KISSsoft

Drivetrain Design Solutions

KISSsoft 03/2018 – Tutorial 8

Verifying a cylindrical gear pair

KISSsoft AG
A Gleason Company
Rosengartenstr. 4, 8608 Bubikon
Switzerland

T. +41 55 254 20 50
F. +41 55 254 20 51
info@KISSsoft.AG
www.KISSsoft.AG

Sharing Knowledge

Contents

1 Task

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

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

- Input the necessary data in KISSsoft
- Analyze it according to ISO 6336
- Document the results

1.1 Input data

The data below are to input in KISSsoft while the explanation for entering the data is described from section 2 in this tutorial:

1.1.1 Power data

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

1.1.2 Geometry

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

1.1.3 Reference profile

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

1.1.4 Additional data

Material:

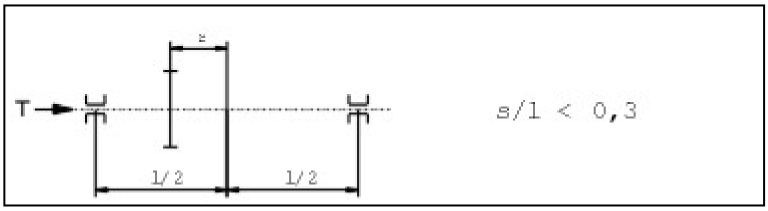
	Material	Hardness data	σFlim	σHlim
Gear 1 (pinion)	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2
Gear 2	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2

Lubrication:

Grease lubrication	Microlube GB 00	80 °C

Base tangent length allowances:

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

Quality [Q] (DIN 3961)	8 / 8
Tooth trace modification	End relief
Contact pattern	not verified or inappropriate
Type of pinion shaft	 Load case for the pinion shaft ISO 6336 Figure 13a; l = 53 mm; s = 5.9 mm; dsh = 14 mm

2 Solution

2.1 Starting the software

You can call KISSsoft as soon as the software has been installed and activated. Usually you start the program by clicking «Start→Program Files→KISSsoft 03-2018→KISSsoft 03-2018». This opens the following KISSsoft user interface:

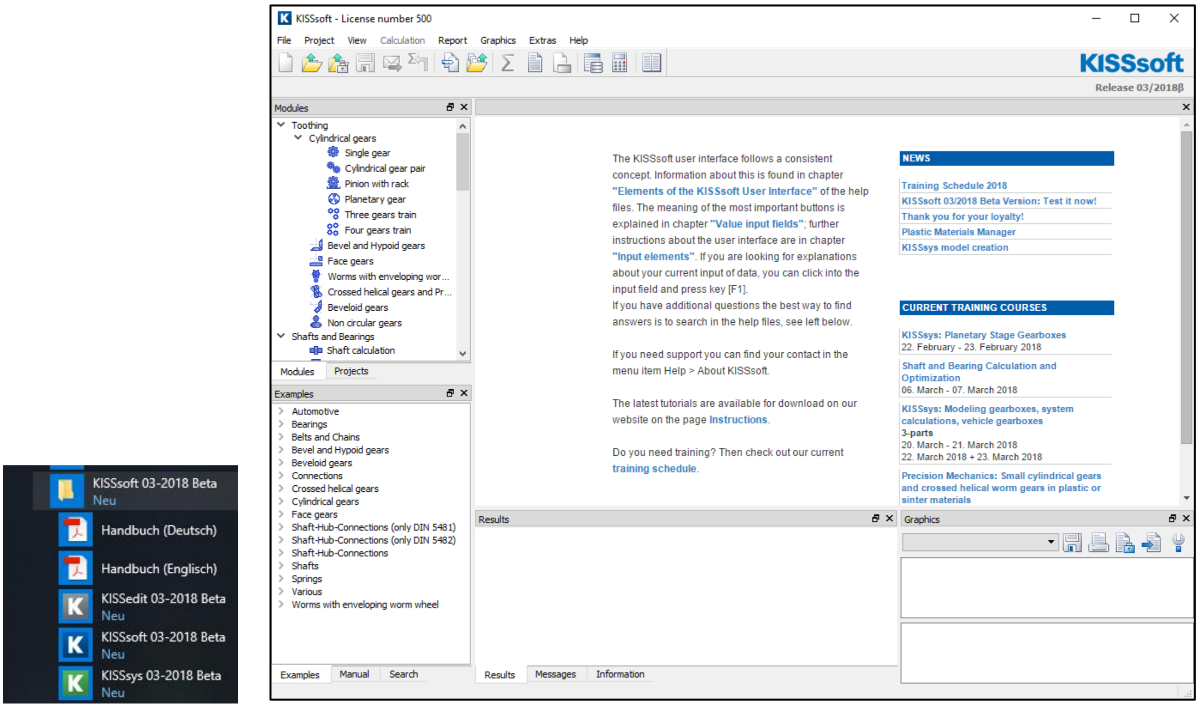


Figure 1. Starting KISSsoft, initial window

2.2 Selecting a calculation

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

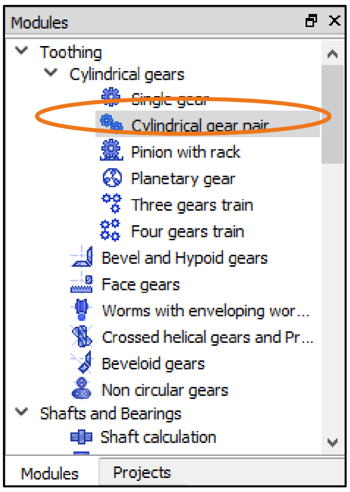


Figure 2. Calling the cylindrical gear calculation

The KISSsoft input window then opens:

