KISSsoft 2019 – Tutorial 8

Verifying a cylindrical gear pair

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Sharing Knowledge

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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:

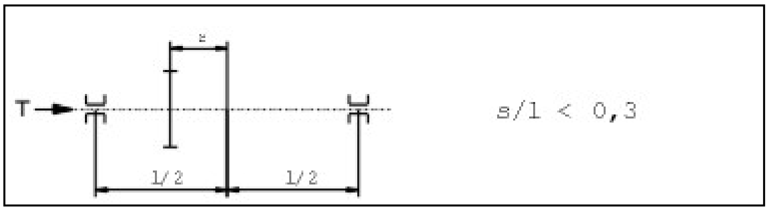
	Material	Hardness data	σFlim	σHlim
Gear 1 (pinion)	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2
Gear 2	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2

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 2019→KISSsoft». This opens the following KISSsoft user interface:

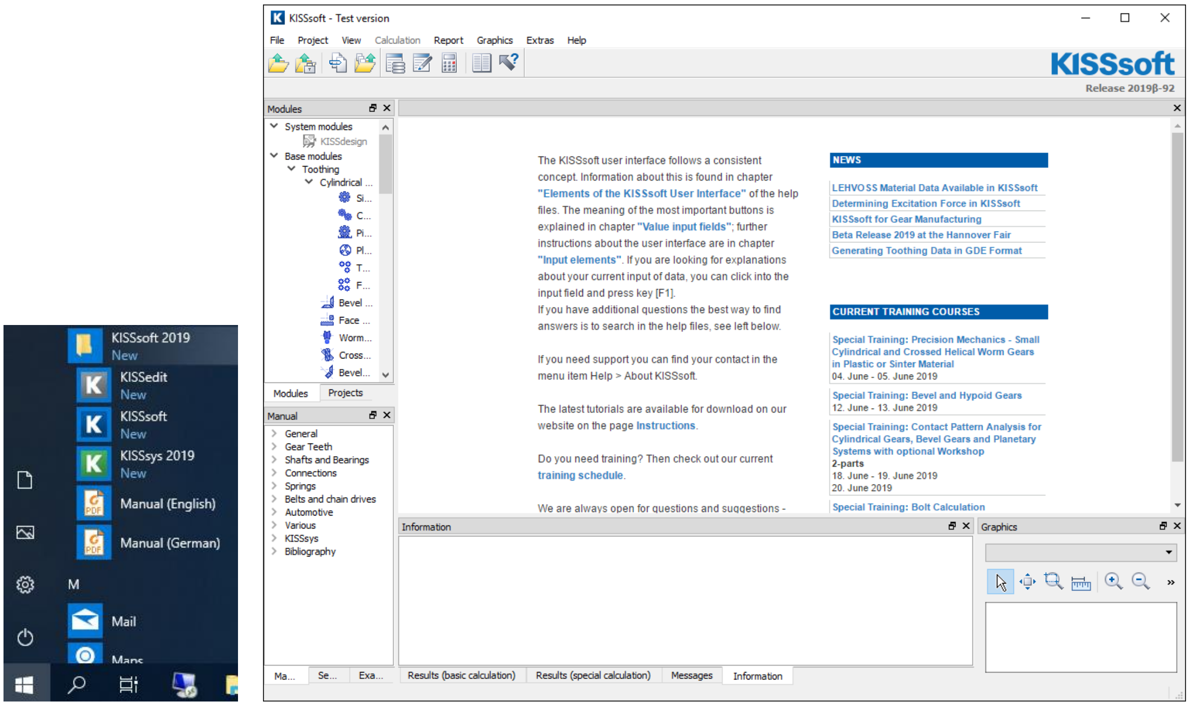


Figure 1. Starting KISSsoft, initial window

2.2 Selecting a calculation

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

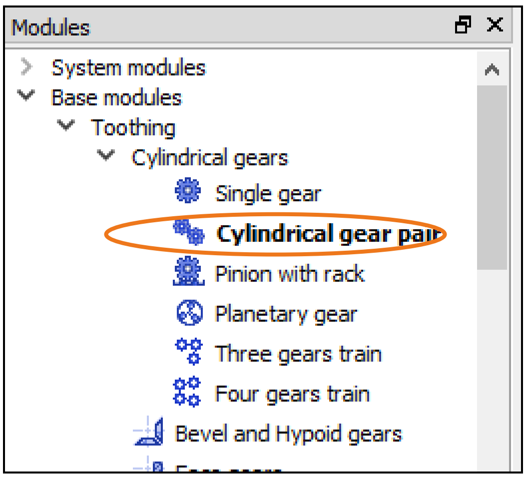


Figure 2. Calling the cylindrical gear calculation

The KISSsoft input window then opens:

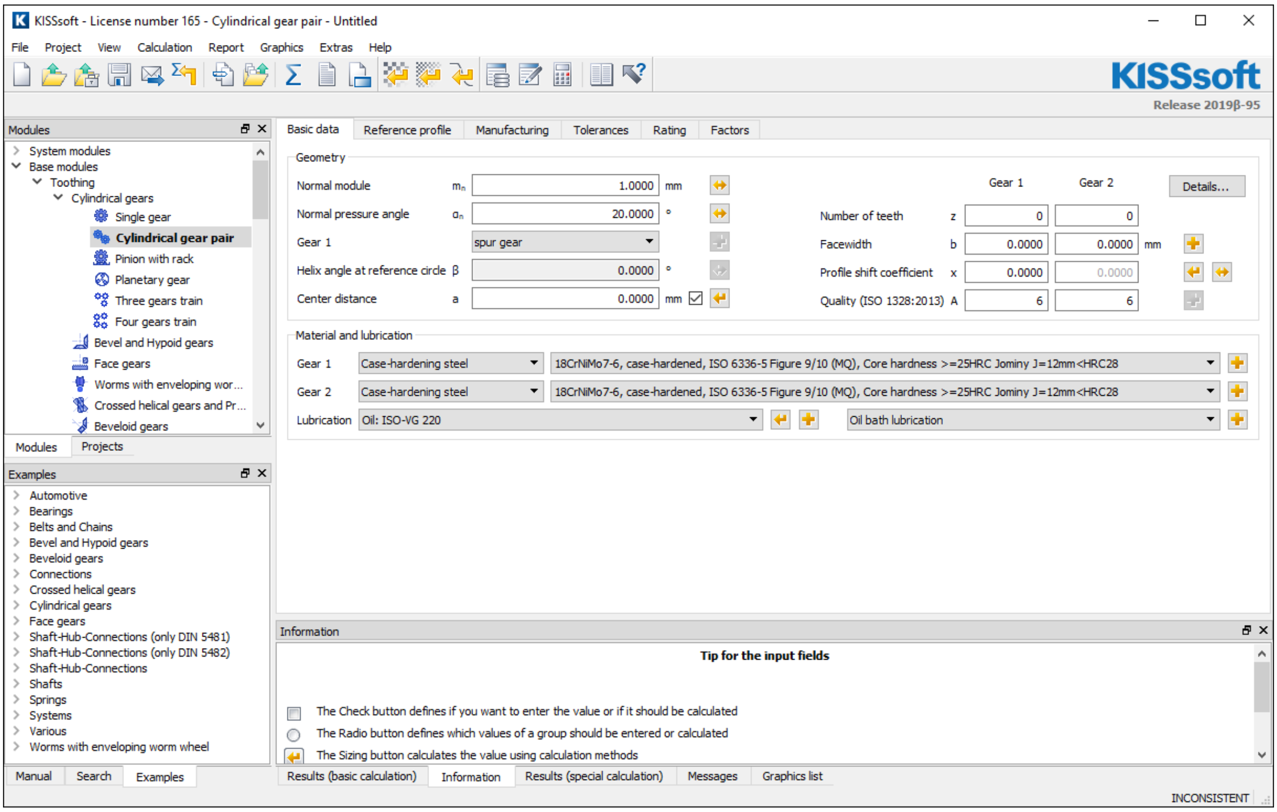


Figure 3. KISSsoft Cylindrical gear calculation input window

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.

