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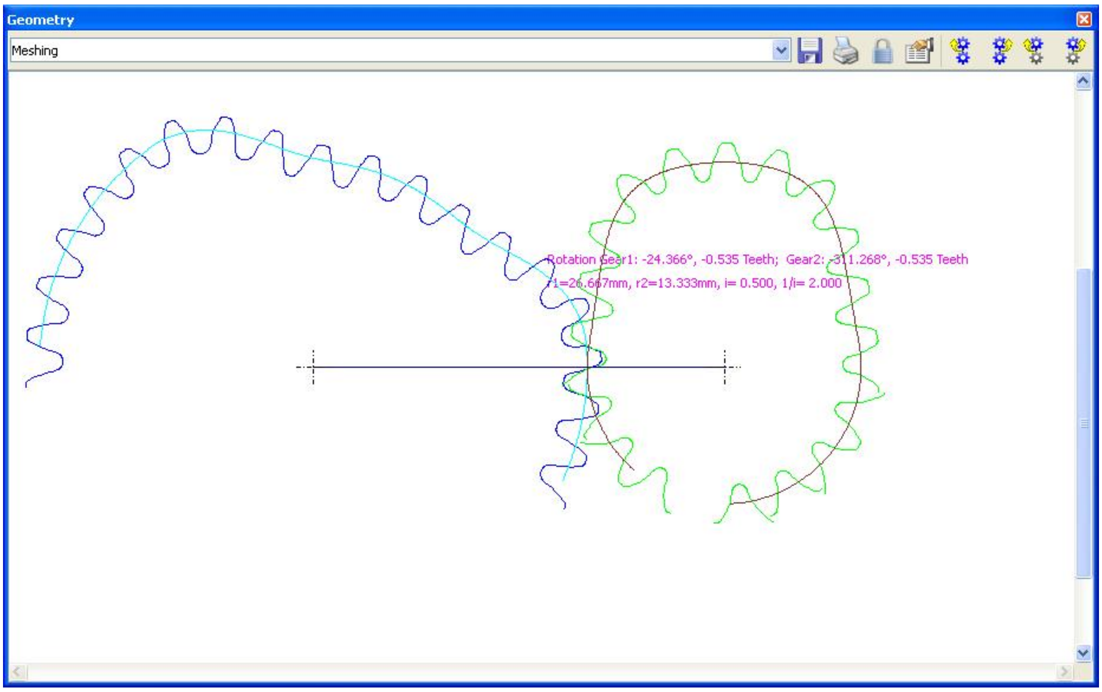
KISSsoft Instructions:

Strength Calculation for Non-circular Gears



These instructions describe the procedure and strategy to use to estimate the strength of non-circular gearings.

Table of contents

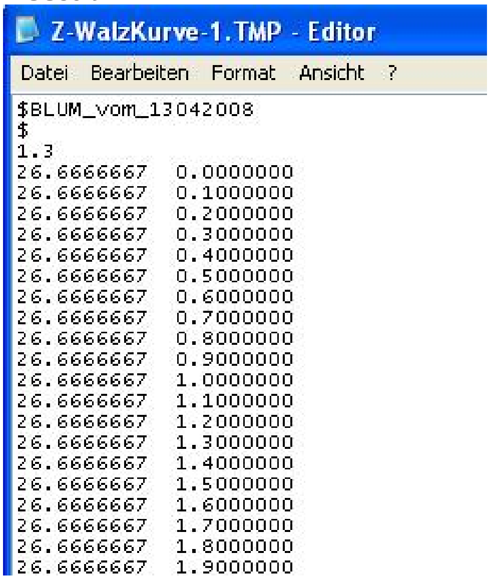
1 Initial situation

1.1 General notes

Non-circular gears have special toothing forms, which are also not symmetrical. It is possible to calculate their strength using an FEM calculation. Although this procedure calculates the root stresses, it cannot, for example, define the wear. For this reason, these instructions describe how to perform a strength analysis. To do this, first define a circular substitute gear. You can then use the classic gear analysis method specified in ISO 6336 or similar methods. The procedure in these instructions is described using a concrete example.

During normal operation, a constant drive torque of 15 Nm is applied to the small gear (gear 2 in the KISSsoft calculation). The course of circumferential force over the rotation angle is calculated from the contact curves of gears 1 and 2. The data provided internally can be used here. In addition, the static proof with 20 Nm on the small gear must also be performed.

These contact curves on gears 1 and 2 (z-contact curve1.TMP; z-contact curve2.TMP) are recorded in a temporary directory. The directory to be used by KISSsoft is specified in the KISS.ini file in the "PATH" section. You will find the KISS.ini file in the KISSsoft main folder. Before you change the default setting, you must ensure that you have read and write access right to the changed directory. You will also find more detailed information about this in section 2 of the manual, "Setting Up KISSsoft".


Z-WalzKurve-1.TMP - Editor
Datei Bearbeiten Format Ansicht ?