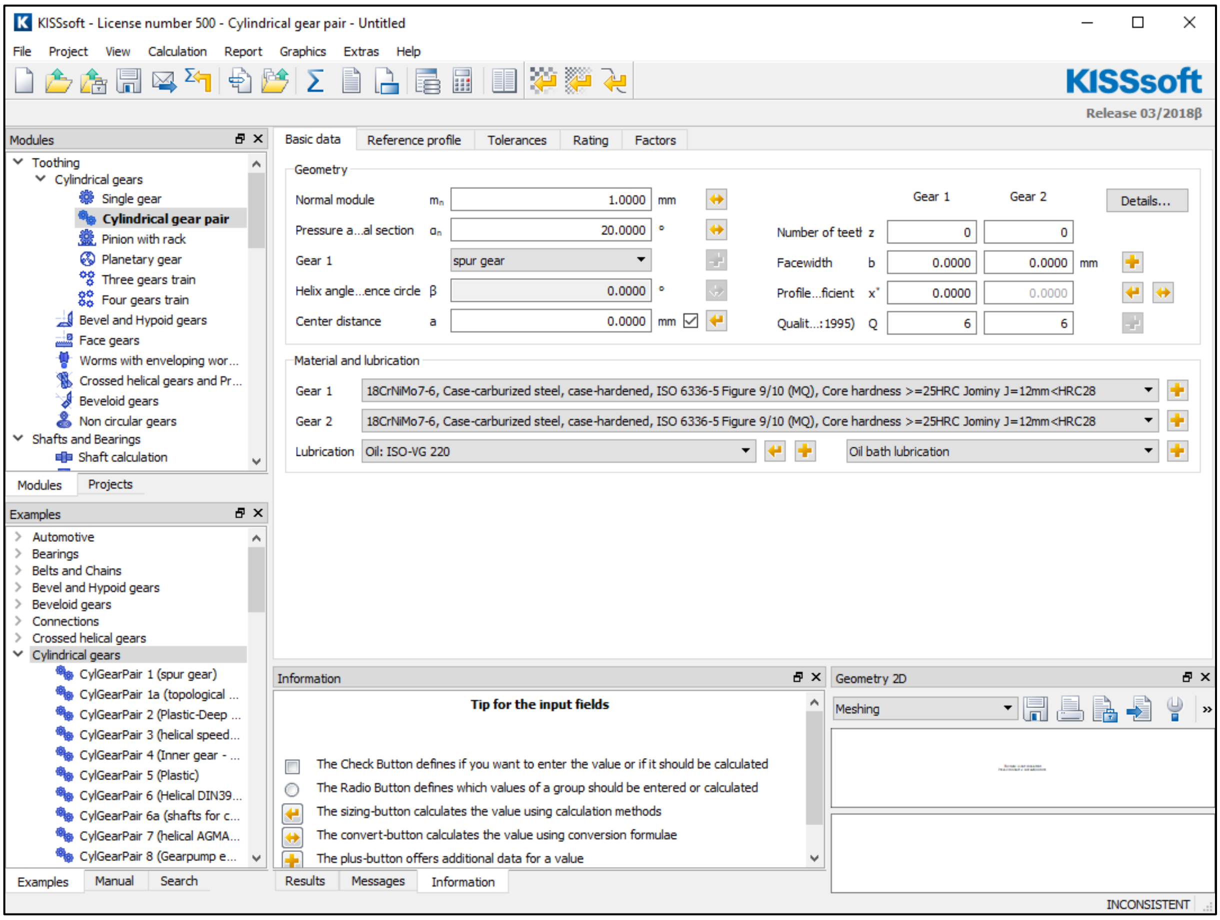


Figure 3. KISSsoft Cylindrical gear calculation input window

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

2.3 Gear Pair Geometry

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

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

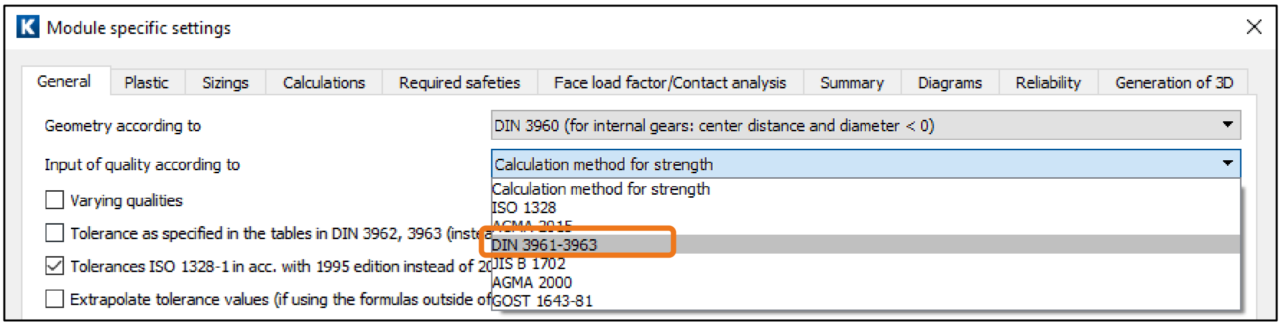


Figure 4. Module-specific settings. Quality does not depend on calculation method.

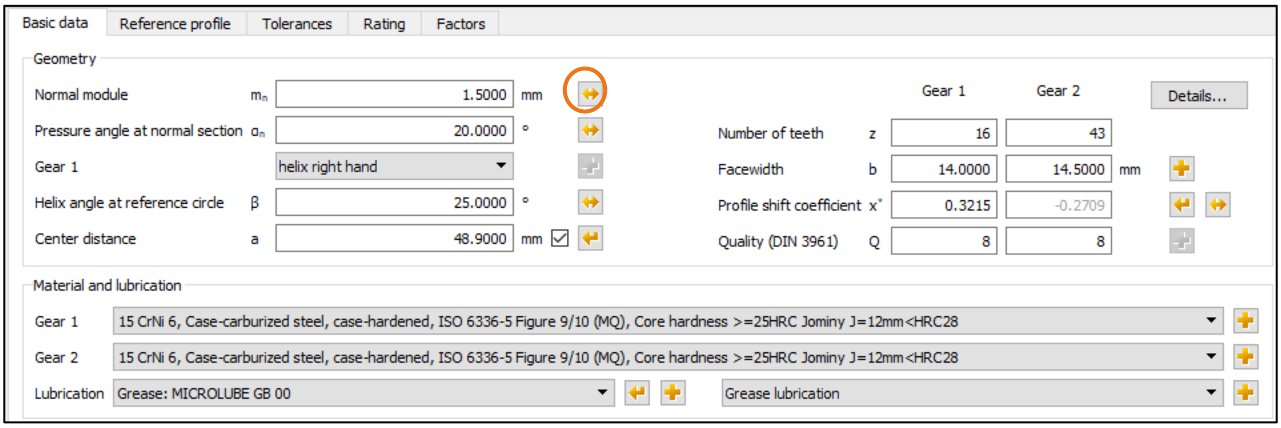


Figure 5. Input window – «Basic data» tab, «Geometry» group

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

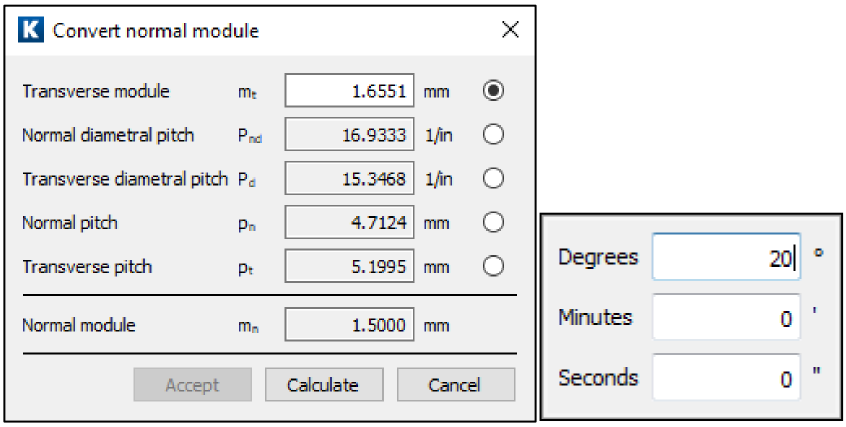


Figure 6. Additional entries, normal module, angle

2.4 Defining the power data and calculation method

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

It is also important that you set the reference gear correctly (first gear - gear 1) for the load.
Input the calculation method in the drop-down list you see on the top left. In this case, you must also switch to ISO 6336 Method B.

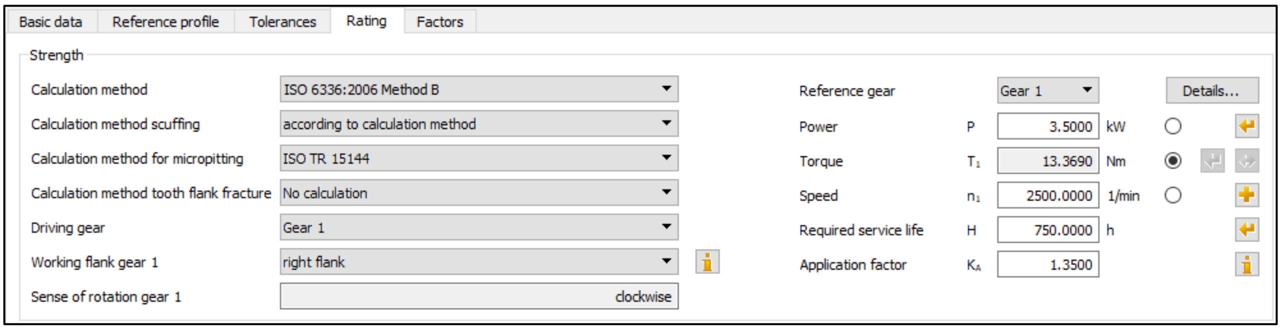


Figure 7. Input window – «Rating» tab, group: Strength

In the input window in the **«Factors»** tab, group "Face load factor/contact analysis", you can input face load factor $K_{H\beta}$ either directly (by using the drop down list "Own Input") or define it by clicking the Plus button next to the input field.