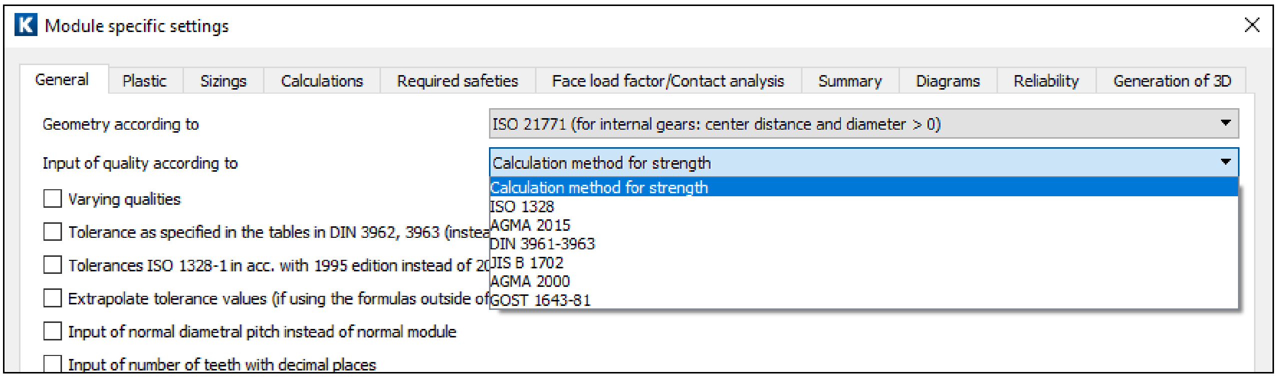


Figure 4. Module-specific settings. Quality does not depend on calculation method.

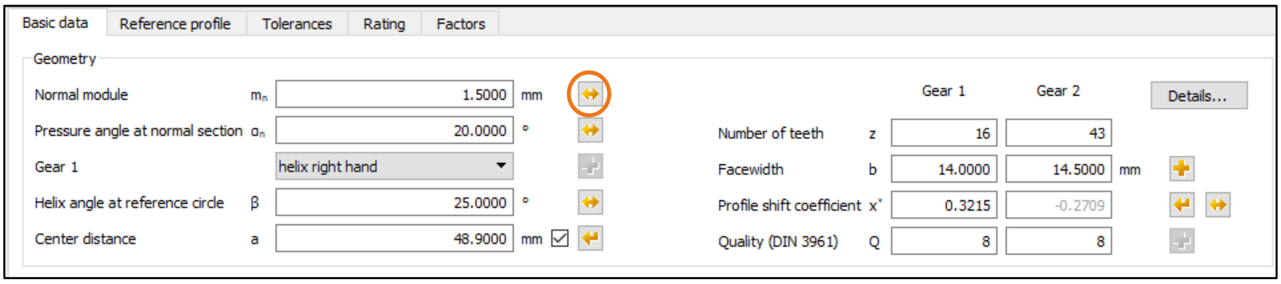


Figure 5. Input window – «Basic data» tab, «Geometry» group

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:

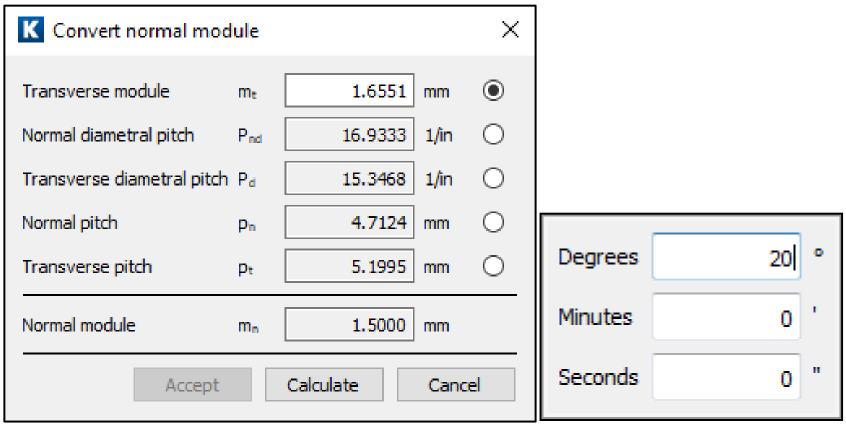


Figure 6. Additional entries, normal module, angle

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.