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$BLUM_vom_13042008
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26.6666667   0.1000000
26.6666667   0.2000000
26.6666667   0.3000000
26.6666667   0.4000000
26.6666667   0.5000000
26.6666667   0.6000000
26.6666667   0.7000000
26.6666667   0.8000000
26.6666667   0.9000000
26.6666667   1.0000000
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26.6666667   1.4000000
26.6666667   1.5000000
26.6666667   1.6000000
26.6666667   1.7000000
26.6666667   1.8000000
26.6666667   1.9000000
```

Figure 1.1-1: Extract of the contact curve for gear 1.

The first 3 lines in the TMP file are predefined. Lines 1 and 2 are where you can add your own comments (text or blank space). Line row 3 must be 1.3 (version number).

The data is now imported to an Excel file so it can undergo further processing. In this case, you must ensure that the reference in the KISSsoft calculation is now set to the angle of rotation of gear 1 (large gear).

2 Procedure

2.1 Analyze the tooth forms

The initial strength analysis for the overall system is performed on the basis of the strength calculation for the "weakest" tooth or the tooth that is subject to the greatest load. A range of different contact settings are analyzed for this purpose. The following figures show the 4 possible variants that can be applied to a strength analysis.

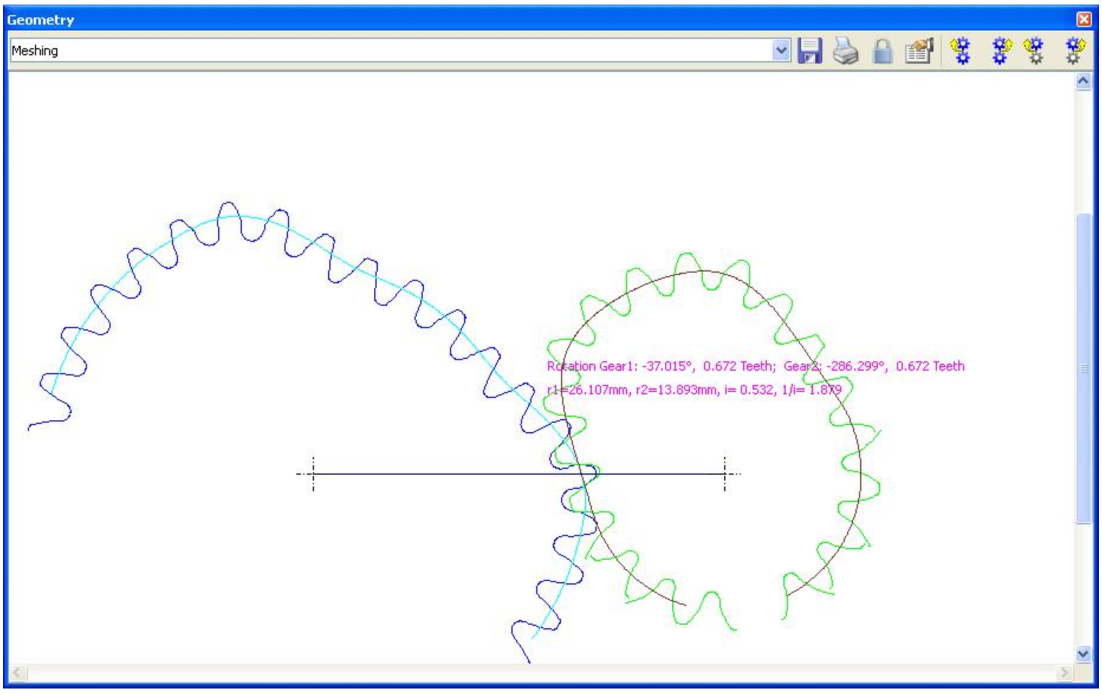

Figure 2.1-1: Weakest tooth in gear 1; tooth thickness at root approximately 2mm.

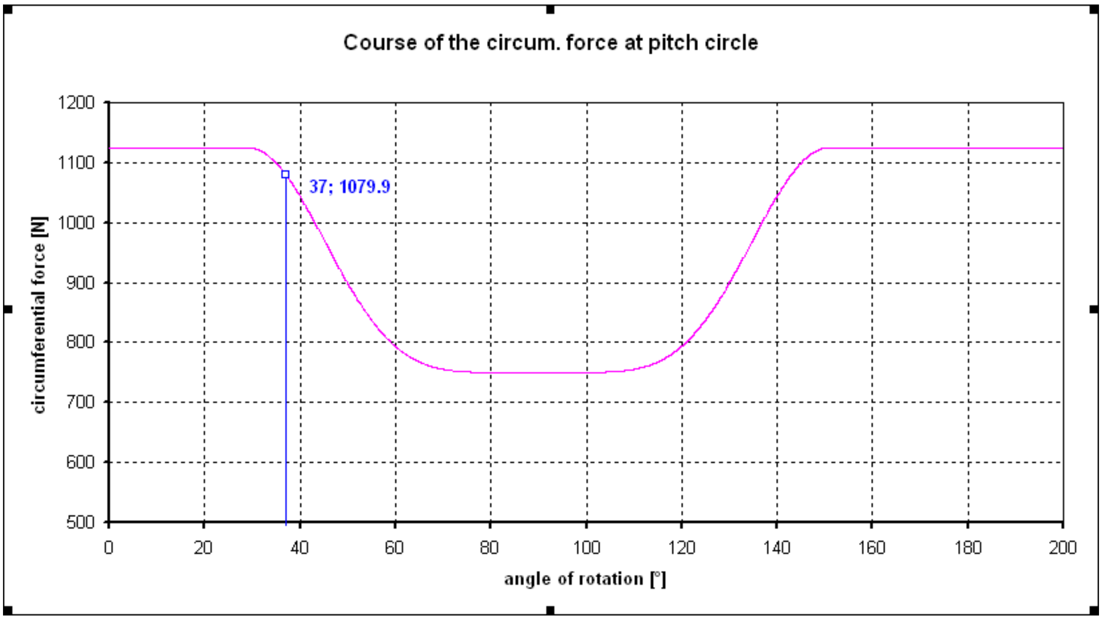

Figure 2.1-2: Nominal circumferential force 1079.9 N at an angle of 37°.

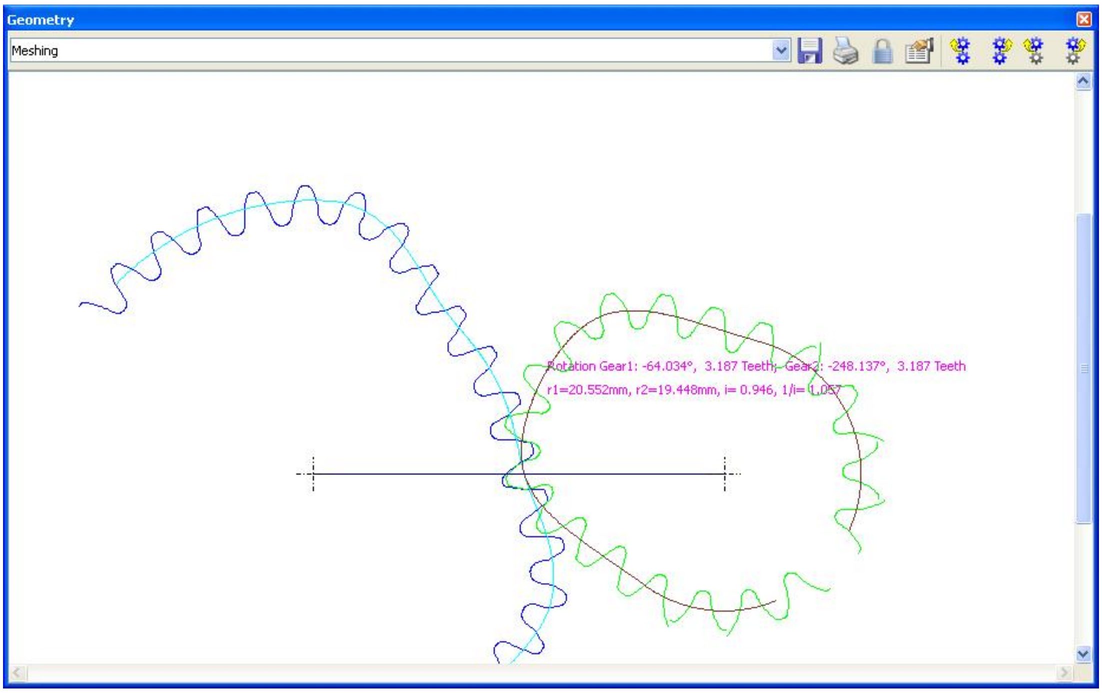

Figure 2.1-3: Weakest tooth in gear 2; tooth thickness at root approximately 2.6 mm.

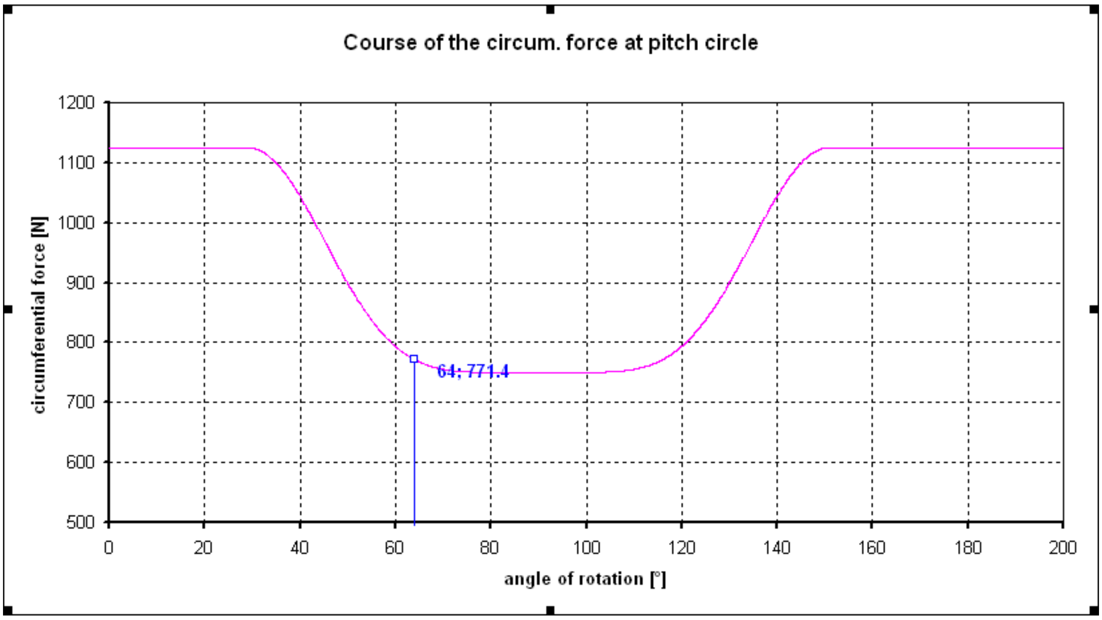

Figure 2.1-4: Nominal circumferential force 771.4 N at an angle of 63.9°.

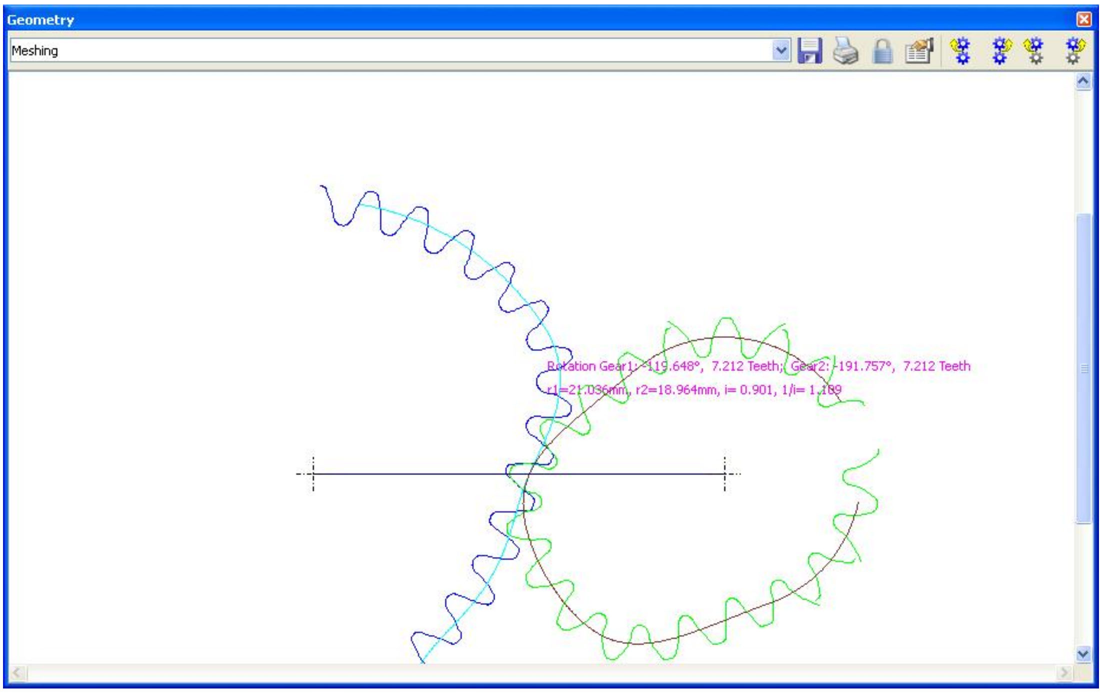

Figure 2.1-5: Weakest tooth in gear 2; tooth thickness at root 2.6 mm.

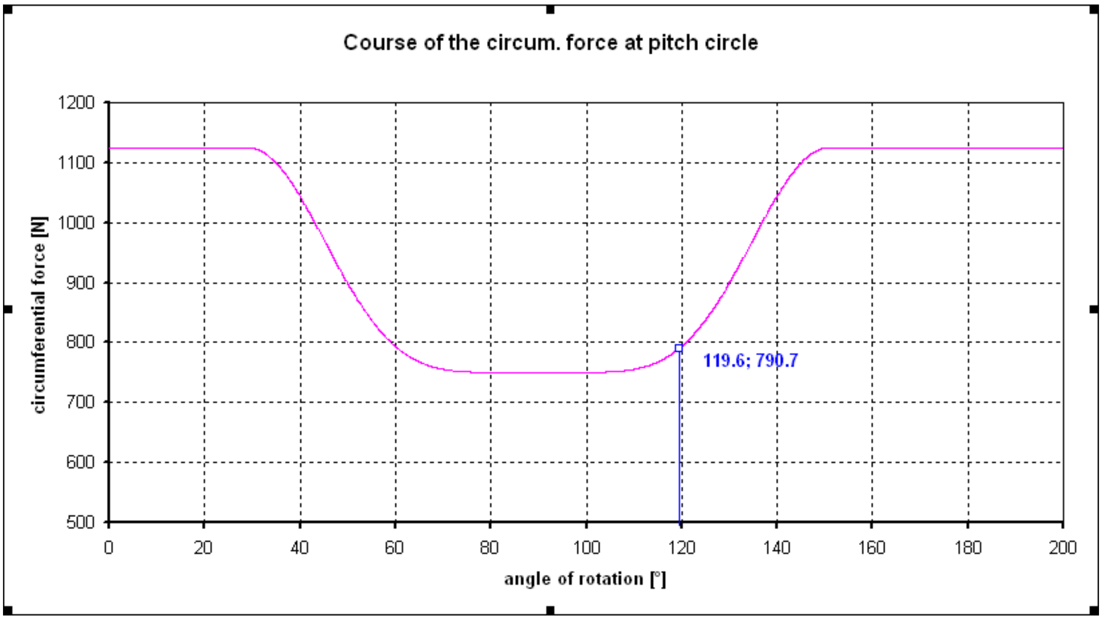

Figure 2.1-6: Nominal circumferential force 790.7 N at an angle of 119.6°.

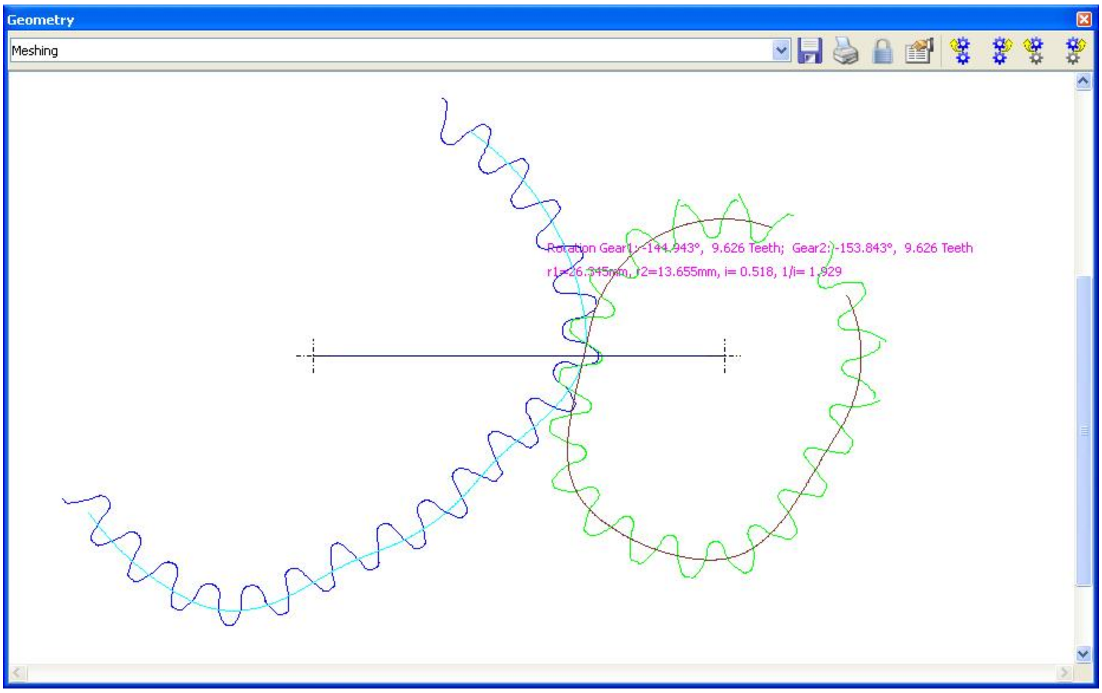

Figure 2.1-7: Weakest tooth in gear 1; tooth thickness at root approximately 2mm.

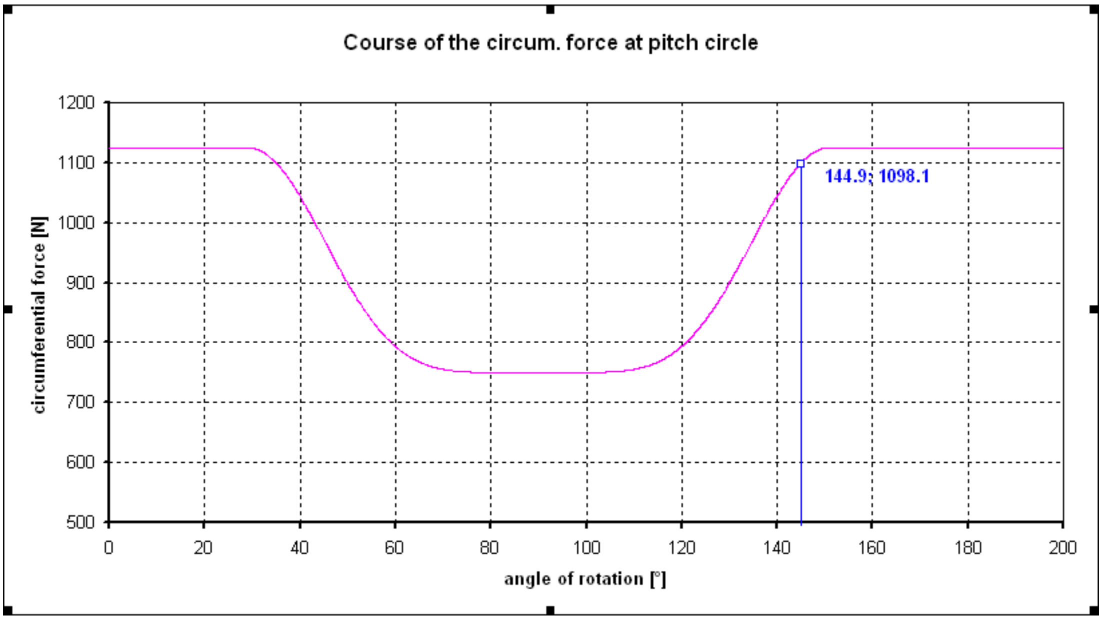

Figure 2.1-8: Nominal circumferential force 1098.1 at an angle of 144.9°.

The highest load appears on gear 1. This is the load represented in **Figure 2.1-1** Although only the second highest circumferential force is present here, the tooth thickness at root for this tooth is the lowest. In this case, the relationship of the tooth thickness compared with the circumferential force for the highest load is the decisive factor, and will therefore be investigated in greater detail.

2.2 Considerations when evaluating the strength

In order to estimate strength, you require a cylindrical gear file [*.Z12] where none of the parameters are set. For this reason, you must open a new, blank cylindrical gear calculation. In the "Module specific settings" window, input the number of teeth with decimal places.

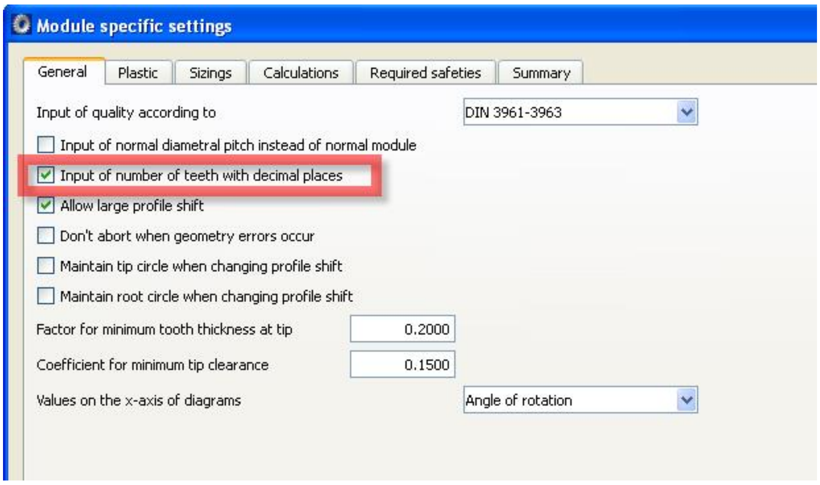

Figure 2.2-1: Change module specific settings.

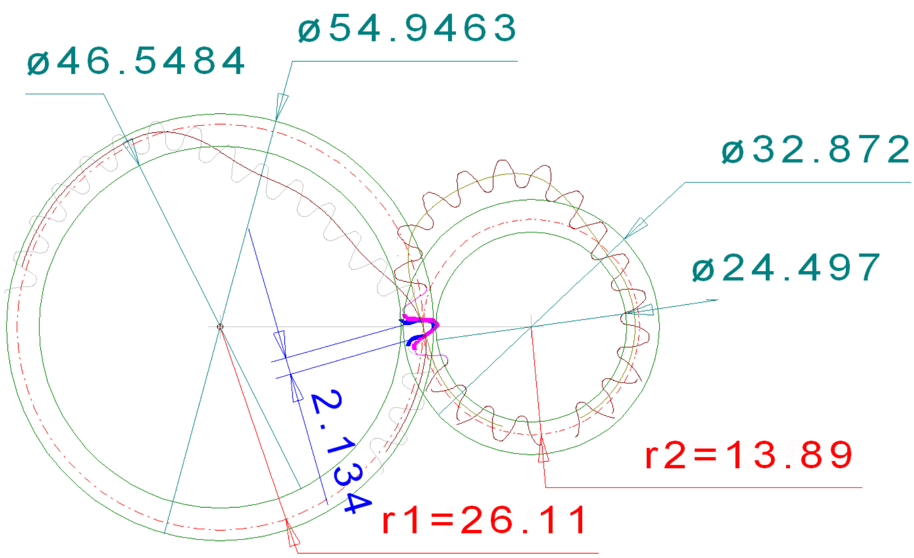

Figure 2.2-2: Defining values for the strength calculation.

The values for the normal module (m_n=1.56) and the pressure angle (α_n=20° as the initial value) are specified in the "Basic data" tab, just like for the non-circular gear calculation. The radii of the segments (r_1, r_2) correspond to the pitch circle radii of the non-circular intermeshing and are taken from the non-circular graphic, see **Figure 2.1-1** with the data r_1=26.110mm etc. The number of teeth for gear 1 is $z_1=2*r_1/m=33.4743$. The center distance is 40 mm. This center distance must be the same as the center distance for the noncircular intermeshing. Therefore, the number of teeth for gear 2 is calculated as z_2=17.8077. In the "Tolerances" tab, select "No backlash" for the tooth thickness deviation. The tolerance of the tip circle diameter is 0.

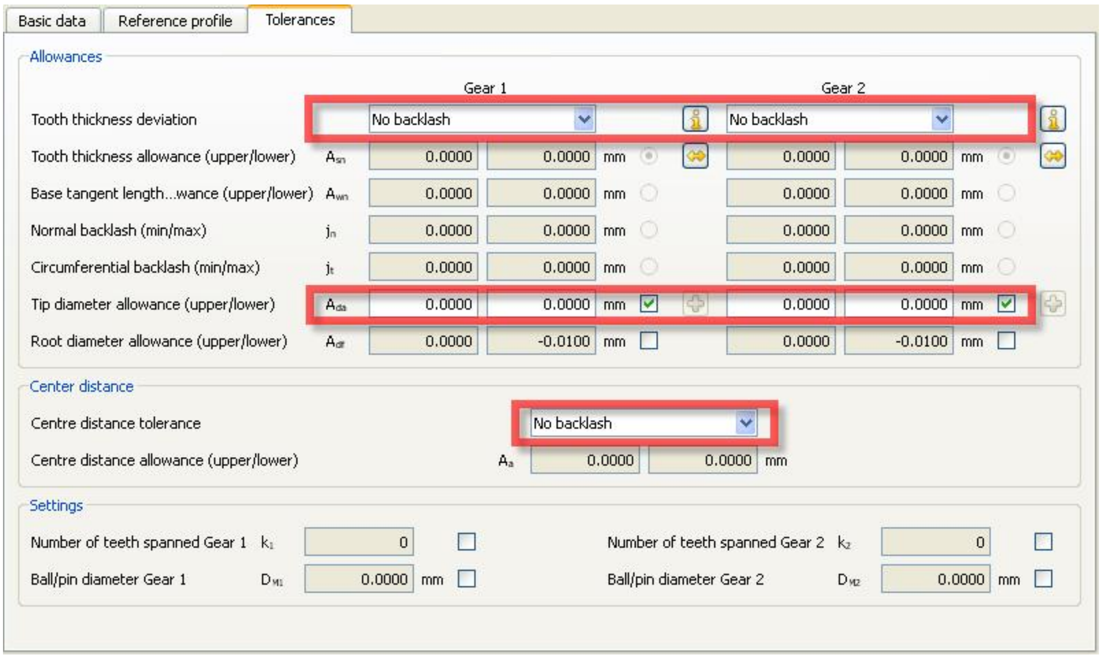

Figure 2.2-3: Settings in the "Tolerances" tab.

The sum of the profile shifts of the substitute gearing is also 0. Click the conversion button and input the measured tooth thickness on gear 1 (s=2,134mm) to define the profile shift of gear 1.

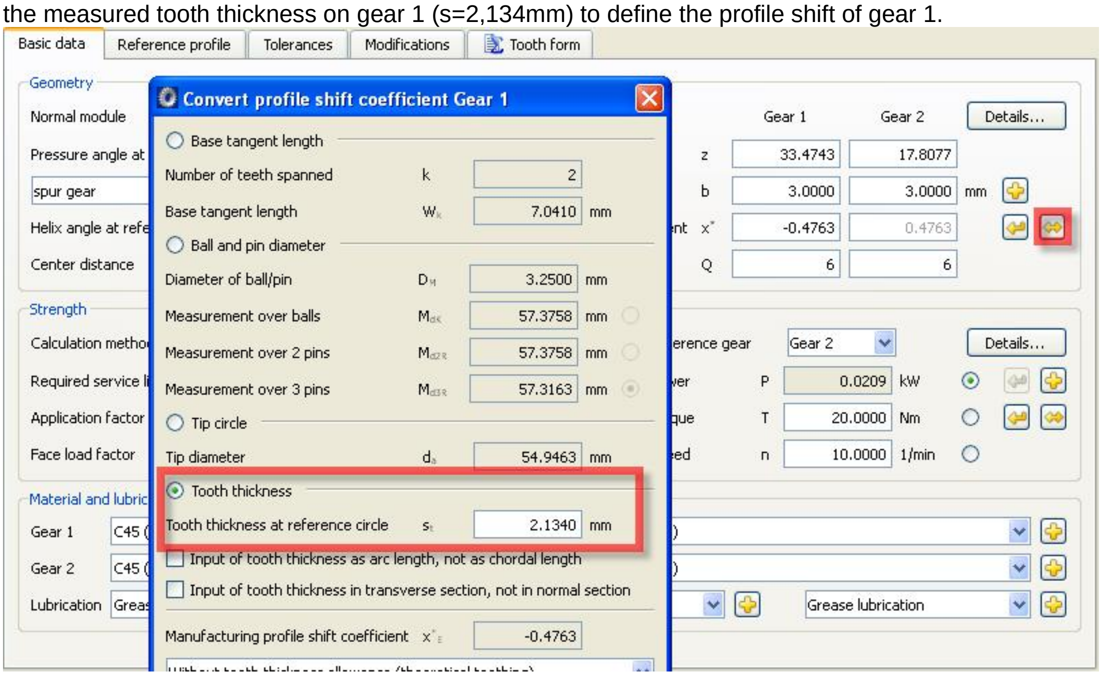

Figure 2.2-4: Define the profile shift coefficient for gear 1.

Click the "Conversion" button in the "Reference profile" tab to input the tip and root diameter (these diameters correspond to the values of the non-circular gears, see **Figure 2.2-2**). Firstly, select "Own input" for the reference profile.

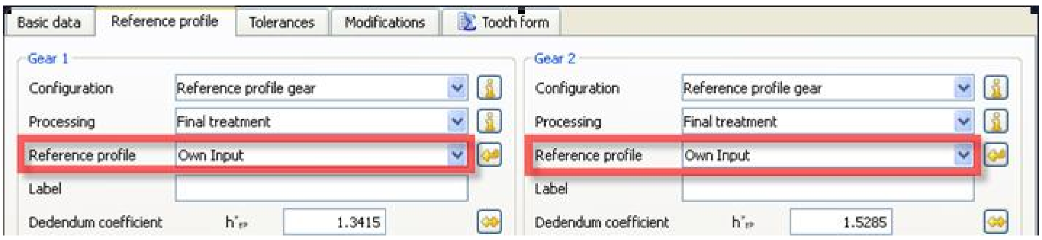