You must select the Position of contact pattern, which is not verified, from the appropriate drop-down list.

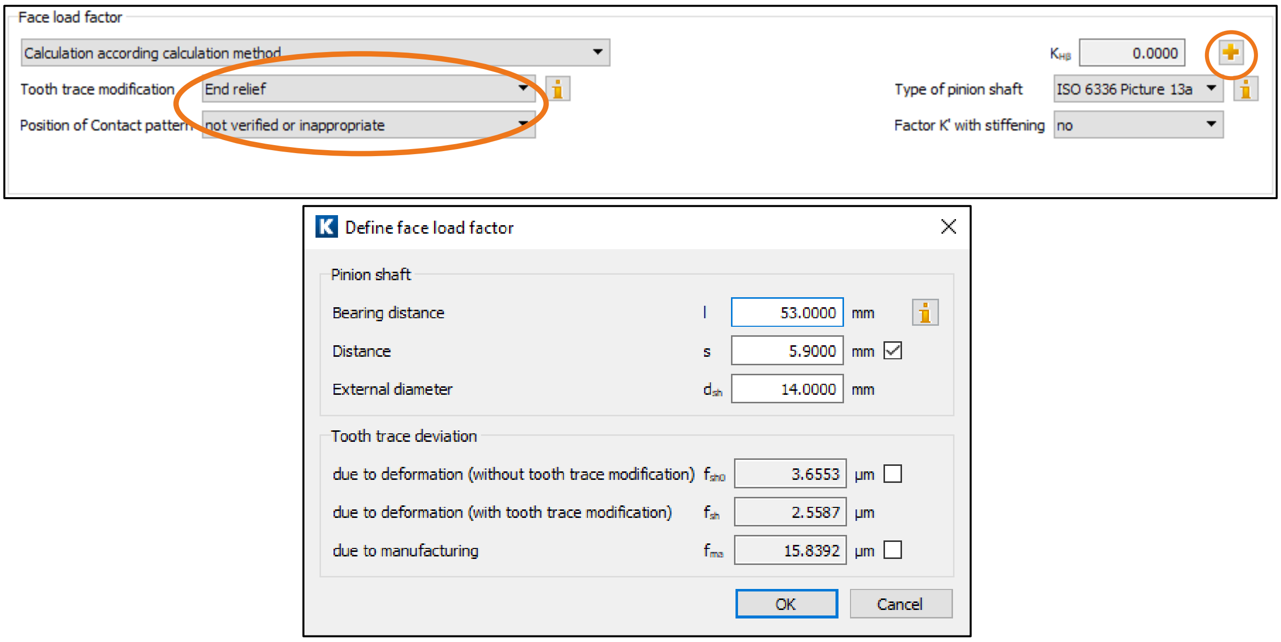


Figure 8. Define the face load factor

To calculate the load coefficients, you must enter:

The tooth trace modification (in this case Figure 8).

Possible shaft configurations. To do this, click the Info button to the right of the **«Type of pinion shaft»** field in the **«Info window»**. See the selection on the right-hand side of the next figure. This example corresponds to Figure A in Figure 9. You can then input the distances l and s as soon as the flag is set in the checkbox to the right of the corresponding input fields.

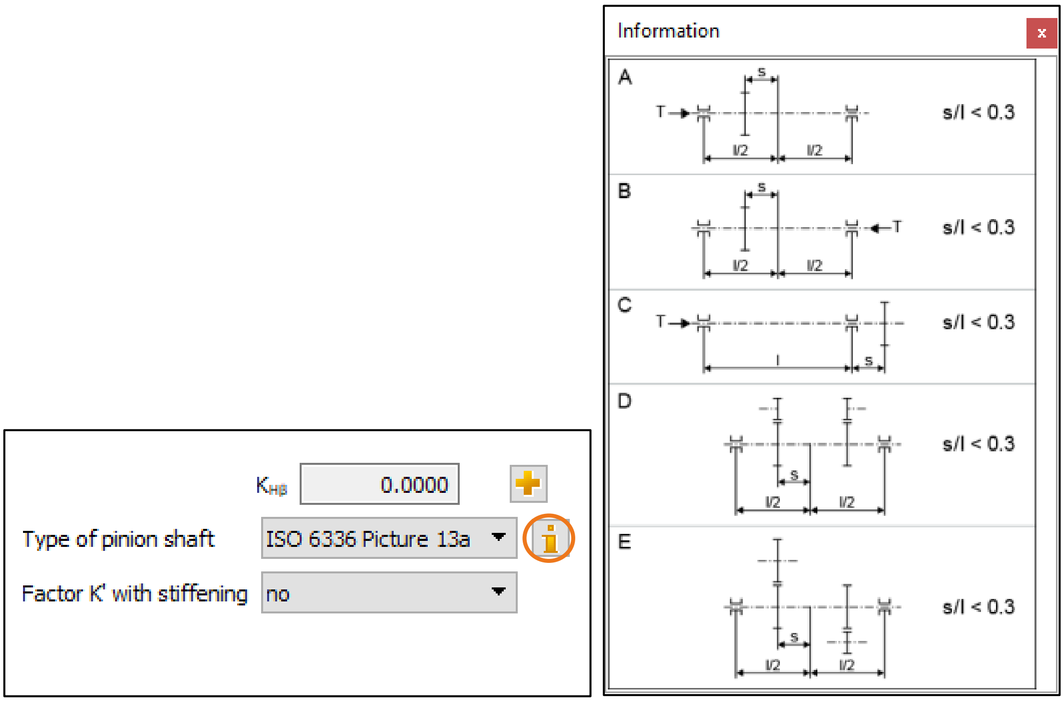


Figure 9. Define face load factor

Note:
You need the shaft configuration to calculate face load factor $K_{H\beta}$. ISO 6336 (or DIN 3990) provides 5 different configurations from which you can select the one you require. These examples are listed A to E in the figure at the top, on the right.
Face load factor $K_{H\beta}$ shows the non-linear distribution of the load across the face width. You can request special instructions from KISSsoft AG about this: see document: «kisssoft-anl-072-E-Contact-Analysis-Cylindrical-Gears.pdf».

2.5 Material and lubrication

In the **«Basic data»** tab, «Material and lubrication» group input window you select the gear materials from a drop-down list. 15 Cr Ni 6, case-carburized steel is used in this example.
You can also select the lubrication as well as the lubrication type.

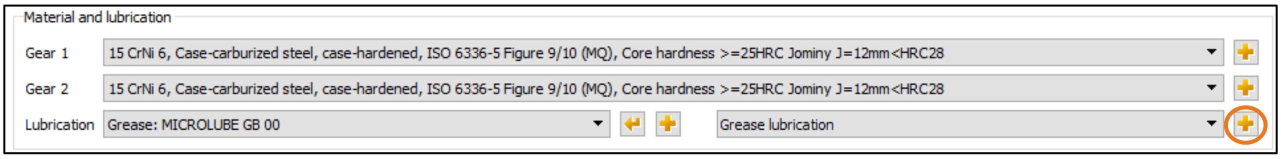


Figure 10. Input window – «Basic data» tab, «Material and Lubrication» group

Click the Plus button on the far bottom right to define the lubricant temperature.