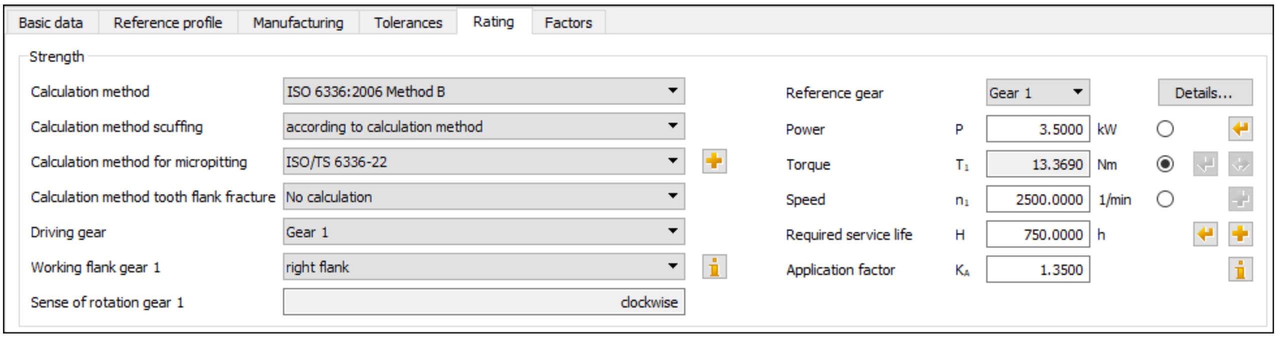


Figure 7. Input window – «Rating» tab, group: Strength

In the input window in the **«Factors»** tab, group “Face load factor”, 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.