Figure 2.2-5: Setting in the "Reference profile" tab for the "Own Input" reference profile.

Then click the appropriate conversion button to define the addendum and dedendum coefficients.

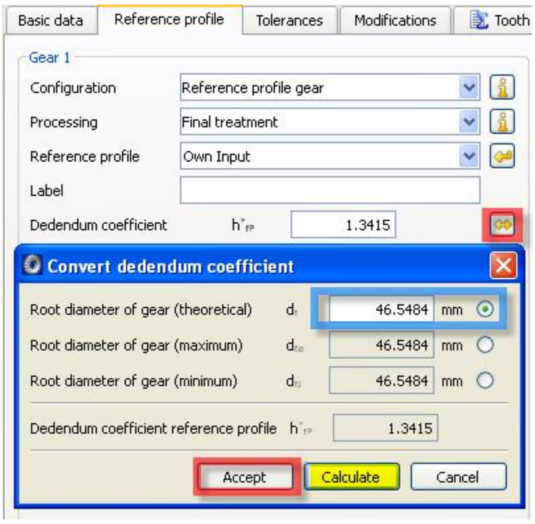

Figure 2.2-6: Setting in the "Reference profile" tab used to convert the addendum and dedendum coefficients.

Then, in "Module specific settings", click the "Maintain tip and root circle when changing profile shift" checkbox.

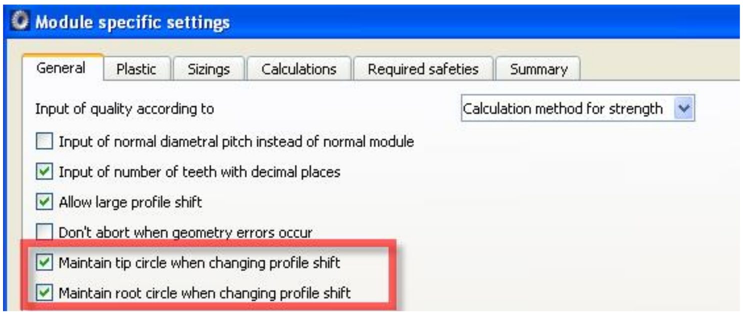

Figure 2.2-7: "Maintain tip and root circle when changing profile shift" checkbox.

If necessary, modify the pressure angle to achieve a better tooth form match with the non-circular gear geometry. α_n=12° is assumed for this in our example. You must then click the the profile shift conversion button again to get the profile shift on gear 1 (s_{n1}=2.134mm).

You must reset the parameters in this way to achieve the best possible match between the two tooth forms. The only way to estimate the strength of a non-circular intermeshing is to use a simple cylindrical gear calculation.

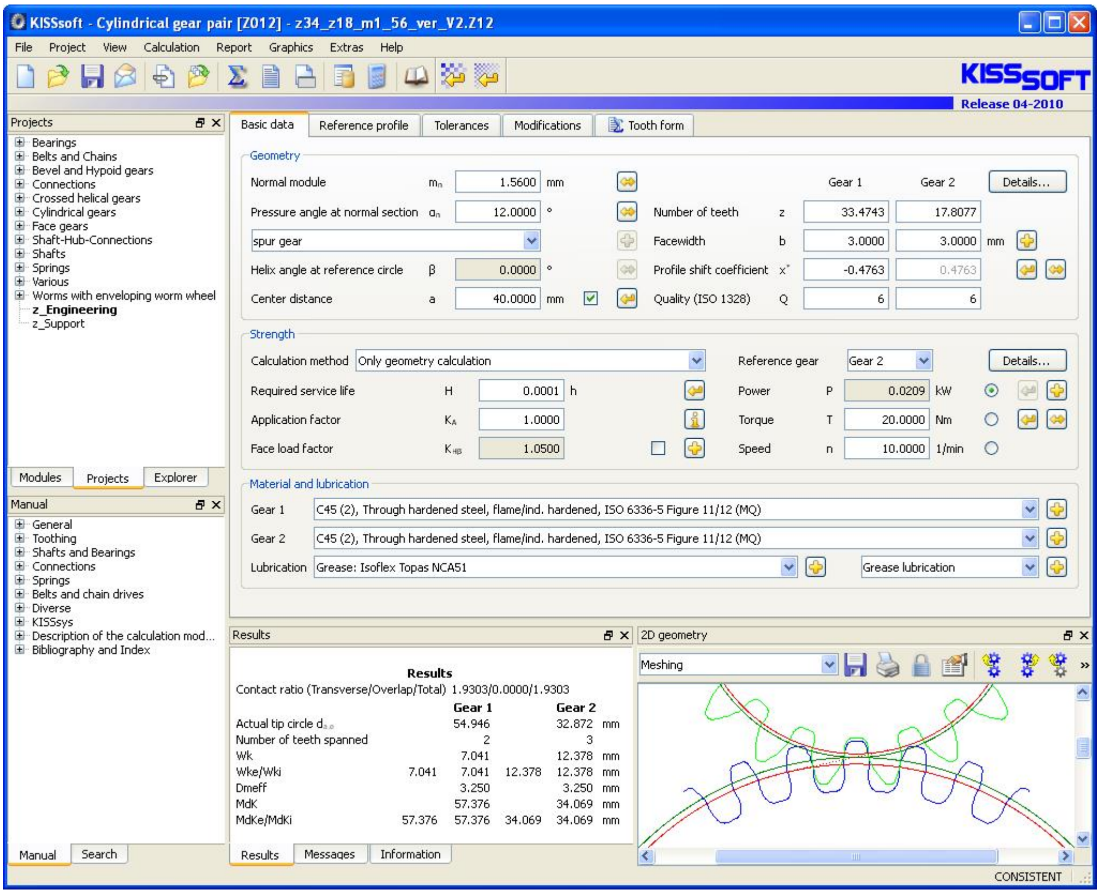

Figure 2.2-8: Resetting the calculation file parameters for the strength calculation.

We recommend you use the graphical method to achieve a more precise root strength analysis. This is especially useful if the tooth form has a deep undercut. It would therefore differ considerably from a standard tooth form. You will find this setting in the details button for strength calculation.

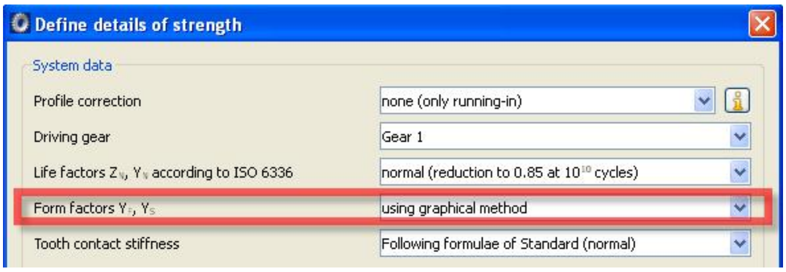

Figure 2.2-9: Setting for using the graphical calculation method.

The data you enter for the corresponding torque on gear 2 must be in accordance with the task at the operational point. In our example, the torque on gear 2 is constant. For a permanent load, the torque on gear 2 is 15.0 Nm. Static strength is calculated using a torque on gear 2 of 20.0 Nm. Furthermore, you must ensure that the number of load cycles has been fixed for both gears and the factor for alternating bending loads is specified as 0.7. This data is due to the fact that the mechanism does not perform a complete rotation. It merely oscillates. You must also input this data in the "Define details of strength" window in the "Gear data" area.

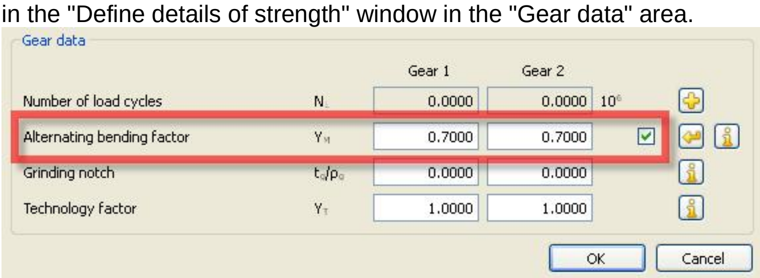

Figure 2.2-10: Setting for calculating changes in load direction and alternating bending loads.

Note: If, in another situation, the circumferential force at the operating point is specified, use the force and the lever arm (pitch circle radii) to determine the torque. To do this, click the conversion button to the right of the field in which you input the torque.

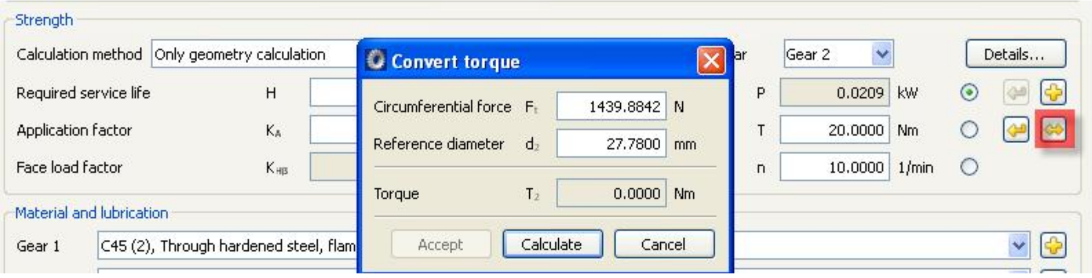

Figure 2.2-11: Conversion of circumferential force into torque.

2.3 Results

The strength calculation is performed using this data:

- Static (overload failure) with overload coupling 20 Nm at the input (the small gear is gear 2 here)
- Finite life calculation: 100,000 cycles; 15 Nm (drive), alternating bending load, approximately 10 rpm on gear 2
- Lubrication: TOPAS NCA 51/25
- the (load-bearing part) facewidth at the tooth root is assumed as 4 mm
- a 3 mm facewidth is calculated for pitting (reduced load-bearing width due to the manufacturing process – stamping).
-

material	static calculation				fatigue strength root			fatigue strength flank		
C45, through hardened		Gear 1	Gear 2			Gear 1	Gear 2		Gear 1	Gear 2
	Actual tip circle $d_{a,e}$	54.946	32.872	mm	Root safety	0.4954	0.8866	Flank safety	0.3828	0.3828
	Root safety R_m/σ_F	0.9324	2.0114							
	Root safety R_p/σ_F	0.6527	1.4080							
C45, surface head -/ induction-hardened	as aforementioned					Gear 1	Gear 2		Gear 1	Gear 2
					Root safety	0.7533	1.2742	Flank safety	0.8647	0.8647
C45, nitrided	as aforementioned					Gear 1	Gear 2		Gear 1	Gear 2
					Root safety	0.6595	1.0555	Flank safety	0.5759	0.5759
18CrNiMo7-6 through hardened		Gear 1	Gear 2			Gear 1	Gear 2		Gear 1	Gear 2
	Actual tip circle $d_{a,e}$	54.946	32.872	mm	Root safety	0.9615	1.5841	Flank safety	1.0632	1.0632
	Root safety R_m/σ_F	1.5985	3.4482							
	Root safety R_p/σ_F	1.1323	2.4425							

Table 2.3-1: Overview of calculation results with 3 different material qualities.

To ensure static safety, a safety level of 2 against fracture and a safety level of 1.5 against yield point must be achieved. Using material C, this can only achieved on the small gear (gear 2). In most cases, the flank safety is usually insufficient. This material (material C45) can only just achieve this value if its surface has been heat/induction hardened.