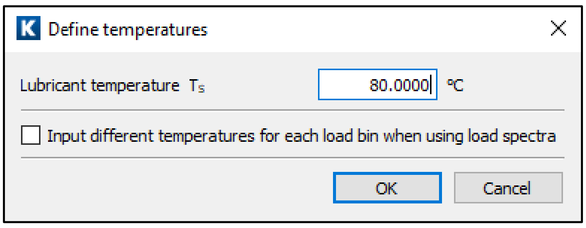


Figure 11. Define the lubricant temperature

2.6 Reference profile

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

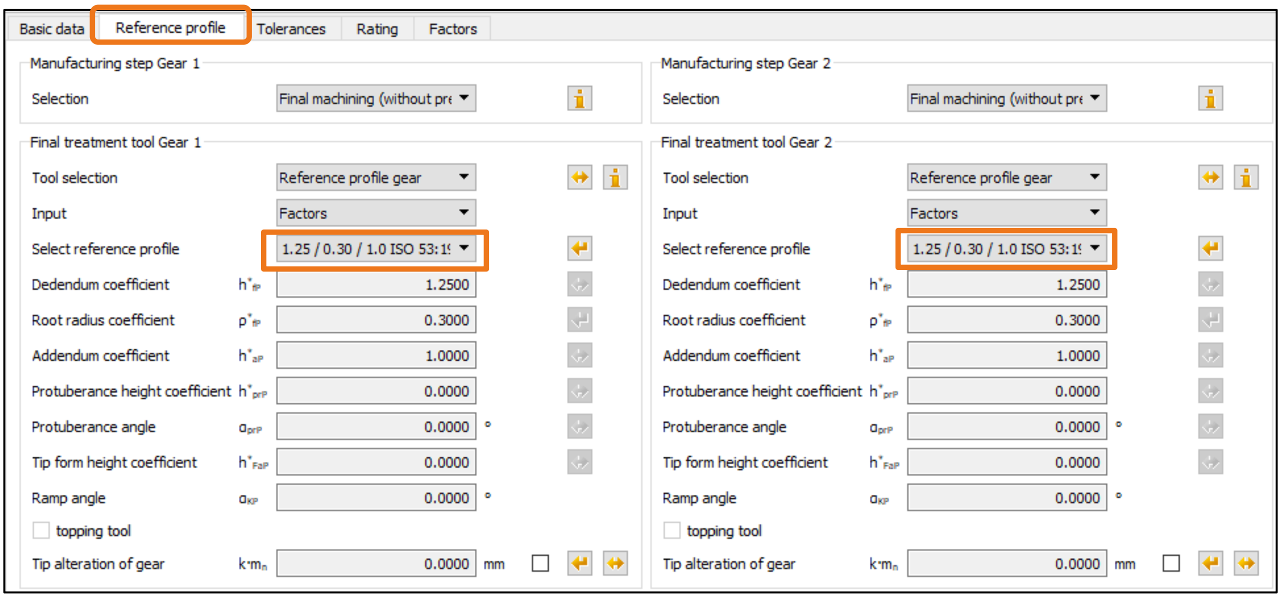


Figure 12. Input window – «Reference profile» tab

2.7 Tolerances

You define the tooth thickness deviation in the **«Tolerances»** tab. In a verification example, it is often the case that only the effective tolerances of base tangent length and the number of teeth spanned are specified. If you input these values, the KISSsoft system will then calculate the correct tooth thickness tolerances for the tooth form.

In this case, you can also input the center distance tolerances either by selecting them from the drop-down list or by inputting your own values as shown in the example.

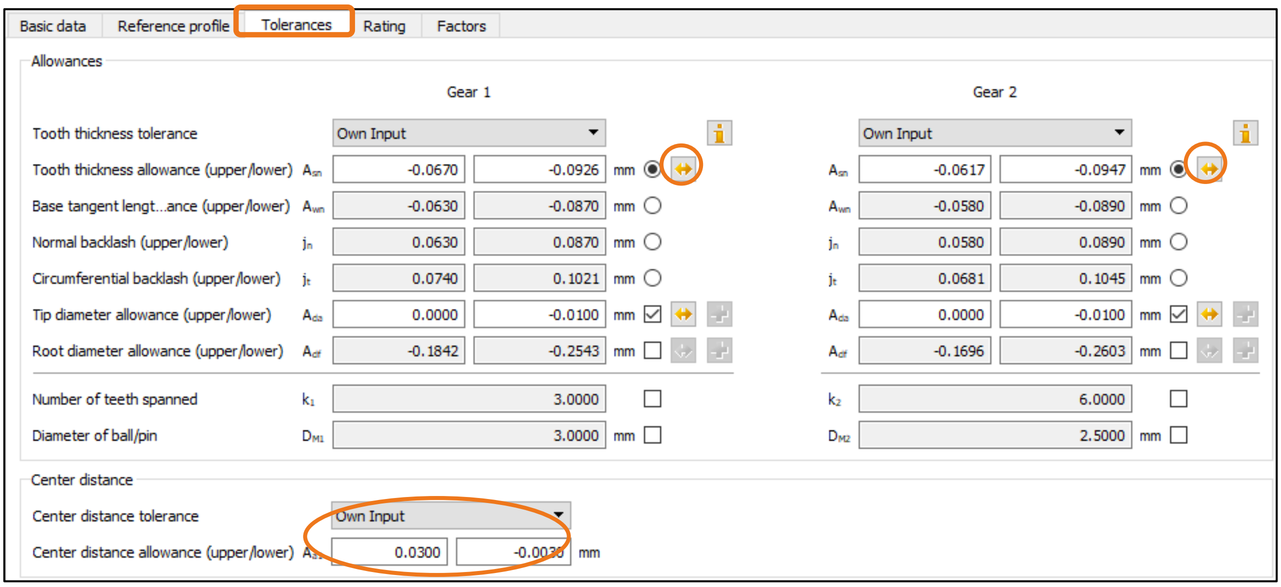


Figure 13. Input window – «Tolerances» tab

To input the base tangent lengths, click the **«Tolerances»** tab, «Allowances» group, and then click the Convert button next to the tooth thickness allowance input window (middle markings).

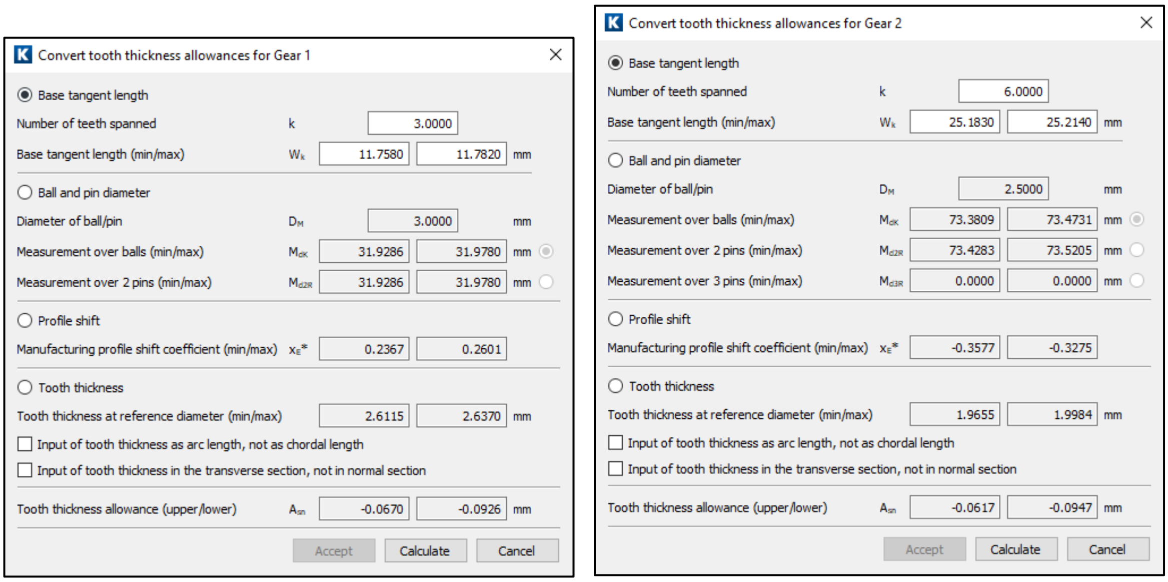


Figure 14. Calculating the base tangent lengths

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

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

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

Figure 15. Input window «Tolerances» tab, «Allowances» group

2.8 Lubrication

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

The **«Lubricant temperature»** input field for oil or grease lubrication defines the basic temperature of the gear body. For this reason, the **«Lubricant temperature»** is also important for calculating the effective lubricant viscosity. The **«Ambient temperature»** does not affect the calculation (see also 2.5 Material and lubrication).