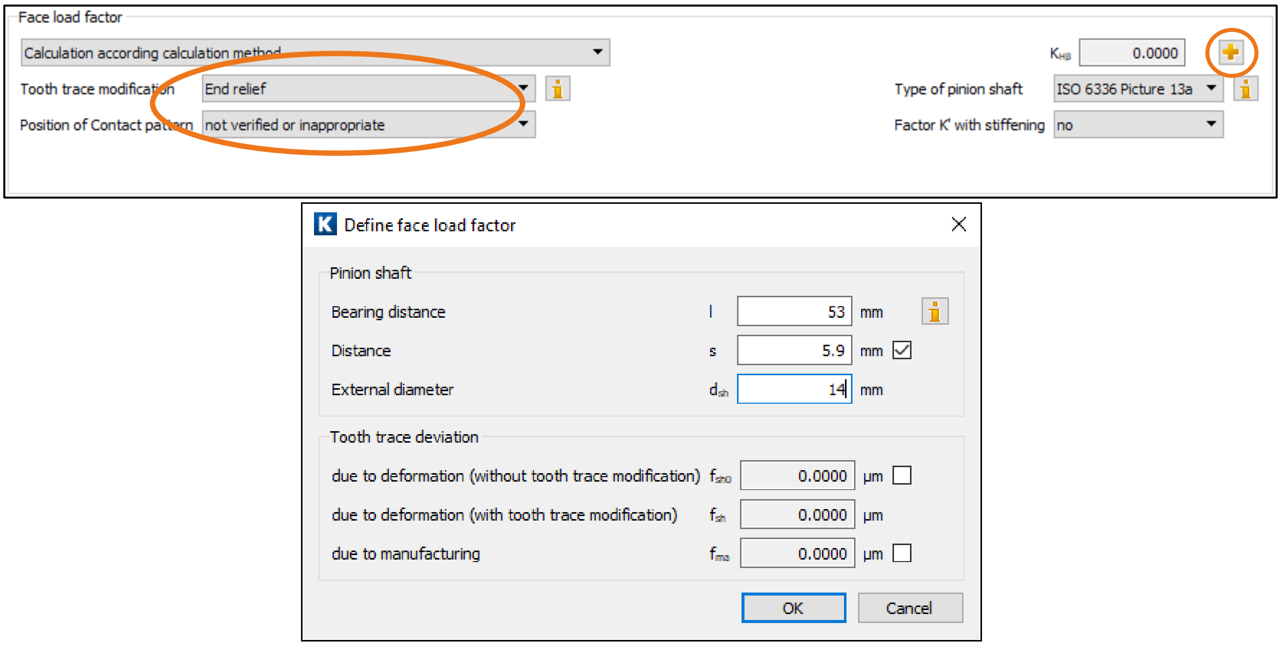


Figure 8. Define the face load factor

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.

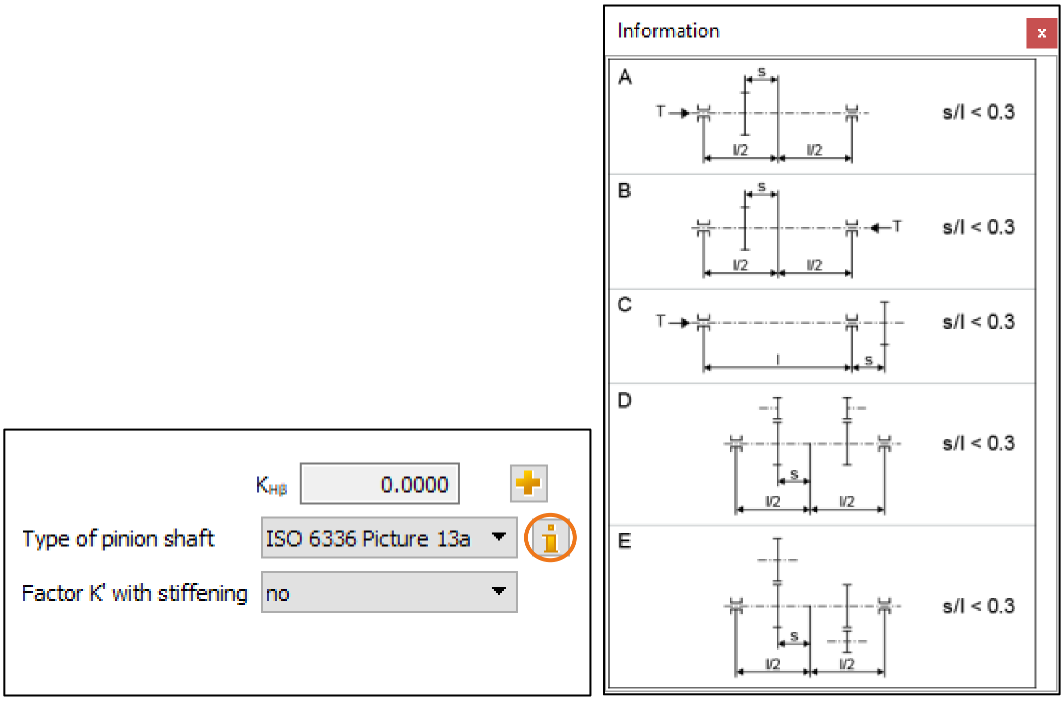


Figure 9. Define face load factor

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 uneven 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.