Better static strength values could be achieved by using 18CrNiMo7-6 (or a similar case-hardened steel). This also results in a significant improvement in the finite life calculation for the tooth root and the flank.

3 Other methods of approach (alternatives)

3.1 Perform the strength calculation using an exact tooth form

As an alternative to the procedure described in section 2.2 (tooth form definition by inputting the reference profile and profile shift) you can export the exact tooth form (half tooth) of the non-circular gear from the calculation for non-circular gears (*.Z40). You can then import it into the strength calculation for circular gear pairs (*.Z12). The procedure for exporting this data is described in the next section 3.2. You should not use this procedure for angular or nonsymmetrical non-circular gears. This is because the tooth form generated in the gear calculation [*.Z12] by the DXF data import will vary too much from the tooth form used in the non-circular gear calculation [*.Z40]. The teeth were slightly inclined (tilted) in the example described above, so therefore this method was not used.

3.2 Options for exporting individual tooth forms

The weakest tooth on gear 1 is tooth number 4. You can now export its data like this. Use a text editor to open the current KISSsoft calculation file (file type [Z40]. For example, you can use "Notepad" or "Workpad".

The **LEFT** flank of the x-th tooth space (therefore the 4th tooth if the “AusgabeKontur=4”) is always produced. The existing entry for the variable ZRnc[0].AusgabeKontur=0 for gear 1 is changed to ZRnc[0].AusgabeKontur=**4**. This change is then saved. The calculation file is now prepared for outputting only tooth number 4 from gear 1.

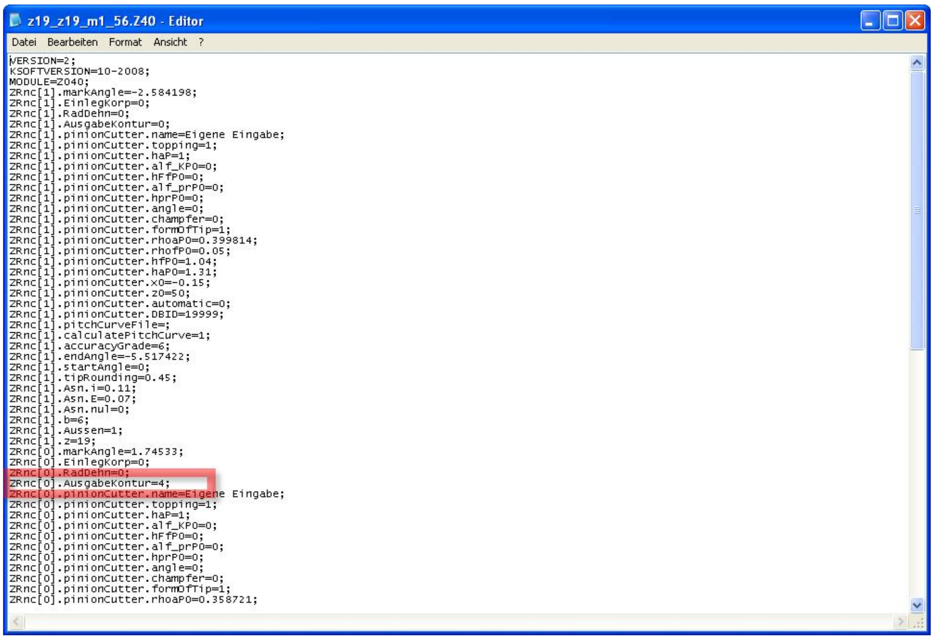

Figure 3.2-1: Changing the entry for variable "ZRnc[0].AusgabeKontur=0".

The KISSsoft file is then loaded again and the tooth form calculation is then performed. The graphic now shows only a half tooth of gear 1. This already has the correct alignment and position for the following import.

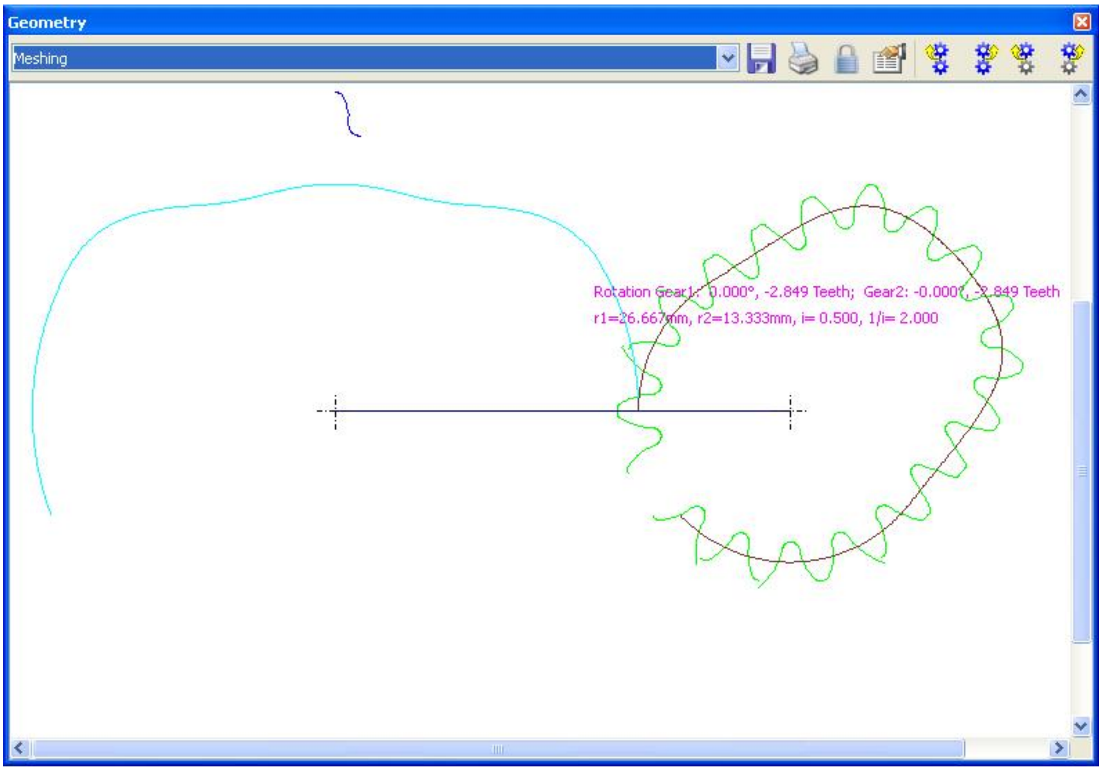

Figure 3.2-2: Effect of changing the entry for variable "ZRnc[0].AusgabeKontur=4".

The tooth form can then be saved in DXF format, as usual, in the display for gear 1.
This process also creates the temporary file ZF-UNRUND-DATHalf-1.TMP. This file contains information that will be required later on to generate the substitute intermeshing.

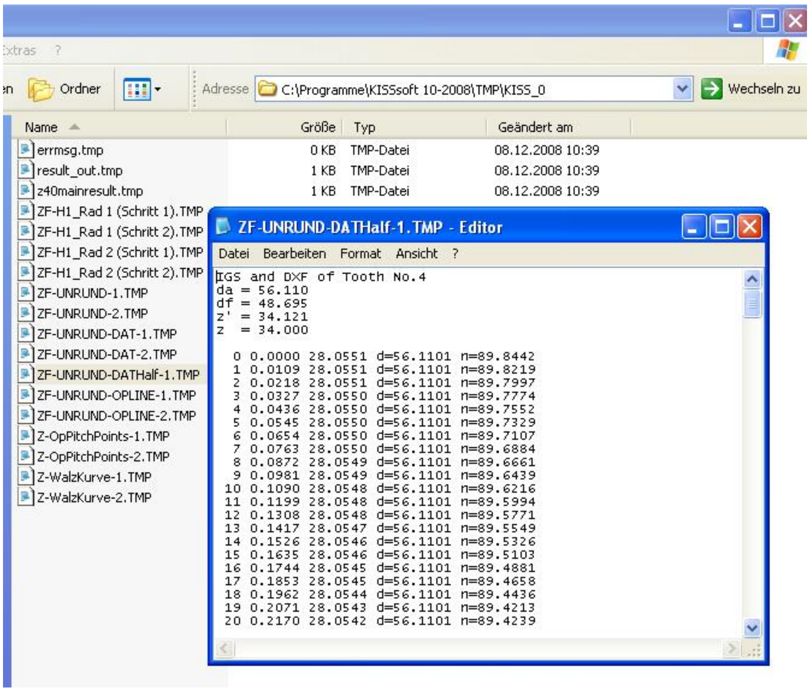

Figure 3.2-3: ZF-UNRUND-DATHalf-1.TMP.

You can also use the same method of approach for gear 2. In this case, you must input the required tooth in variable ZRnc[1].AusgabeKontur= ??? accordingly.
The tooth form, in DXF format, can be imported into a KISSsoft cylindrical gear calculation and then used for the strength calculation.

4 Appendices

4.1 Static strength

——————————————————————— KISSsoft - Release 04-2010
KISSsoft-Entwicklungs-Version   KISSsoft AG   CH-8634 HOMBRECHTIKON

———————————————————————————————— File
Name   : z34_z18_m1_56_ver_V2
Changed by : ho   on: 22.04.2010   at: 13:52:08

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

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

Calculation method Static calculation

		GEAR 1	GEAR 2
Power (W)	[P]	20.9440	
Speed (1/min)	[n]	5.3	10.0
Torque (Nm)	[T]	37.6	20.0
Application factor	[KA]	1.00	
Required service life	[H]	0.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(Geometry calculation according ISO 21771)

		GEAR 1	GEAR 2
Center distance (mm)	[a]	40.000	
Centre distance tolerance		No backlash	
Normal module (mm)	[mn]	1.5600	
Pressure angle at normal section (°)	[alfn]	12.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	33.4743	17.8077
Facewidth (mm)	[b]	3.00	3.00
Hand of gear		Spur gear	
Accuracy grade	[Q-ISO1328]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inside diameter of rim (mm)	[dbi]	0.00	0.00

Material
Gear 1:   C45 (2), Through hardened steel, flame/ind. hardened
          ISO 6336-5 Figure 11/12 (MQ)
Gear 2:   C45 (2), Through hardened steel, flame/ind. hardened
          ISO 6336-5 Figure 11/12 (MQ)

		GEAR 1	GEAR 2
Surface hardness		HRC 57	HRC 57
Fatigue strength. tooth root stress (N/mm^2)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm^2)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm^2)	[Rm]	700.00	700.00
Yield point (N/mm^2)	[Rp]	490.00	490.00
Young's modulus (N/mm^2)	[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]	10.00	20.00

Tool or reference profile of gear 1 :
Reference profile (Own input)

Addendum coefficient	[haP*]	1.350
Dedendum coefficient	[hfP*]	1.342
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 (Own input)

Addendum coefficient	[haP*]	1.156
Dedendum coefficient	[hfP*]	1.529
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