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

Exceptions:

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

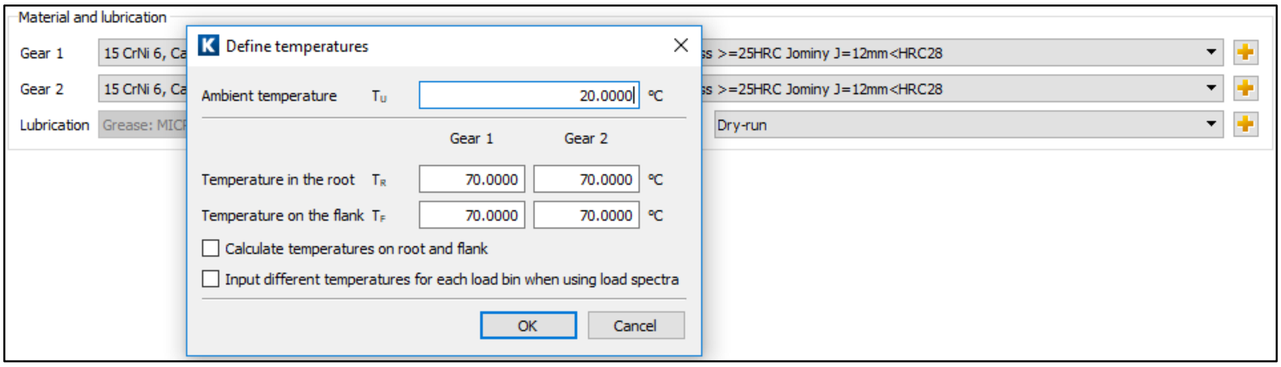


Figure 16. Inputting the temperature for a dry run

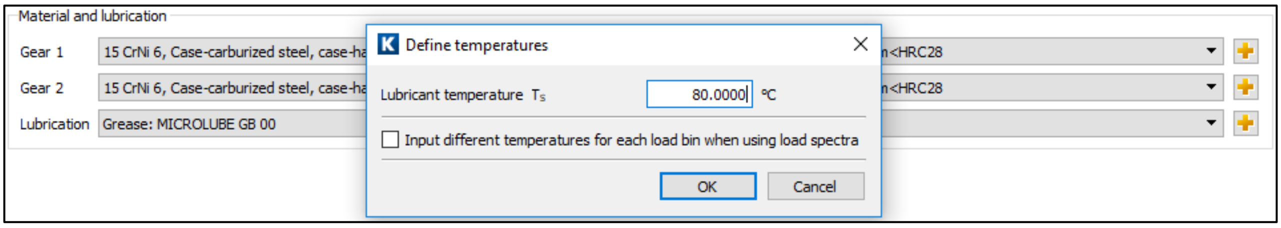


Figure 17. Inputting the temperature for grease lubrication

2.9 Calculate

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

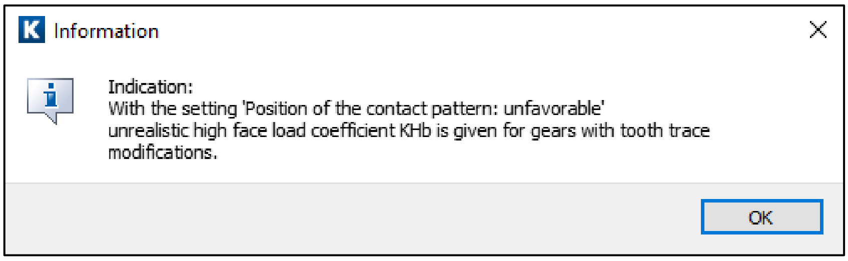


Figure 18. Information window after «Calculation»

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

If you have worked through this tutorial correctly, the highlighted strength values should match Figure 19:

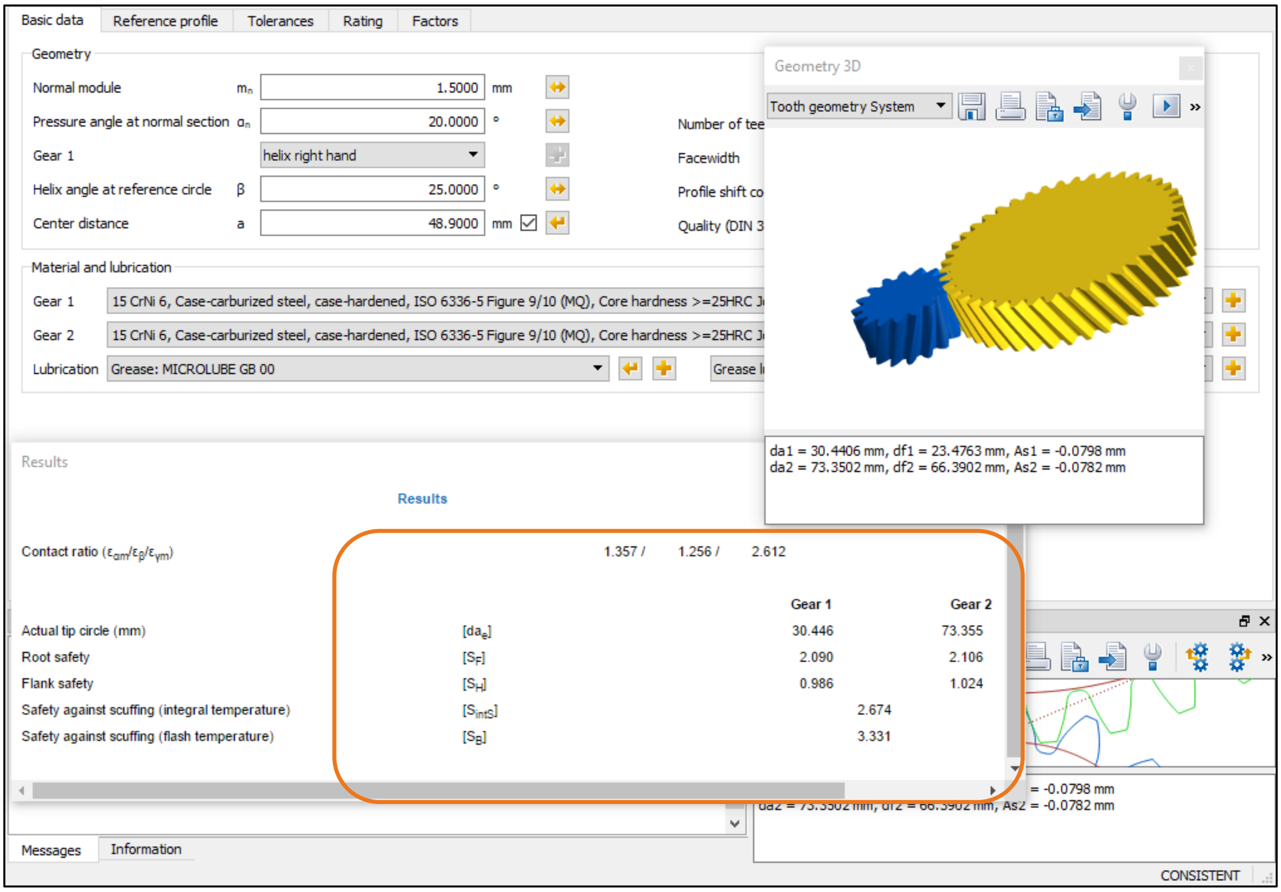


Figure 19. End result of tutorial

2.10 Report

——— KISSsoft Release 03/2018 β ———

KISSsoft Calculation programs for machine design

——— File ———

Name : Tutorial-008
Description: KISSsoft Tutorial
Changed by: mhoffmann on: 13.02.2018 at: 15:10:36

Important hint: At least one warning has occurred during the calculation:

1-> Indication:
With the setting 'Position of the contact pattern: unfavorable'
unrealistic high face load coefficient KHb is given for gears with tooth trace modifications.