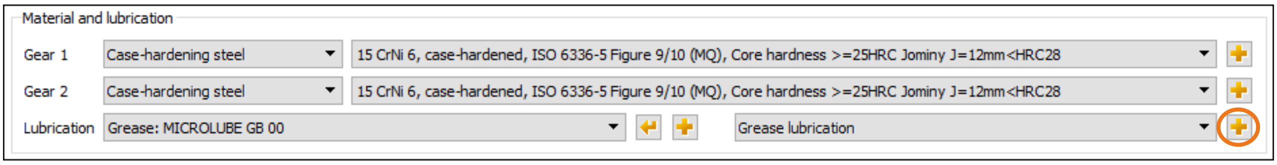


Figure 10. Input window – «Basic data» tab, «Material and Lubrication» group

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

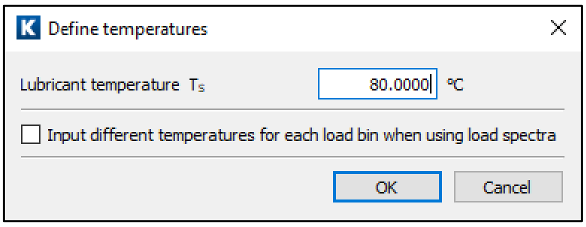


Figure 11. Define the lubricant temperature

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.

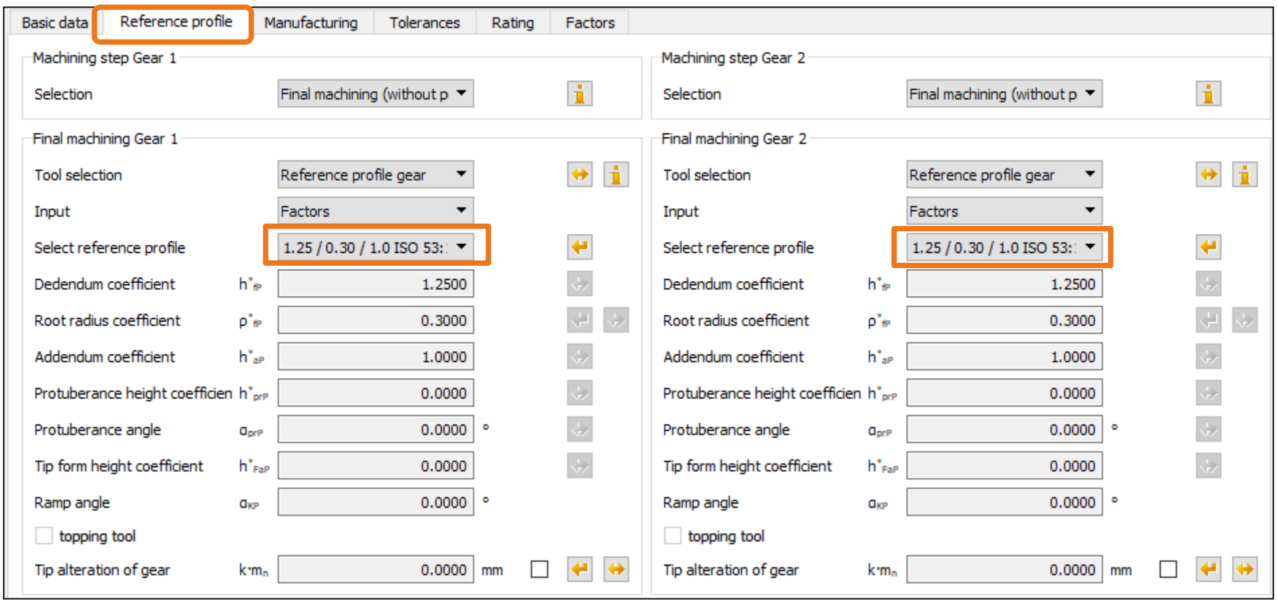


Figure 12. Input window – «Reference profile» tab

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.