```
Sum of reference profile gears:
Dedendum reference profile (module)      [hfP*]              1.342               1.529
Tooth root radius Refer. profile (module)
                                         [rofP*]             0.300               0.300
Addendum Reference profile (module)      [haP*]              1.350               1.156
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:
                                                          No
Tip relief (µm)                          [Ca]              3.40                3.40

Lubrication type                                Grease lubrication
Type of  grease                                 Grease: Isoflex Topas NCA51
Lubricant base                                  Synthetic oil based on Polyalphaolefin
Kinem. viscosity  base oil at  40 °C (mm²/s)    [nu40]                  30.00
Kinem. viscosity  base oil at  100 °C (mm²/s)   [nu100]                  6.00
FZG-Test A/8.3/90  step                  [FZGtestA]                     10
Specific density at 15 °C (kg/dm³)       [roOil]                         0.870
Grease temperature (°C)                  [TS]                           70.000

                                                         ------- GEAR 1 -------- GEAR 2 --
Overall transmission ratio               [itot]                         -0.532
Gear ratio                               [u]                             1.880
Transverse module (mm)                   [mt]                            1.560
Pressure angle at Pitch circle (°)       [alft]                         12.000
Working transverse pressure angle (°)    [alfwt]                        12.000
                                         [alfwt.e/i]              12.000 / 12.000
Working pressure angle at normal section (°) [alfwn]                    12.000
Helix angle at operating pitch circle (°)
                                         [betaw]                         0.000
Base helix angle (°)                     [betab]                         0.000
Reference centre distance (mm)           [ad]                           40.000
Sum of profile shift coefficients        [Summexi]                       0.0000
Profile shift coefficient                [x]                 -0.4763              0.4763
Tooth thickness (Arc) (module)           [sn*]                1.3683              1.7733