CALCULATION OF A HELICAL GEAR PAIR

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

Calculation method DIN 3990:1987 Method B

		------- GEAR 1 --------	GEAR 2 --
Power (kW)	[P]	3.500	
Speed (1/min)	[n]	2500.0	930.2
Torque (Nm)	[T]	13.4	35.9
Application factor	[KA]	1.35	
Required service life (h)	[H]	750.00	
Gear driving (+) / driven (-)		+	-

Working flank gear 1: Right flank
Sense of rotation gear 1 clockwise

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		------- GEAR 1 --------	GEAR 2 --
Center distance (mm)	[a]	48.900	
Center distance allowances (mm)	[Aa.e/i]	0.030 / -0.030	
Normal module (mm)	[mn]	1.5000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	16	43
Facewidth (mm)	[b]	14.00	14.50
Hand of gear		right	left
Accuracy grade	[Q-DIN 3961:1978]	8	8
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

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

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

		------- GEAR 1 --------	GEAR 2 --
Surface hardness		HRC 60	HRC 60
Fatigue strength. tooth root stress (N/mm²)	[σFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[σHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[σB]	1000.00	1000.00
Yield point (N/mm²)	[σS]	685.00	685.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[v]	0.300	0.300
Roughness average value DS, flank (µm)	[RAH]	0.60	0.60
Roughness average value DS, root (µm)	[RAF]	3.00	3.00
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Gear reference profile 1 :
Reference profile 1.25 / 0.30 / 1.0 ISO 53:1998 Profil B

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.300 (rhofPmax*= 0.472)
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[alfKP]	0.000

not topping

Gear reference profile 2 :
Reference profile 1.25 / 0.30 / 1.0 ISO 53:1998 Profil B

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.300 (rhofPmax*= 0.472)
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Protuberance height coefficient	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Tip form height coefficient	[hFaP*]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

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

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

Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type		Grease lubrication
Type of grease		Grease: MICROLUBE GB 00
Lubricant base		Mineral-oil base
Kinem. viscosity base oil at 40 °C (mm²/s)	[nu40]	700.00
Kinem. viscosity base oil at 100 °C (mm²/s)	[nu100]	35.00

FZG-Test A/8.3/90 step	[FZGtestA]	12			
Specific density at 15 °C (kg/dm³)	[roOil]	0.930			
Grease temperature (°C)	[TS]	80.000			
		------- GEAR 1 -------- GEAR 2 --			
Overall transmission ratio	[itot]	-2.688			
Gear ratio	[u]	2.688			
Transverse module (mm)	[mt]	1.655			
Pressure angle at pitch circle (°)	[alft]	21.880			
Working transverse pressure angle (°)	[alfwt]	22.100			
	[alfwt.e/i]	22.186 /	22.013		
Working pressure angle at normal section (°)	[alfwn]	20.199			
Helix angle at operating pitch circle (°)	[betaw]	25.034			
Base helix angle (°)	[betab]	23.399			
Reference center distance (mm)	[ad]	48.824			
Sum of profile shift coefficients	[Summexi]	0.0506			
Profile shift coefficient	[x]	0.3215		-0.2709	
Tooth thickness (Arc) (module) (module)	[sn*]	1.8048		1.3736	
Tip alteration (mm)	[k*mn]	0.000		0.000	
Reference diameter (mm)	[d]	26.481		71.168	
Base diameter (mm)	[db]	24.574		66.041	
Tip diameter (mm)	[da]	30.446		73.355	
(mm)	[da.e/i]	30.446 /	30.436	73.355 /	73.345
Tip diameter allowances (mm)	[Ada.e/i]	0.000 /	-0.010	0.000 /	-0.010
Tip form diameter (mm)	[dFa]	30.446		73.355	
(mm)	[dFa.e/i]	30.446 /	30.436	73.355 /	73.345
Active tip diameter (mm)	[dNa]	30.446		73.355	
Active tip diameter (mm)	[dNa.e/i]	30.446 /	30.436	73.355 /	73.345
Operating pitch diameter (mm)	[dw]	26.522		71.278	
(mm)	[dw.e/i]	26.538 /	26.506	71.322 /	71.234
Root diameter (mm)	[df]	23.696		66.605	
Generating Profile shift coefficient	[xE.e/i]	0.2601/	0.2367	-0.3275/	-0.3577
Manufactured root diameter with xE (mm)	[df.e/i]	23.511 /	23.441	66.436 /	66.345
Theoretical tip clearance (mm)	[c]	0.375		0.375	
Effective tip clearance (mm)	[c.e/i]	0.540 /	0.429	0.537 /	0.437
Active root diameter (mm)	[dNf]	25.050		68.670	
(mm)	[dNf.e/i]	25.086 /	25.020	68.719 /	68.627
Root form diameter (mm)	[dFf]	24.894		67.921	
(mm)	[dFf.e/i]	24.820 /	24.794	67.816 /	67.761
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.146 /	0.100	0.479 /	0.405
Addendum (mm)	[ha=mn*(haP*+x+k)]	1.982		1.094	
(mm)	[ha.e/i]	1.982 /	1.977	1.094 /	1.089
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.393		2.281	
(mm)	[hf.e/i]	1.485 /	1.520	2.366 /	2.412
Roll angle at dFa (°)	[xsi_dFa.e/i]	41.909 /	41.870	27.702 /	27.682
Roll angle to dNa (°)	[xsi_dNa.e/i]	41.909 /	41.870	27.702 /	27.682
Roll angle to dNf (°)	[xsi_dNf.e/i]	11.766 /	10.969	16.480 /	16.189
Roll angle at dFf (°)	[xsi_dFf.e/i]	8.135 /	7.696	13.371 /	13.160
Tooth height (mm)	[h]	3.375		3.375	
Virtual gear no. of teeth	[zn]	20.960		56.329	
Normal tooth thickness at tip circle (mm)	[san]	0.874		1.225	
(mm)	[san.e/i]	0.806 /	0.771	1.166 /	1.127
Normal tooth thickness on tip form circle (mm)	[sFan]	0.874		1.225	
(mm)	[sFan.e/i]	0.806 /	0.771	1.166 /	1.127
Normal space width at root circle (mm)	[efn]	0.000		1.352	
(mm)	[efn.e/i]	0.000 /	0.000	1.388 /	1.409

Max. sliding velocity at tip (m/s)	[vga]	1.436	0.919
Specific sliding at the tip	[zetaa]	0.610	0.591
Specific sliding at the root	[zetaf]	-1.443	-1.567
Mean specific sliding	[zetam]	0.603	
Sliding factor on tip	[Kga]	0.414	0.265
Sliding factor on root	[Kgf]	-0.265	-0.414
Pitch on reference circle (mm)	[pt]	5.200	
Base pitch (mm)	[pbt]	4.825	
Transverse pitch on contact-path (mm)	[pet]	4.825	
Lead height (mm)	[pz]	178.407	479.470
Axial pitch (mm)	[px]	11.150	
Length of path of contact (mm)	[ga, e/i]	6.555 (6.635 / 6.456)	
Length T1-A, T2-A (mm)	[T1A, T2A]	2.432(2.352/ 2.523)	15.965(15.965/ 15.954)
Length T1-B (mm)	[T1B, T2B]	4.162(4.162/ 4.154)	14.235(14.155/ 14.323)
Length T1-C (mm)	[T1C, T2C]	4.989(4.967/ 5.011)	13.408(13.350/ 13.466)
Length T1-D (mm)	[T1D, T2D]	7.257(7.177/ 7.348)	11.140(11.140/ 11.129)
Length T1-E (mm)	[T1E, T2E]	8.987(8.987/ 8.979)	9.410(9.330/ 9.498)
Length T1-T2 (mm)	[T1T2]	18.397 (18.317 / 18.477)	
Diameter of single contact point B (mm)	[d-B]	25.945(25.945/ 25.940)	71.916(71.853/ 71.986)
Diameter of single contact point D (mm)	[d-D]	28.540(28.459/ 28.633)	69.698(69.698/ 69.691)
Addendum contact ratio	[eps]	0.829(0.833/ 0.822)	0.530(0.542/ 0.516)
Minimal length of contact line (mm)	[Lmin]	19.611	
Transverse contact ratio	[eps_a]	1.359	
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.375 / 1.357 / 1.338	
Overlap ratio	[eps_b]	1.256	
Total contact ratio	[eps_g]	2.614	
Total contact ratio with allowances	[eps_g.e/m/i]	2.631 / 2.612 / 2.594	