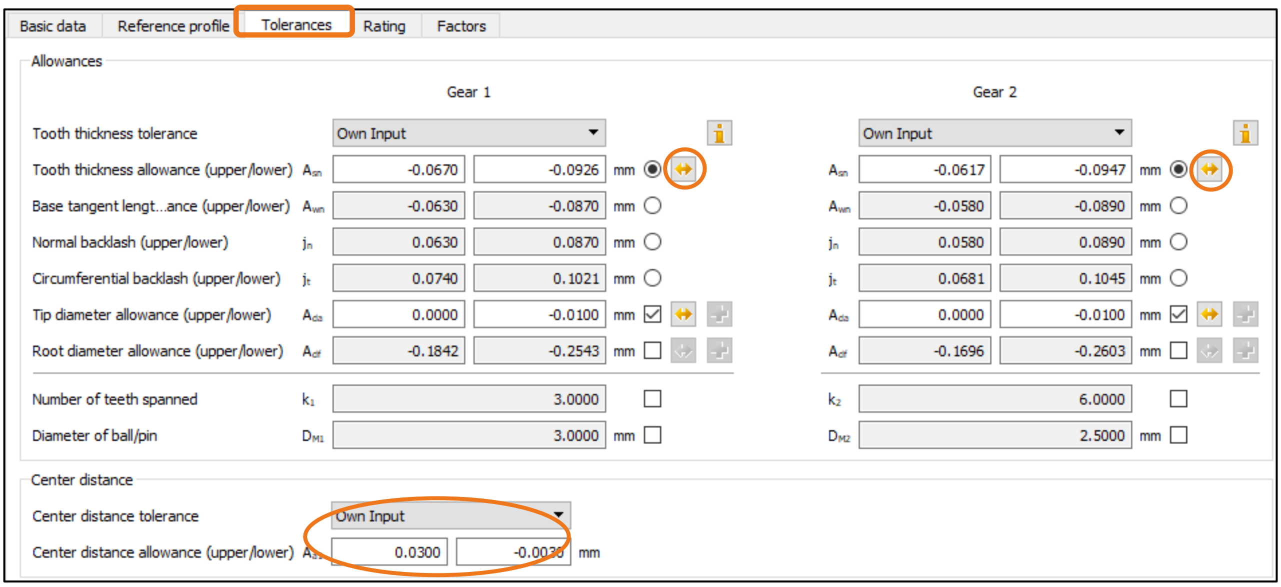


Figure 13. Input window – «Tolerances» tab

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).

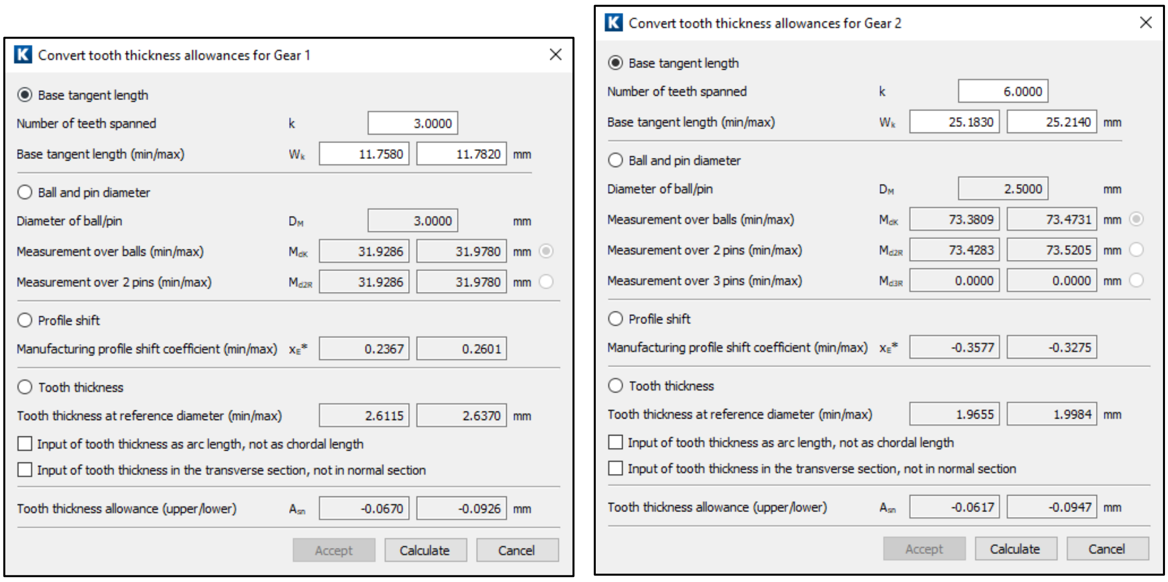


Figure 14. Calculating the base tangent lengths

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.