Tip alteration (mm)                      [k]                 0.000               0.000
Reference diameter (mm)                  [d]                52.220              27.780
Base diameter (mm)                       [dB]               51.079              27.173
Tip diameter (mm)                        [da]               54.946              32.872
                     (mm)                [da.e/i]   54.946 / 54.946    32.872 / 32.872
Tip diameter allowances (mm)             [Ada.e/i]   0.000 /  0.000     0.000 /  0.000
Chamfer (1) / Tip rounding (2) / pointed tooth (3)           2                   2
Tip chamfer / tip rounding (mm)          [hK]                0.450               0.450
Tip form diameter (mm)                   [dFa]              54.328              32.442
                         (mm)            [dFa.e/i]  54.328 / 54.328    32.442 / 32.442
Operating pitch diameter (mm)            [dw]               52.220              27.780
                     (mm)                [dw.e/i]   52.220 / 52.220    27.780 / 27.780
Root diameter (mm)                       [df]               46.548              24.497
Generating Profile shift coefficient     [xE.e/i]   -0.4763 / -0.4763     0.4763 / 0.4763
Manufactured root diameter with xE (mm)  [df.e/i]   46.548 / 46.548    24.497 / 24.497
Theoretical tip clearance (mm)           [c]                 0.278               0.290
Effective tip clearance (mm)             [c.e/i]     0.278 /  0.278     0.290 /  0.290
Active root diameter (mm)                [dNf]               0.000               0.000
                     (mm)                [dNf.e/i]   0.000 /  0.000     0.000 /  0.000
 (Indication 0.0 is for dNf.e/i in case of contact interference)
Root form diameter (mm)                  [dFf]              51.079              27.173
                         (mm)            [dFf.e/i]  51.079 / 51.079    27.173 / 27.173
Addendum (mm)                            [ha]                1.363               2.546
         (mm)                            [ha.e/i]    1.363 /  1.363     2.546 /  2.546
Dedendum (mm)                            [hf]                2.836               1.642
         (mm)                            [hf.e/i]    2.836 /  2.836     1.642 /  1.642
Roll angle at dFa (°)                [xsi_dFa.e/i]  20.759 / 20.759    37.371 / 37.371
Roll angle to dNa (°)                [xsi_dNa.e/i]  20.759 / 20.759    37.371 / 37.371
Roll angle to dNf (°)                [xsi_dNf.e/i]   0.000 /  0.000     0.000 /  0.000
Roll angle at dFf (°)                [xsi_dFf.e/i]   0.036 /  0.036     0.049 /  0.049
Tooth height (mm)                        [H]                 4.199               4.188
Virtual gear  no. of teeth               [zn]               33.474              17.808
Normal Tooth thickness at Tip cyl. (mm)  [san]               1.373               0.645
                                 (mm)    [san.e/i]   1.373 /  1.373     0.645 /  0.645
 (without consideration of tip chamfer/ tip rounding)
Normal space width at tip cylinder (mm)  [efn]               0.000               0.000
                                   (mm)  [efn.e/i]   0.000 /  0.000     0.000 /  0.000
Max. sliding velocity at tip (m/s)       [vga]               0.006               0.009
Specific sliding at the tip              [zetaa]             1.190               1.000
Specific sliding at the root             [zetaf]         -9999.000               6.255
Sliding factor on tip                    [Kga]               0.422               0.599
Sliding factor on root                   [Kgf]              -0.599              -0.422
Pitch on reference circle (mm)           [pt]                            4.901
Base pitch (mm)                          [pbt]                           4.794
Transverse pitch on contact-path (mm)    [pet]                           4.794
Length of path of contact (mm)           [ga, e/i]                 9.253 ( 9.253 /  9.253)
Length T1-A, T2-A (mm)               [T1A, T2A]  0.000( 0.000/ 0.000)  8.316( 8.316/ 8.316)
Length T1-B (mm)                     [T1B, T2B]  4.459( 4.459/ 4.459)  3.857( 3.857/ 3.857)
Length T1-C (mm)                     [T1C, T2C]  5.429( 5.429/ 5.429)  2.888( 2.888/ 2.888)
Length T1-D (mm)                     [T1D, T2D]  4.794( 4.794/ 4.794)  3.523( 3.523/ 3.523)
Length T1-E (mm)                     [T1E, T2E]  9.253( 9.253/ 9.253) -0.937(-0.937/-0.937)
Length T1-T2 (mm)                    [T1T2]              8.316 ( 8.316 /  8.316)
Diameter of single contact point B (mm)
```

```
                                       [d-B]    51.852(51.852/51.852) 28.247(28.247/28.247)
Diameter of single contact point D (mm)
                                       [d-D]    51.971(51.971/51.971) 28.071(28.071/28.071)
Addendum contact ratio                  [eps]     0.798( 0.798/ 0.798)  1.132( 1.132/ 1.132)
Minimal length of contact line (mm)     [Lmin]                      3.000

Transverse contact ratio                [eps_a]                     1.930
Transverse contact ratio with allowances [eps_a.e/m/i]         1.930 / 1.930 / 1.930
Overlap ratio                           [eps_b]                     0.000
Total contact ratio                     [eps_g]                     1.930
Total contact ratio with allowances     [eps_g.e/m/i]         1.930 / 1.930 / 1.930
```

2. FACTORS OF GENERAL INFLUENCE

```
                                                ------- GEAR 1 -------- GEAR 2 --
Nominal circum. force at pitch circle (N)
                                        [Ft]                       1439.9
Axial force (N)                         [Fa]                          0.0
Radial force (N)                        [Fr]                        306.1
Normal force (N)                        [Fnorm]                    1472.1
Tangent.load at p.c.d.per mm (N/mm) (N/mm)
                                        [w]                        479.96
Only as information:  Forces at pitch circle:
Nominal circumferential force (N)       [Ftw]                      1439.9
Axial force (N)                         [Faw]                         0.0
Radial force (N)                        [Frw]                       306.1
Circumferential speed pitch d.. (m/sec)  [v]                          0.01


Dynamic factor                          [KV]                        1.000

Width factor -  flank                   [KHb]                       1.000
                 -  Tooth root          [KFb]                       1.000
                 -  Scuffing            [KBb]                       1.000

Transverse coefficient - flank          [KHa]                       1.000
                 -  Tooth root          [KFa]                       1.000
                 -  Scuffing            [KBa]                       1.000

Helix angle coefficient scuffing        [Kbg]                       1.000
```

3. TOOTH ROOT STRENGTH

```
                                                ------- GEAR 1 -------- GEAR 2 --
Calculation of Tooth form coefficients according method:  B
Calculation of tooth form coefficients with graphical method
(Determination of biggest value for YF * YS on the effective tooth shape)
Tooth form factor                       [YF]                3.25               1.50
Working angle (°)                       [alfen]             7.85               9.89
Force application diameter (mm)         [den]              51.97              28.25
Bending lever arm (mm)                  [hF]                2.25               1.54
Tooth thickness at root (mm)            [sFn]               2.56               3.10
Tooth root radius (mm)                  [roF]               0.98               0.61
(hF* = 1.441/0.985  sFn* = 1.641/1.989 roF* = 0.631/0.391 dsFn = 47.14/24.71 alfsFn =
35.17/47.13)

Contact ratio factor                    [Yeps]                       1.000
Helix angle factor                      [Ybet]                       1.000
Deep tooth factor                       [YDT]                        1.000
Gear rim factor                         [YB]                1.000              1.000
Effective facewidth (mm)                [beff]              3.00               3.00
Nominal shear stress at tooth root (N/mm²)
                                        [sigF0]          1000.33             462.96
Tooth root stress (N/mm²)               [sigF]           1000.33             462.96

Calculation formulae:
                    sigF0 = Ft / beff / mn * YF * Yeps * Ybeta * YB * YDT
                    sigF  = sigF0 * KA * KV * KFa * KFb
                    YF, YS, YB, YDT : ISO6336-3

Yield point (N/mm²)                     [Rp]              490.00             490.00
Tensile strength (N/mm²)                [Rm]              700.00             700.00
Safety against plastic deformation      [Ss=Rp/sigF]        0.49               1.06
Safety for tensile stress               [Sb=Rm/sigF]        0.70               1.51

Extensions for aerospace industry:
Calculation formula:
                   sigF0 = Ft / beff / mn * YF * YS * Yeps * Ybeta * YB * YDT
Stress correction factor                [YS]                1.46               2.18
Tooth root stress (N/mm²)               [sigF]           1462.66            1007.48
Safety against plastic deformation      [Ss=Rp/sigF]        0.34               0.49
Safety for tensile stress               [Sb=Rm/sigF]        0.48               0.69
```

6. MEASUREMENTS FOR TOOTH THICKNESS

