease: Microlube GB 0	
Lubricant base	Mineral-oil base	
Kinem. viscosity base oil at 40 °C (mm²/s)	[nu40]	400.00
Kinem. viscosity base oil at 100 °C (mm²/s)	[nu100]	25.00
FZG-Test A/8.3/90 step	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.900
Grease temperature (°C)	[TS]	80.000
ambient temperature (°C)	[TU]	20.000

		------- 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]	22.189 / 22.010	
Working pressure angle at normal section (°)	[alfwn]	20.199	
Helix angle at operating pitch diameter (°)	[betaw]	25.034	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	48.824	
Sum of the Addendum modification	[Summexi]	0.0506	
Profile shift coefficient	[x]	0.3215	-0.2709
Tooth thickness (Arc) (module)	[sn*]	1.8048	1.3736
Modification of tip diam. (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 tolerance (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip chamfer/ tip rounding (mm)	[Fased]	0.000	0.000
Tip form circle (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]	26.539 / 26.505	71.323 / 71.233
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 clearence (mm)	[c]	0.375	0.375
Effective tip clearence (mm)	[c.e/i]	0.541 / 0.428	0.538 / 0.436
Active root diameter (mm)	[dNf]	25.050	68.670
(mm)	[dNf.e/i]	25.087 / 25.019	68.720 / 68.625
Root form circle (mm)	[dFf]	24.894	67.921

(mm)	[dFf.e/i]	24.820 / 24.794		67.816 / 67.761
Reserve (dNf-dFf)/2 (mm)	[rNf-rFf.e/i]	0.147 / 0.099		0.480 / 0.405
Addendum (mm)	[ha]	1.982		1.094
(mm)	[ha.e/i]	1.982 / 1.977		1.094 / 1.089
Dedendum (mm)	[hf]	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 dNf (°)	[xsi_dNf.e/i]	11.778 / 10.956		16.485 / 16.184
Roll angle to dNa (°)	[xsi_dNa.e/i]	41.909 / 41.870		27.702 / 27.682
Roll angle to dNf (°)	[xsi_dNf.e/i]	11.778 / 10.956		16.485 / 16.184
Roll angle at dFf (°)	[xsi_dFf.e/i]	8.135 / 7.696		13.371 / 13.160
Tooth depth (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 Tooth space as Tip cylinder (mm)	[efn]	0.000		1.352
(mm)	[efn.e/i]	0.000 / 0.000		1.388 / 1.409
Max. sliding speed 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 (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 (6.638 / 6.453)	
Length T1-A, T2-A (mm)	[T1A, T2A]	2.432(2.349/ 2.526)		15.965(15.965/15.954)
Length T1-B (mm)	[T1B, T2B]	4.162(4.162/ 4.154)		14.235(14.152/14.326)
Length T1-C (mm)	[T1C, T2C]	4.989(4.967/ 5.011)		13.408(13.348/13.468)
Length T1-D (mm)	[T1D, T2D]	7.257(7.174/ 7.351)		11.140(11.140/11.129)
Length T1-E (mm)	[T1E, T2E]	8.987(8.987/ 8.979)		9.410(9.327/ 9.501)
Length T1-T2 (mm)	[T1T2]		18.397 (18.314 / 18.479)	
Diameter of single contact point B (mm)	[d-B]	25.945(25.945/25.940)		71.916(71.851/71.988)
Diameter of single contact point D (mm)	[d-D]	28.540(28.456/28.635)		69.698(69.698/69.691)
Addendum contact ratio	[eps]	0.829(0.833/ 0.822)		0.530(0.542/ 0.515)
Minimal length of contact line (mm)	[Lmin]		19.611	
Transverse contact ratio	[eps_a]		1.359	
Transverse contact ratio, effective	[eps_a.e/m/i]		1.376 / 1.357 / 1.337	
Overlap ratio	[eps_b]		1.256	
Total contact ratio	[eps_g]		2.614	
Total contact ratio, effective	[eps_g.e/m/i]		2.631 / 2.612 / 2.593	