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 -------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	1009.7
Axial force (N)	[Fa]	470.8
Radial force (N)	[Fr]	405.5
Normal force (N)	[Fnorm]	1185.6
Nominal circumferential force per mm (N/mm)	[w]	72.12
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	1008.1
Axial force (N)	[Faw]	470.8
Radial force (N)	[Frw]	409.4
Circumferential speed reference circle (m/s)	[v]	3.47
Circumferential speed operating pitch circle (m/s)	[v(dw)]	3.47
Running-in value (µm)	[yp]	1.1
Running-in value (µm)	[yf]	0.9
Correction factor	[CM]	0.800
Gear blank factor	[CR]	1.000
Basic rack factor	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	11.915
Meshing stiffness (N/mm/µm)	[cg]	15.120
Reduced mass (kg/mm)	[mRed]	0.00235
Resonance speed (min-1)	[nE1]	47834
Resonance ratio (-)	[N]	0.052

Subcritical range

Running-in value (µm)	[ya]	1.1	
Bearing distance l of pinion shaft (mm)	[l]	53.000	
Distance s of pinion shaft (mm)	[s]	5.900	
Outside diameter of pinion shaft (mm)	[dsh]	14.000	
Load according to Figure 6.8, DIN 3990-1:1987	[-]	0	
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)			
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']	0.80	
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]	12.41	
from deformation of shaft (µm)	[fsh*B1]	2.56	
(fsh (µm) = 3.65, B1= 0.70, fHb5 (µm) = 6.00)			
Tooth trace: with end relief			
Position of Contact pattern: not verified or inappropriate			
from production tolerances (µm)	[fma*B2]	11.20	
(B2= 0.70)			
Tooth trace deviation, theoretical (µm)	[Fbx]	14.60	
Running-in value (µm)	[yb]	2.19	
Dynamic factor	[KV]	1.049	
Face load factor - flank	[KHb]	1.919	
- Tooth root	[KFb]	1.644	
- Scuffing	[KBb]	1.919	
Transverse load factor - flank	[KHa]	1.344	
- Tooth root	[KFa]	1.344	
- Scuffing	[KBa]	1.344	
Helical load factor scuffing	[Kbg]	1.242	
Number of load cycles (in mio.)	[NL]	112.500	41.860

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B

		------- GEAR 1 --------	GEAR 2 --
Calculated with manufacturing profile shift	[xE.e]	0.2601	-0.3275
Tooth form factor	[YF]	1.38	1.68
Stress correction factor	[YS]	2.14	1.84
Force application angle (°)	[alfFen]	21.76	19.00
Bending moment arm (mm)	[hF]	1.53	1.85
Tooth thickness at root (mm)	[sFn]	3.14	3.15
Tooth root radius (mm)	[roF]	0.65	0.82

(hF* = 1.021/ 1.231 sFn* = 2.093/ 2.102 roF* = 0.431/ 0.545)
(den (mm) = 32.728/ 84.649 dsFn(mm) = 23.995/ 67.030 alfsFn(°) = 30.00/ 30.00 qs = 2.426/ 1.930)

Contact ratio factor	[Yeps]	1.000	
Helix angle factor	[Ybet]	0.792	
Effective facewidth (mm)	[beff]	14.00	14.50
Nominal stress at tooth root (N/mm²)	[sigF0]	112.82	113.68
Tooth root stress (N/mm²)	[sigF]	353.05	355.72

Permissible bending stress at root of Test-gear

Notch sensitivity factor	[YdrelT]	0.999	0.994
Surface factor	[YRrelT]	0.957	0.957
size factor (Tooth root)	[YX]	1.000	1.000
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.956	0.951
Alternating bending factor (mean stress influence coefficient)	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	860.00	860.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	632.47	629.34
Limit strength tooth root (N/mm²)	[sigFG]	822.21	818.14
Required safety	[SFmin]	1.30	1.30
Safety for tooth root stress	[SF=sigFG/sigF]	2.33	2.30
Transmittable power (kW)	[kWRating]	6.27	6.19

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.291	
Elasticity factor (√N/mm²)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.858	
Helix angle factor	[Zbet]	0.952	
Effective facewidth (mm)	[beff]	14.00	
Nominal contact stress (N/mm²)	[sigH0]	686.65	
Contact stress at operating pitch circle (N/mm²)	[sigHw]	1312.18	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Contact stress (N/mm²)	[sigHB, sigHD]	1312.18	1312.18
Lubrication coefficient at NL	[ZL]	1.096	1.093
Speed coefficient at NL	[ZV]	0.974	0.975
Roughness coefficient at NL	[ZR]	0.945	0.946
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.014
	[ZL*ZV*ZR*ZNT]	1.009	1.022
Limited pitting is permitted:	No		
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress (N/mm²)	[sigHP=sigHG/SHmin]	1592.92	1614.07
Pitting stress limit (N/mm²)	[sigHG]	1513.28	1533.36
Required safety	[SHmin]	0.95	0.95
Safety factor for contact stress at operating pitch circle			
	[SHw]	1.15	1.17
Safety for stress at single tooth contact	[SHBD=sigHG/sigHBD]	1.15	1.17
(Safety regarding transmittable torque)	[(SHBD)^2]	1.33	1.37
Transmittable power (kW)	[kWRating]	5.16	5.30

4b. MICROPITTING ACCORDING TO ISO/TR 15144-1:2014

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. SCUFFING LOAD CAPACITY

Calculation method according to DIN 3990:1987

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

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Scuffing test and load stage	[FZGtest]	FZG - Test A / 8.3 / 90 (ISO 14635 - 1)	12
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	6.44	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	14.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	327.144	
Angle factor	[Xalfbet]	0.990	
(ε1:0.829, ε2:0.530)			

Flash temperature-criteria		
Tooth mass temperature (°C)	[theMB]	116.03
(theMB = theoil + XS*0.47*theflamax)		
Maximum flash temperature (°C)	[theflamax]	63.89
Scuffing temperature (°C)	[theS]	398.47
Coordinate gamma (point of highest temp.)	[Gamma]	0.455
[Gamma.A]=-0.513 [Gamma.E]=0.801		
Highest contact temp. (°C)	[theB]	179.93
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Geometry factor	[XB]	0.215
Load sharing factor	[XGam]	1.000
Dynamic viscosity (mPa*s)	[etaM]	18.93 (80.0 °C)
Coefficient of friction	[mym]	0.111
Required safety	[SBmin]	2.000
Safety factor for scuffing (flash temperature)	[SB]	3.187

Integral temperature-criteria		
Tooth mass temperature (°C)	[theMC]	100.31
(theMC = theoil + XS*0.70*theflaint)		
Mean flash temperature (°C)	[theflaint]	24.18
Integral scuffing temperature (°C)	[theSint]	398.47
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Contact ratio factor	[Xeps]	0.282
Dynamic viscosity (mPa*s)	[etaOil]	66.26 (80.0 °C)
Mean coefficient of friction	[mym]	0.088
Geometry factor	[XBE]	0.364
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.000
Integral tooth flank temperature (°C)	[theint]	136.57
Required safety	[SSmin]	1.800
Safety factor for scuffing (intg.-temp.)	[SSint]	2.918
Safety referring to transmittable torque	[SSL]	5.629