```
                                                ------- GEAR 1 -------- GEAR 2 --
Tooth thickness deviation                            No backlash       No backlash
Tooth thickness allowance (normal section) (mm)
                                        [As.e/i]        0.000 / 0.000     0.000 / 0.000
```

Number of teeth spanned	[k]	2.000	3.000
Base tangent length (no backlash) (mm)	[Wk]	7.041	12.378
Actual base tangent length ('span') (mm)	[Wk.e/i]	7.041 / 7.041	12.378 / 12.378
Diameter of contact point (mm)	[dMWk.m]	51.562	29.859
Theoretical diameter of ball/pin (mm)	[DM]	3.044	3.061
Eff. Diameter of ball/pin (mm)	[DMeff]	3.250	3.250
Theor. dim. centre to ball (mm)	[MrK]	28.718	17.095
Actual dimension centre to ball (mm)	[MrK.e/i]	28.718 / 28.718	17.095 / 17.095
Diameter of contact point (mm)	[dMMr.m]	53.189	29.524
Diametral measurement over two balls without clearance (mm)	[MdK]	57.376	34.069
Actual dimension over balls (mm)	[MdK.e/i]	57.376 / 57.376	34.069 / 34.069
Theor. dimension over two pins (mm)	[MdR]	57.376	34.069
Actual dimension over rolls (mm)	[MdR.e/i]	57.376 / 57.376	34.069 / 34.069
Dimensions over 3 pins without clearance (mm)	[Md3R]	57.316	33.949
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	57.316 / 57.316	33.949 / 33.949
Chordal tooth thickness (no backlash) (mm)	['sn]	2.134	2.762
Actual chordal tooth thickness (mm)	['sn.e/i]	2.134 / 2.134	2.762 / 2.762
Reference chordal height from da.m (mm)	[ha]	1.385	2.615
Tooth thickness (Arc) (mm)	[sn]	2.135	2.766
(mm)	[sn.e/i]	2.135 / 2.135	2.766 / 2.766

Backlash free center distance (mm)	[aControl.e/i]	40.000 / 40.000
Backlash free center distance, allowances (mm)	[jta]	0.000 / 0.000
Centre distance allowances (mm)	[Aa.e/i]	0.000 / 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.000 / 0.000
Radial clearance (mm)	[jr]	0.000 / 0.000
Circumferential backlash (transverse section) (mm)	[jt]	0.000 / 0.000
Torsional angle using fixed values gear 1 (°)		0.0000 /0.0000
Normal backlash (mm)	[jn]	0.000 / 0.000

7. TOLERANCES

		------- GEAR 1	-------- GEAR 2 --
According ISO 1328:			
Accuracy grade	[Q-ISO1328]	6	6
Single normal pitch deviation (µm)	[fpt]	7.50	7.00
Base circle pitch deviation (µm)	[fpb]	7.50	7.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	12.00	9.50
Profile deviation (µm)	[ffa]	6.50	5.50
Profile angular deviation (µm)	[fHa]	5.50	4.60
Profile total deviation (µm)	[Fa]	8.50	7.50
Helix form deviation (µm)	[ffb]	6.00	6.00
Helix slope deviation (µm)	[fHb]	6.00	6.00
Tooth helix deviation (µm)	[Fb]	8.50	8.50
Total cumulative pitch deviation (µm)	[Fp]	26.00	20.00
Runout tolerance (µm)	[Fr]	21.00	16.00
Total radial composite tolerance (µm)	[Fi"]	31.00	26.00
Tooth-to-tooth radial composite tolerance (µm)	[fi"]	9.50	9.50
Total tangential composite deviation (µm)	[Fi']	40.00	33.00
Tooth-to-tooth tangential composite deviation (µm)	[fi']	13.00	13.00

Tolerance for alignment of axes (recommendation acc. ISO/TR 10064, Quality 6)

Maximum value for deviation error of axis (µm)	[fSigbet]	8.50
Maximum value for inclination error of axes (µm)	[fSigdel]	17.01

9. DETERMINATION OF TOOTHFORM

Calculation of Gear 1

Gear 1 (Step 1): Automatically (Tool: Hobbing cutter)
haP*= 1.350, hfP*= 1.342, rofP*= 0.300
Gear 1 (Step 2): Automatically (tip chamfer/rounding) (Tool: Hobbing cutter)
r= 0.450 mm, in transverse section

Calculation of Gear 2

Gear 2 (Step 1): Automatically (Tool: Hobbing cutter)
haP*= 1.156, hfP*= 1.529, rofP*= 0.300
Gear 2 (Step 2): Automatically (tip chamfer/rounding) (Tool: Hobbing cutter)
r= 0.450 mm, in transverse section

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..

End report                                                    lines:  363
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4.2 Example endurance limit (flank)

```
———————————————————————— KISSsoft - Release 04-2010
KISSsoft-Entwicklungs-Version       KISSsoft AG      CH-8634 HOMBRECHTIKON

——————————————————————————————————— File
Name        : z34_z18_m1_56_ver_V2
Changed by : ho          on: 22.04.2010          at: 13:53:43
```

CALCULATION OF A CYLINDRICAL SPUR 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 (W)                                 [P]                        20.9440
Speed (1/min)                             [n]                 5.3                   10.0
Torque (Nm)                               [T]                37.6                   20.0
Application factor                        [KA]                          1.00
Required service life                     [H]                           0.00
Gear driving (+) / driven (-)                              +                    -
```

1. TOOTH GEOMETRY AND MATERIAL

```
   (Geometry calculation according ISO 21771)
                                                       ------- GEAR 1 -------- GEAR 2 --
Center distance (mm)                      [a]                          40.000
Centre distance tolerance                                               No backlash
Normal module (mm)                        [mn]                         1.5600
Pressure angle at normal section (°)      [alfn]                      12.0000
Helix angle at reference circle (°)       [beta]                       0.0000
Number of teeth                           [z]               33.4743               17.8077
Facewidth (mm)                            [b]                  3.00                  3.00
Hand of gear                                                 Spur gear
Accuracy grade                            [Q-ISO1328]            6                     6
Inner diameter (mm)                       [di]                 0.00                  0.00
Inside diameter of rim (mm)               [dbi]                0.00                  0.00

Material
Gear 1:                   C45 (2), Through hardened steel, flame/ind. hardened
                          ISO 6336-5 Figure 11/12 (MQ)
Gear 2:                   C45 (2), Through hardened steel, flame/ind. hardened
                          ISO 6336-5 Figure 11/12 (MQ)

                                                       ------- GEAR 1 -------- GEAR 2 --
Surface hardness                                            HRC 57                HRC 57
Material treatment according to ISO6336:  Normal (Life factors ZNT and YNT >=0.85)
Fatigue strength. tooth root stress (N/mm²)
                                          [sigFlim]          370.00                370.00
Fatigue strength for Hertzian pressure (N/mm²)
                                          [sigHlim]         1220.00               1220.00
Tensile strength (N/mm²)                  [Rm]               700.00                700.00
Yield point (N/mm²)                       [Rp]               490.00                490.00
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]               10.00                 20.00

Tool or reference profile of gear  1 :
Reference profile (Own input)
Addendum coefficient                          [haP*]                    1.350
Dedendum coefficient                          [hfP*]                    1.342
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 (Own input)
Addendum coefficient                          [haP*]                    1.156
```

Dedendum coefficient	[hfP*]	1.529
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

Sum of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.342	1.529
Tooth root radius Refer. profile (module)	[rofP*]	0.300	0.300
Addendum Reference profile (module)	[haP*]	1.350	1.156
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:

		No	
Tip relief (µm)	[Ca]	3.40	3.40

Lubrication type		Grease lubrication
Type of grease		Grease: Isoflex Topas NCA51
Lubricant base		Synthetic oil based on Polyalphaolefin
Kinem. viscosity base oil at 40 °C (mm²/s)	[nu40]	30.00
Kinem. viscosity base oil at 100 °C (mm²/s)	[nu100]	6.00
FZG-Test A/8.3/90 step	[FZGtestA]	10
Specific density at 15 °C (kg/dm³)	[roOil]	0.870
Grease temperature (°C)	[TS]	70.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-0.532	
Gear ratio	[u]	1.880	
Transverse module (mm)	[mt]	1.560	
Pressure angle at Pitch circle (°)	[alft]	12.000	
Working transverse pressure angle (°)	[alfwt]	12.000	
	[alfwt.e/i]	12.000 / 12.000	
Working pressure angle at normal section (°)	[alfwn]	12.000	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference centre distance (mm)	[ad]	40.000	
Sum of profile shift coefficients	[Summexi]	0.0000	
Profile shift coefficient	[x]	-0.4763	0.4763
Tooth thickness (Arc) (module)	[sn*]	1.3683	1.7733
Tip alteration (mm)	[k]	0.000	0.000
Reference diameter (mm)	[d]	52.220	27.780
Base diameter (mm)	[dB]	51.079	27.173
Tip diameter (mm)	[da]	54.946	32.872
(mm)	[da.e/i]	54.946 / 54.946	32.872 / 32.872
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / 0.000	0.000 / 0.000
Chamfer (1) / Tip rounding (2) / pointed tooth (3)		2	2
Tip chamfer / tip rounding (mm)	[hK]	0.450	0.450
Tip form diameter (mm)	[dFa]	54.328	32.442
(mm)	[dFa.e/i]	54.328 / 54.328	32.442 / 32.442
Operating pitch diameter (mm)	[dw]	52.220	27.780
(mm)	[dw.e/i]	52.220 / 52.220	27.780 / 27.780
Root diameter (mm)	[df]	46.548	24.497
Generating Profile shift coefficient	[xE.e/i]	-0.4763 / -0.4763	0.4763 / 0.4763
Manufactured root diameter with xE (mm)	[df.e/i]	46.548 / 46.548	24.497 / 24.497
Theoretical tip clearance (mm)	[c]	0.278	0.290
Effective tip clearance (mm)	[c.e/i]	0.278 / 0.278	0.290 / 0.290
Active root diameter (mm)	[dNf]	0.000	0.000
(mm)	[dNf.e/i]	0.000 / 0.000	0.000 / 0.000
(Indication 0.0 is for dNf.e/i in case of contact interference)			
Root form diameter (mm)	[dFf]	51.079	27.173
(mm)	[dFf.e/i]	51.079 / 51.079	27.173 / 27.173
Addendum (mm)	[ha]	1.363	2.546
(mm)	[ha.e/i]	1.363 / 1.363	2.546 / 2.546
Dedendum (mm)	[hf]	2.836	1.642
(mm)	[hf.e/i]	2.836 / 2.836	1.642 / 1.642
Roll angle at dFa (°)	[xsi_dFa.e/i]	20.759 / 20.759	37.371 / 37.371
Roll angle to dNa (°)	[xsi_dNa.e/i]	20.759 / 20.759	37.371 / 37.371
Roll angle to dNf (°)	[xsi_dNf.e/i]	0.000 / 0.000	0.000 / 0.000
Roll angle at dFf (°)	[xsi_dFf.e/i]	0.036 / 0.036	0.049 / 0.049
Tooth height (mm)	[H]	4.199	4.188
Virtual gear no. of teeth	[zn]	33.474	17.808
Normal Tooth thickness at Tip cyl. (mm)	[san]	1.373	0.645
(mm)	[san.e/i]	1.373 / 1.373	0.645 / 0.645
(without consideration of tip chamfer/ tip rounding)			
Normal space width at tip cylinder (mm)	[efn]	0.000	0.000
(mm)	[efn.e/i]	0.000 / 0.000	0.000 / 0.000
Max. sliding velocity at tip (m/s)	[vga]	0.006	0.009
Specific sliding at the tip	[zetaa]	1.190	1.000
Specific sliding at the root	[zetaf]	-9999.000	6.255
Sliding factor on tip	[Kga]	0.422	0.599
Sliding factor on root	[Kgf]	-0.599	-0.422
Pitch on reference circle (mm)	[pt]	4.901	
Base pitch (mm)	[pbt]	4.794	
Transverse pitch on contact-path (mm)	[pet]	4.794	

```
Length of path of contact (mm)          [ga, e/i]              9.253 ( 9.253 /  9.253)
Length T1-A, T2-A (mm)              [T1A, T2A]  0.000( 0.000/ 0.000)  8.316( 8.316/ 8.316)
Length T1-B (mm)                    [T1B, T2B]  4.459( 4.459/ 4.459)  3.857( 3.857/ 3.857)
Length T1-C (mm)                    [T1C, T2C]  5.429( 5.429/ 5.429)  2.888( 2.888/ 2.888)
Length T1-D (mm)                    [T1D, T2D]  4.794( 4.794/ 4.794)  3.523( 3.523/ 3.523)
Length T1-E (mm)                    [T1E, T2E]  9.253( 9.253/ 9.253) -0.937(-0.937/-0.937)
Length T1-T2 (mm)                   [T1T2]                 8.316 ( 8.316 /  8.316)
Diameter of single contact point B (mm)
                                      [d-B]    51.852(51.852/51.852) 28.247(28.247/28.247)
Diameter of single contact point D (mm)
                                      [d-D]    51.971(51.971/51.971) 28.071(28.071/28.071)
Addendum contact ratio                  [eps]     0.798( 0.798/ 0.798)  1.132( 1.132/ 1.132)
Minimal length of contact line (mm)     [Lmin]                        3.000

Transverse contact ratio                [eps_a]                       1.930
Transverse contact ratio with allowances [eps_a.e/m/i]        1.930 / 1.930 / 1.930
Overlap ratio                           [eps_b]                       0.000
Total contact ratio                     [eps_g]                       1.930
Total contact ratio with allowances     [eps_g.e/m/i]         1.930 / 1.930 / 1.930
```