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 for information: Forces at the 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 y.a (µm)	[ya]	1.1
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	1.000
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	12.468
Meshing spring stiffness (N/mm/µm)	[cgalf]	15.821
Meshing spring stiffness (N/mm/µm)	[cgbet]	13.448
Reduced mass (kg/mm)	[mRed]	0.002
Resonance speed (min-1)	[nE1]	48931
Nominal speed (-)	[N]	0.051
Subcritical range		
Bearing distance l of pinion shaft (mm)	[l]	53.000
Distance s of pinion shaft (mm)	[s]	5.900
Outside diameter of the pinion shaft (mm)	[dsh]	14.000
load according ISO 6336/1 Diagram 16	[-]	0

```
 0:a), 1:b), 2:c), 3:d), 4:e)
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:  End relief
 Position of Contact pattern: Without verification or unfavourable
 from production tolerances (µm)         [fma*B2]                         14.36
 Tooth trace deviation, theoretical (µm)   [Fbx]                          17.77
 Running in value y.b (µm)               [yb]                              2.67

Dynamic coefficient                      [KV]                             1.051

Face coefficient -  flank                [KHb]                            1.992
                 -  Tooth root           [KFb]                            1.692
                 -  Scuffing             [KBb]                            1.992

Transverse coefficient - flank           [KHa]                            1.347
                 -  Tooth root           [KFa]                            1.347
                 -  Scuffing             [KBa]                            1.347

Helix angle coefficient scuffing         [Kbg]                            1.242

No 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 shape coefficient YF with manufactured 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]               363.13                366.46

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
Limited-life factor                      [YNT]                 0.930                 0.949
Alternating bending coefficient          [Kwb]                 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]        2.11                  2.12
Transmittable power (kW)                 [kWRating]             5.67                  5.70
```

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 diameter (N/mm²)
                                         [sigHw]                        1339.84
Single tooth contact factor              [ZBD]                  1.00                  1.00
Surface pressure on flank (N/mm²)        [sigH]              1339.84               1339.84