<u>6. MEASUREMENTS FOR TOOTH THICKNESS</u>

	------- Gear 1 ------	Gear 2 --
Tooth thickness deviation	Own Input	Own Input

Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.067 / -0.093	-0.062 / -0.095
Number of teeth spanned	[k]	3.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	11.845	25.272
Actual base tangent length ('span') (mm)	[Wk.e/i]	11.782 / 11.758	25.214 / 25.183
(mm)	[ΔWk.e/i]	-0.063 / -0.087	-0.058 / -0.089
Diameter of measuring circle (mm)	[dMWk.m]	26.843	69.973
Theoretical diameter of ball/pin (mm)	[DM]	2.789	2.496
Effective diameter of ball/pin (mm)	[DMeff]	3.000	2.500
Radial single-ball measurement backlash free (mm)	[MrK]	16.053	36.846
Radial single-ball measurement (mm)	[MrK.e/i]	15.989 / 15.964	36.760 / 36.714
Diameter of measuring circle (mm)	[dMMr.m]	27.596	70.166
Diametral measurement over two balls without clearance (mm)	[MdK]	32.107	73.644
Diametral two ball measure (mm)	[MdK.e/i]	31.978 / 31.929	73.473 / 73.381
Diametral measurement over pins without clearance (mm)	[MdR]	32.107	73.691
Measurement over pins according to DIN 3960 (mm)	[MdR.e/i]	31.978 / 31.929	73.520 / 73.428
Measurement over 2 pins (free) according to AGMA 2002 (mm)	[dk2f.e/i]	0.000 / 0.000	73.460 / 73.368
Measurement over 2 pins (axial) according to AGMA 2002 (mm)	[dk2t.e/i]	0.000 / 0.000	73.567 / 73.475
Measurement over 3 pins (axial) according to AGMA 2002 (mm)	[dk3A.e/i]	31.978 / 31.929	73.520 / 73.428
Chordal tooth thickness (no backlash) (mm)	[sc]	2.704	2.060
Actual chordal tooth thickness (mm)	[sc.e/i]	2.637 / 2.611	1.998 / 1.965
Reference chordal height from da.m (mm)	[ha]	2.037	1.103
Tooth thickness (Arc) (mm)	[sn]	2.707	2.060
(mm)	[sn.e/i]	2.640 / 2.615	1.999 / 1.966
Backlash free center distance (mm)	[aControl.e/i]	48.723 / 48.641	
Backlash free center distance, allowances (mm)	[jta]	-0.177 / -0.259	
dNf.i with aControl (mm)	[dNf0.i]	24.816	68.300
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	-0.002	0.242
Tip clearance (mm)	[c0.i(aControl)]	0.200	0.208
Center distance allowances (mm)	[Aa.e/i]	0.030 / -0.030	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.024 / -0.024	
Radial clearance (mm)	[jrw.e/i]	0.289 / 0.147	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.231 / 0.118	
Normal backlash (mm)	[jnw.e/i]	0.197 / 0.100	
Torsional angle at entry with fixed output:			
Entire torsional angle (°)	[j.tSys]	0.9996/ 0.5096	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3961:1978			
Accuracy grade	[Q-DIN3961]	8	8
Profile form deviation (µm)	[ff]	12.00	12.00
Profile slope deviation (µm)	[fHa]	10.00	10.00
Total profile deviation (µm)	[Ff]	16.00	16.00
Helix form deviation (µm)	[fbf]	8.00	8.00
Helix slope deviation (µm)	[fHb]	16.00	16.00
Total helix deviation (µm)	[Fb]	18.00	18.00
Normal base pitch deviation (µm)	[fpe]	13.00	14.00

Single pitch deviation (µm)	[fp]	13.00	14.00
Adjacent pitch difference (µm)	[fu]	17.00	18.00
Total cumulative pitch deviation (µm)	[Fp]	38.00	49.00
Sector pitch deviation over z/8 pitches (µm)	[Fpz/8]	24.00	31.00
Runout (µm)	[Fr]	27.00	32.00
Tooth Thickness Variation (µm)	[Rs]	15.00	19.00
Single flank composite, total (µm)	[Fi']	44.00	52.00
Single flank composite, tooth-to-tooth (µm)	[fi']	21.00	21.00
Radial composite, total (µm)	[Fi'']	33.00	40.00
Radial composite, tooth-to-tooth (µm)	[fi'']	13.00	16.00

According to DIN 58405:1972 (Feinwerktechnik):

Tooth-to-tooth composite error (µm)	[fi'']	14.00	16.00
Composite error (µm)	[Fi'']	40.00	45.00
Axis alignment error (µm)	[fp]	13.69	13.69
Flank direction error (µm)	[fbeta]	9.00	9.00
Runout (µm)	[Trk, Fr]	56.00	65.00

Axis alignment tolerances (recommendation acc. to ISO TR 10064-3:1996, Quality) 8)

Maximum value for deviation error of axis (µm)	[fSigbet]	39.75 (Fb=21.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	79.50

8. ADDITIONAL DATA

Maximal possible center distance (eps_a=1.0)	[aMAX]	49.577	
Mass (g)	[m]	63.09	436.69
Total mass (g)	[m]	499.78	
Moment of inertia (system with reference to the drive):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	5.779e-006	0.0002673
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	4.279e-005	
Verdrehsteifigkeit am Antrieb bei festgehaltenem Abtrieb:			
Torsional stiffness (MNm/rad)	[cr]	0.032	
Torsion when subjected to nominal torque (°)	[delcr]	0.024	
Mean coeff. of friction (acc. Niemann)	[mum]	0.098	
Wear sliding coef. by Niemann	[zetw]	0.819	
Gear power loss (kW)	[PVZ]	0.061	
(Meshing efficiency (%)	[etaz]	98.257)	
Sound pressure level (according to Masuda, without contact analysis)	[dB(A)]	50.5	

Indications for the manufacturing by wire cutting:

Deviation from theoretical tooth trace (µm)	[WireErr]	400.3	149.6
Permissible deviation (µm)	[Fb/2]	9.0	9.0

9. MODIFICATIONS AND TOOTH FORM DEFINITION

Data for the tooth form calculation :

Calculation of Gear 1

Tooth form, Gear 1, Step 1: Automatic (final machining)
haP*= 1.071, hfP*= 1.250, rofP*= 0.300

Calculation of Gear 2

Tooth form, Gear 2, Step 1: Automatic (final machining)

haP*= 1.070, hfP*= 1.250, rofP*= 0.300

10. SERVICE LIFE, DAMAGE

Required safety for tooth root	[SFmin]	1.30	
Required safety for tooth flank	[SHmin]	0.95	

Service life (calculated with required safeties):

System service life (h)	[Hatt]	>	1000000

Tooth root service life (h)	[HFatt]	1e+006	1e+006
Tooth flank service life (h)	[HHatt]	1e+006	1e+006

Note: The entry 1e+006 h means that the Service life > 1,000,000 h.

Damage calculated on the basis of the required service life [H] (750.0 h)

F1%	F2%	H1%	H2%
0.00	0.00	0.00	0.00

Calculation of the factors required to define reliability R(t) according to B. Bertsche with Weibull distribution:

R(t) = 100 * Exp(-((t*fac - t0)/(T - t0))^b) %; t (h)

Gear		fac	b	t0	T	R(H)%
1	Tooth root	150000	1.7	9.654e+029	1.484e+030	100.00
1	Tooth flank	150000	1.3	9.014e+029	4.295e+030	100.00
2	Tooth root	55814	1.7	9.654e+029	1.484e+030	100.00
2	Tooth flank	55814	1.3	9.014e+029	4.295e+030	100.00

Reliability of the configuration for required service life (%) 100.00 (Bertsche)

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
  KHa, KFa according to method B

End of Report lines: 546