2. FACTORS OF GENERAL INFLUENCE

```
                                                      ------- GEAR 1 -------- GEAR 2 --
Nominal circum. force at pitch circle (N)
                                        [Ft]                         1439.9
Axial force (N)                         [Fa]                            0.0
Radial force (N)                        [Fr]                          306.1
Normal force (N)                        [Fnorm]                      1472.1
Tangent.load at p.c.d.per mm (N/mm) (N/mm)
                                        [w]                          479.96
Only as information:  Forces at pitch circle:
Nominal circumferential force (N)       [Ftw]                        1439.9
Axial force (N)                         [Faw]                           0.0
Radial force (N)                        [Frw]                         306.1
Circumferential speed pitch d.. (m/sec)  [v]                           0.01

Running-in value (µm)                   [yp]                           0.6
Running-in value (µm)                   [yf]                           0.5
Correction coefficient                  [CM]                           0.800
Gear body coefficient                   [CR]                           1.000
Reference profile coefficient           [CBS]                          0.741
Material coefficient                    [E/Est]                        1.000
Singular tooth stiffness (N/mm/µm)      [c']                           9.339
Meshing stiffness (N/mm/µm)             [cgalf]                       15.855
Meshing stiffness (N/mm/µm)             [cgbet]                       13.477
Reduced mass (kg/mm)                    [mRed]                         0.00207
Resonance speed (min-1)                 [nE1]                         24955
Nominal speed (-)                       [N]                           0.000
 Subcritical range
Running-in value (µm)                   [ya]                          0.6
Bearing distance l of pinion shaft (mm)  [l]                           6.000
Distance s        of pinion shaft (mm)   [s]                           0.600
Outside diameter of pinion shaft (mm)    [dsh]                         3.000
load according ISO 6336/1 Diagram 16     [-]                               4
 0:a), 1:b), 2:c), 3:d), 4:e)
coefficient K' following ISO 6336/1 Diagram 13
                                        [K']                         -1.00
Without support effect
Tooth trace deviation (active) (µm)     [Fby]                         2.55
 from deformation of shaft (µm)         [fsh*B1]                      4.36
 Tooth without tooth trace correction
 Position of Contact pattern: favorable
 from production tolerances (µm)        [fma*B2]                      8.49
 Tooth trace deviation, theoretical (µm)   [Fbx]                      3.00
 Running-in value (µm)                  [yb]                          0.4

Dynamic factor                          [KV]                          1.000

Width factor -  flank                   [KHb]                         1.050
                -  Tooth root           [KFb]                         1.034
                -  Scuffing             [KBb]                         1.050

Transverse coefficient - flank          [KHa]                         1.000
                -  Tooth root           [KFa]                         1.000
                -  Scuffing             [KBa]                         1.000

Helix angle coefficient scuffing        [Kbg]                         1.000

Number of load changes (in mio.)        [NL]                0.100               0.100
```

3. TOOTH ROOT STRENGTH

```
                                                      ------- GEAR 1 -------- GEAR 2 --
Calculation of Tooth form coefficients according method:  B
Calculation of tooth form coefficients with graphical method
(Determination of biggest value for YF * YS on the effective tooth shape)
Tooth form factor                       [YF]                3.25                1.50
Stress correction factor                [YS]                1.46                2.18
Working angle (°)                       [alfen]             7.85                9.89
Force application diameter (mm)         [den]              51.97               28.25
Bending lever arm (mm)                  [hF]                2.25                1.54
Tooth thickness at root (mm)            [sFn]               2.56                3.10
```

```
Tooth root radius (mm)                  [roF]               0.98                0.61
(hF* = 1.441/0.985  sFn* = 1.641/1.989 roF* = 0.631/0.391 dsFn = 47.14/24.71 alfsFn =
35.17/47.13)

Contact ratio factor                    [Yeps]                        1.000
Helix angle factor                      [Ybet]                        1.000
Deep tooth factor                       [YDT]                         1.000
Gear rim factor                         [YB]                1.000               1.000
Effective facewidth (mm)                [beff]              3.00                3.00
Nominal shear stress at tooth root (N/mm²)
                                        [sigF0]          1462.66             1007.48
Tooth root stress (N/mm²)               [sigF]           1513.01             1042.16

Permissible bending stress at root of Test-gear
Support factor                          [YdrelT]           0.885               1.032
Surface factor                          [YRrelT]           1.001               0.975
Size coefficient (Tooth root)           [YX]               1.000               1.000
Finite life factor                      [YNT]              1.476               1.476
                        [YdrelT*YRrelT*YX*YNT]             1.307               1.486
Alternating bending coefficient         [YM]               0.700               0.700
Stress correction factor                [Yst]                         2.00
Limit strength tooth root (N/mm²)       [sigFG]           677.28              769.50
Permissible tooth root stress (N/mm²)
                                    [sigFP=sigFG/SFmin]   516.22              586.51
Required safety                         [SFmin]             1.31                1.31
Safety for Tooth root stress            [SF=sigFG/sigF]     0.45                0.74
Transmittable power (W)                 [kWRating]          7.15               11.79
```

4. SAFETY AGAINST PITTING (TOOTH FLANK)

```
                                                   ------- GEAR 1 -------- GEAR 2 --
Zone factor                             [ZH]                          3.136
Elasticity coefficient (N^.5/mm)        [ZE]                        189.812
Contact ratio factor                    [Zeps]                        0.831
Helix angle factor                      [Zbet]                        1.000
Effective facewidth (mm)                [beff]                        3.00
Nominal flank pressure (N/mm²)          [sigH0]                     2543.65
Surface pressure at Operating pitch circle (N/mm²)
                                        [sigHw]                     2606.55
Single tooth contact factor             [ZB,ZD]             1.00                1.00
Flank pressure (N/mm²)                  [sigH]           2606.55             2606.55

Lubrication factor                      [ZL]               1.000               1.000
Speed factor                            [ZV]               1.000               1.000
Roughness factor                        [ZR]               1.000               1.000
Material mating factor                  [ZW]               1.000               1.000
Finite life factor                      [ZNT]              1.600               1.600
                                [ZL*ZV*ZR*ZNT]             1.600               1.600
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]          1952.00             1952.00
Permissible surface pressure (N/mm²) [sigHP=sigHG/SHmin] 2041.84             2041.84

Safety for surface pressure at pitch circle
                                        [SHw]               0.75                0.75
Required safety                         [SHmin]             0.96                0.96
Transmittable power (W)                 [kWRating]         12.85               12.85
Safety for stress at single tooth contact
                                        [SHBD=sigHG/sigH]   0.75                0.75
(Safety regarding nominal torque)       [(SHBD)^2]          0.56                0.56
```

6. MEASUREMENTS FOR TOOTH THICKNESS

```
                                                   ------- GEAR 1 -------- GEAR 2 --
Tooth thickness deviation                              No backlash       No backlash
Tooth thickness allowance (normal section) (mm)
                                        [As.e/i]      0.000 / 0.000     0.000 / 0.000

Number of teeth spanned                 [k]                2.000               3.000
Base tangent length (no backlash) (mm)  [Wk]               7.041              12.378
Actual base tangent length ('span') (mm) [Wk.e/i]     7.041 / 7.041     12.378 / 12.378
Diameter of contact point (mm)          [dMWk.m]          51.562              29.859

Theoretical diameter of ball/pin (mm)   [DM]               3.044               3.061
Eff. Diameter of ball/pin (mm)          [DMeff]            3.250               3.250
Theor. dim. centre to ball (mm)         [MrK]             28.718              17.095
Actual dimension centre to ball (mm)    [MrK.e/i]     28.718 / 28.718    17.095 / 17.095
Diameter of contact point (mm)          [dMMr.m]          53.189              29.524
Diametral measurement over two balls without clearance (mm)
                                        [MdK]             57.376              34.069
Actual dimension over balls (mm)        [MdK.e/i]     57.376 / 57.376    34.069 / 34.069
Theor. dimension over two pins (mm)     [MdR]             57.376              34.069
Actual dimension over rolls (mm)        [MdR.e/i]     57.376 / 57.376    34.069 / 34.069
Dimensions over 3 pins without clearance (mm)
                                        [Md3R]            57.316              33.949
Actual dimensions over 3 rolls (mm)     [Md3R.e/i]    57.316 / 57.316    33.949 / 33.949

Chordal tooth thickness (no backlash) (mm)
                                        ['sn]              2.134               2.762
Actual chordal tooth thickness (mm)     ['sn.e/i]     2.134 / 2.134      2.762 / 2.762
Reference chordal height from da.m (mm) [ha]               1.385               2.615
Tooth thickness (Arc) (mm)              [sn]               2.135               2.766
```

(mm)	[sn.e/i]	2.135 / 2.135	2.766 / 2.766

Backlash free center distance (mm)	[aControl.e/i]	40.000 / 40.000	
Backlash free center distance, allowances (mm)	[jta]	0.000 / 0.000	
Centre distance allowances (mm)	[Aa.e/i]	0.000 / 0.000	
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.000 / 0.000	
Radial clearance (mm)	[jr]	0.000 / 0.000	
Circumferential backlash (transverse section) (mm)	[jt]	0.000 / 0.000	
Torsional angle using fixed values gear 1 (°)		0.0000 /0.0000	
Normal backlash (mm)	[jn]	0.000 / 0.000	

7. TOLERANCES

		------- GEAR 1	-------- GEAR 2 --
According ISO 1328:			
Accuracy grade	[Q-ISO1328]	6	6
Single normal pitch deviation (μm)	[fpt]	7.50	7.00
Base circle pitch deviation (μm)	[fpb]	7.50	7.00
Cumulative circular pitch deviation over z/8 pitches (μm)	[Fpz/8]	12.00	9.50
Profile deviation (μm)	[ffa]	6.50	5.50
Profile angular deviation (μm)	[fHa]	5.50	4.60
Profile total deviation (μm)	[Fa]	8.50	7.50
Helix form deviation (μm)	[ffb]	6.00	6.00
Helix slope deviation (μm)	[fHb]	6.00	6.00
Tooth helix deviation (μm)	[Fb]	8.50	8.50
Total cumulative pitch deviation (μm)	[Fp]	26.00	20.00
Runout tolerance (μm)	[Fr]	21.00	16.00
Total radial composite tolerance (μm)	[Fi"]	31.00	26.00
Tooth-to-tooth radial composite tolerance (μm)	[fi"]	9.50	9.50
Total tangential composite deviation (μm)	[Fi']	40.00	33.00
Tooth-to-tooth tangential composite deviation (μm)	[fi']	13.00	13.00

Tolerance for alignment of axes (recommendation acc. ISO/TR 10064, Quality 6)

Maximum value for deviation error of axis (μm)	[fSigbet]	8.50
Maximum value for inclination error of axes (μm)	[fSigdel]	17.01

8. ADDITIONAL DATA

Maximal possible centre distance (eps_a=1.0)	[aMAX]	41.331	
Torsional stiffness (MNm/rad)	[cr]	0.0	0.0
Mean coeff. of friction (acc. Niemann)	[mum]	0.200	
Wear sliding coef. by Niemann	[zetw]	2.146	
Power loss from gear load (W)	[PVZ]	1.119	
(Meshing efficiency (%)	[etaz]	94.656)	
Weight - calculated with da (g)	[Mass]	55.70	19.94

Moment of inertia (System referenced to wheel 1):
calculation without consideration of the exact tooth shape

single gears ((da+df)/2...di) (kgm²)	[TraeghMom]	1.529e-005	1.561e-006
System ((da+df)/2...di) (kgm²)	[TraeghMom]	2.081e-005	

9. DETERMINATION OF TOOTHFORM

Calculation of Gear 1
Gear 1 (Step 1): Automatically (Tool: Hobbing cutter)
haP*= 1.350, hfP*= 1.342, rofP*= 0.300
Gear 1 (Step 2): Automatically (tip chamfer/rounding) (Tool: Hobbing cutter)
r= 0.450 mm, in transverse section

Calculation of Gear 2
Gear 2 (Step 1): Automatically (Tool: Hobbing cutter)
haP*= 1.156, hfP*= 1.529, rofP*= 0.300
Gear 2 (Step 2): Automatically (tip chamfer/rounding) (Tool: Hobbing cutter)
r= 0.450 mm, in transverse section

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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