Lubrication factor                       [ZL]                  1.063                 1.061
```

Speed factor	[ZV]	0.974	0.975
Roughness factor	[ZR]	0.937	0.939
Material mating factor	[ZW]	1.000	1.000
Limited-life factor	[ZNT]	0.975	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]	1420.17	1476.89
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1494.92	1554.63
Safety for surface pressure at pitch diameter	[SHw]	1.06	1.10
Required safety	[SHmin]	0.95	0.95
Transmittable power (kW)	[kWRating]	4.36	4.71
Safety for stress at single tooth contact	[SHBD=sigHG/sigH]	1.06	1.10
(Safety regarding nominal torque)	[(SHBD)^2]	1.12	1.22)

5. STRENGTH AGAINST SCUFFING

Calculation method according DIN3990
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 (Scoring)	[XS]	1.200	
Relative structure coefficient (Scoring)	[XWrelT]	1.000	
Therm. contact factor (N/mm/s^.5/K)	[BM]	13.795	13.795
Effective facewidth (mm)	[beff]	14.000	
Applicable circumferential force/tooth width	[wbt]	341.080	
Angle factor	[Xalfbet]	0.990	
(eps1: 0.829, eps2: 0.530)			

Flashtemperature-criteria (DIN3990)

Tooth mass temperature (°C)	[theM-B]	122.47
theM-B = theoil + XS*0.47*theflamax	[theflamax]	75.31
Scuffing temperature (°C)	[theS]	401.51
Coordinate gamma (point of highest temp.)	[Gamma]	0.455
Highest contact temp. (°C)	[theB]	197.78
Flash factor	[XM]	50.002
Geometry-factor	[XB]	0.215
Distribution factor	[XGam]	1.000
Coefficient of friction	[mymy]	0.127
Required safety	[SBmin]	2.000
Safety coefficient for scuffing (flash-temp)	[SB]	2.729

Integraltemperature-criteria (DIN3990)

Tooth mass temperature (°C)	[theM-C]	103.56
theM-C = theoil + XS*0.70*theflaint	[theflaint]	28.05
Integral scuffing temperature (°C)	[theSint]	401.51
Flash factor	[XM]	50.002
Contact ratio factor	[Xeps]	0.282
Mean coefficient of friction	[mym]	0.099
Geometry-factor	[XBE]	0.364
Meshing factor	[XQ]	1.000
Tip relief-factor	[XCa]	1.000
Integral-tooth flank temperature (°C)	[theint]	145.64
Required safety	[SSmin]	1.800
Safety coefficient for scuffing (intg.-temp.)	[SSint]	2.757
Safety referring to transfered torque	[SSL]	4.898

6. TOOTH THICKNESS DIMENSIONS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness tolerance		Own Input	Own Input
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.067 / -0.093	-0.062 / -0.095
No of teeth over which to measure	[k]	3.000	6.000
Base tangent length ('span') (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
Theor. ball/roller diameter (mm)	[DM]	2.789	2.496
Actual ball/roller diameter (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
Theor. dimension over two balls (mm)	[MdK]	32.107	73.644
Actual dimension over balls (mm)	[MdK.e/i]	31.978 / 31.929	73.473 / 73.381
Actual dimension over rolls (mm)	[MdR.e/i]	31.978 / 31.929	73.520 / 73.428
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
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

Axial Distance Without Backlash (mm)	[aControl.e/i]	48.725 / 48.646
Backlash free centre-distance, Tolerances (mm)	[jta]	-0.175 / -0.254
Centre distance deviation (mm)	[Aa.e/i]	0.031 / -0.031
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.025 / -0.025
Radial clearance (mm)	[jr]	0.285 / 0.144
Circumferential backlash (mm)	[jt]	0.232 / 0.117
Normal backlash (mm)	[jn]	0.198 / 0.100

7. TOLERANCES

		------- GEAR 1	-------- GEAR 2 --
According ISO 1328:			
Accuracy grade	[Q-ISO1328]	8	8
Single pitch deviation (µm)	[fpt]	14.00	15.00
Single pitch deviation (µm)	[fpb]	13.00	14.00
Cumulative circular pitch error over z/8 pitches (µm)	[Fpz/8]	19.00	24.00
Profile deviation (µm)	[ffa]	11.00	13.00
Profile angular deviation (µm)	[fHa]	9.50	11.00
Profile total 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
Tooth helix deviation (µm)	[Fb]	20.00	21.00
Total cumulative pitch deviation (µm)	[Fp]	41.00	52.00
Runout tolerance (µm)	[Fr]	32.00	42.00
Total radial composite tolerance (µm)	[Fi"]	45.00	55.00
Tooth-to-tooth radial composite tolerance (µm)	[fi"]	13.00	13.00
Total tangential composite deviation (µm)	[Fi']	61.00	74.00
Tooth-to-tooth tangential 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
Medium coef. of friction (acc. Niemann)	[mum]	0.100	
Wear sliding coef. by Niemann	[zetw]	0.819	
Power loss from gear load (kW)	[PVZ]	0.062	
(Meshing efficiency (%)	[etaz]	98.219)	
Weight (g)	[Mass]	79.80	479.82
Inertia (System referenced to wheel 1): calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kgm^2)	[TraeghMom]	5.684e-006	0.0002656
System ((da+df)/2...di) (kgm^2)	[TraeghMom]	4.246e-005	

Indications for the manufacturing by wire cutting:

Deviation from theoretical tooth trace (µm)	[WireErr]	400.3	149.6
Admissible deviation (µm)	[Fb/2]	10.0	10.5

9. MANUFACTURING

Calculation of Gear 1

Gear 1 (Step 1): Automatically (Tool: Hobbing/Milling cutter)
haP*= 1.071, hfP*= 1.250, rofP*= 0.300

Calculation of Gear 2

Gear 2 (Step 1): Automatically (Tool: Hobbing/Milling cutter)
haP*= 1.070, hfP*= 1.250, rofP*= 0.300

REMARKS:
- Specifications with [.e/i] imply: Maximum [e] and Minimul 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.
  The maximum and the minimum backlash respective to the max. and min. tolerances are indicated.
  The calculation is done for the pitch diameter..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according methode C
  fma following equation (64), Fbx following (52/53/57)
  KHa, KFa according to method B

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