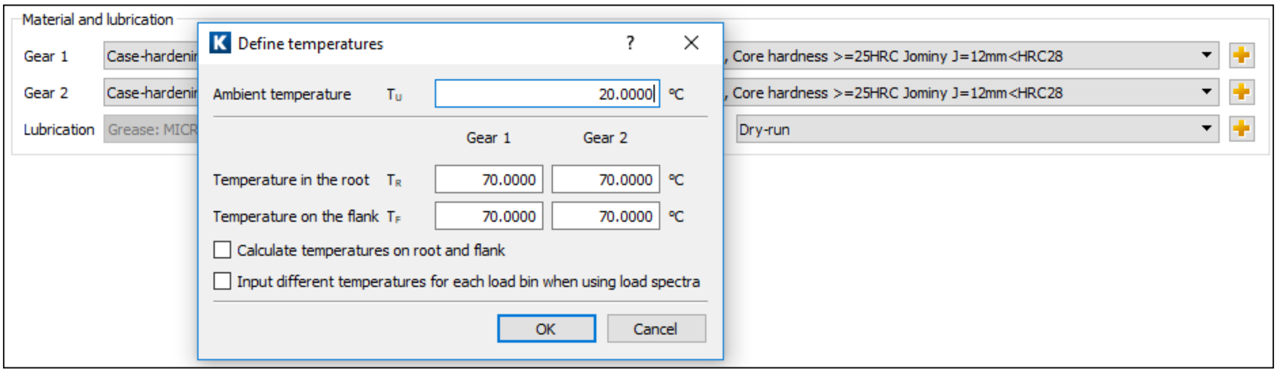


Figure 16. Inputting the temperature for a dry run

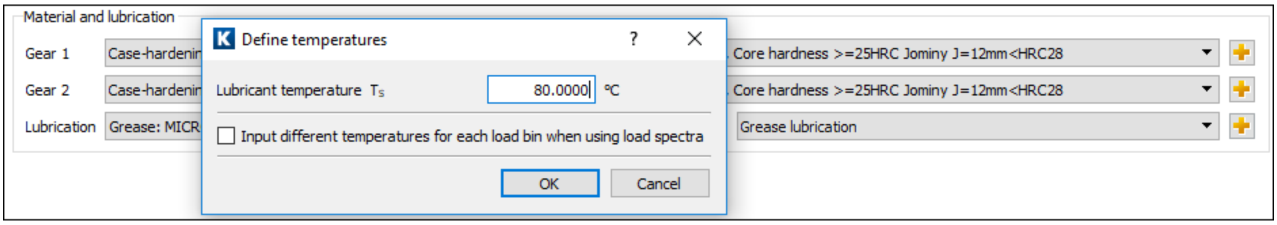


Figure 17. Inputting the temperature for grease lubrication

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.

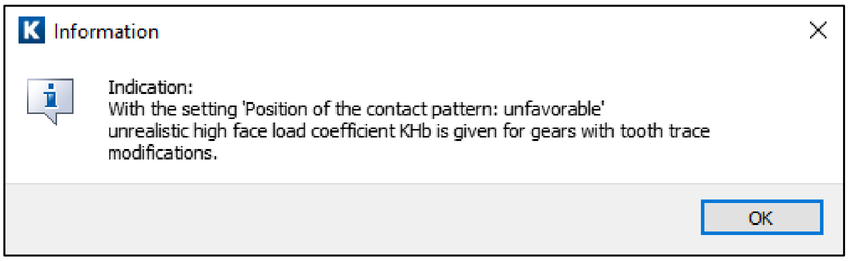


Figure 18. Information window after «Calculation»

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:

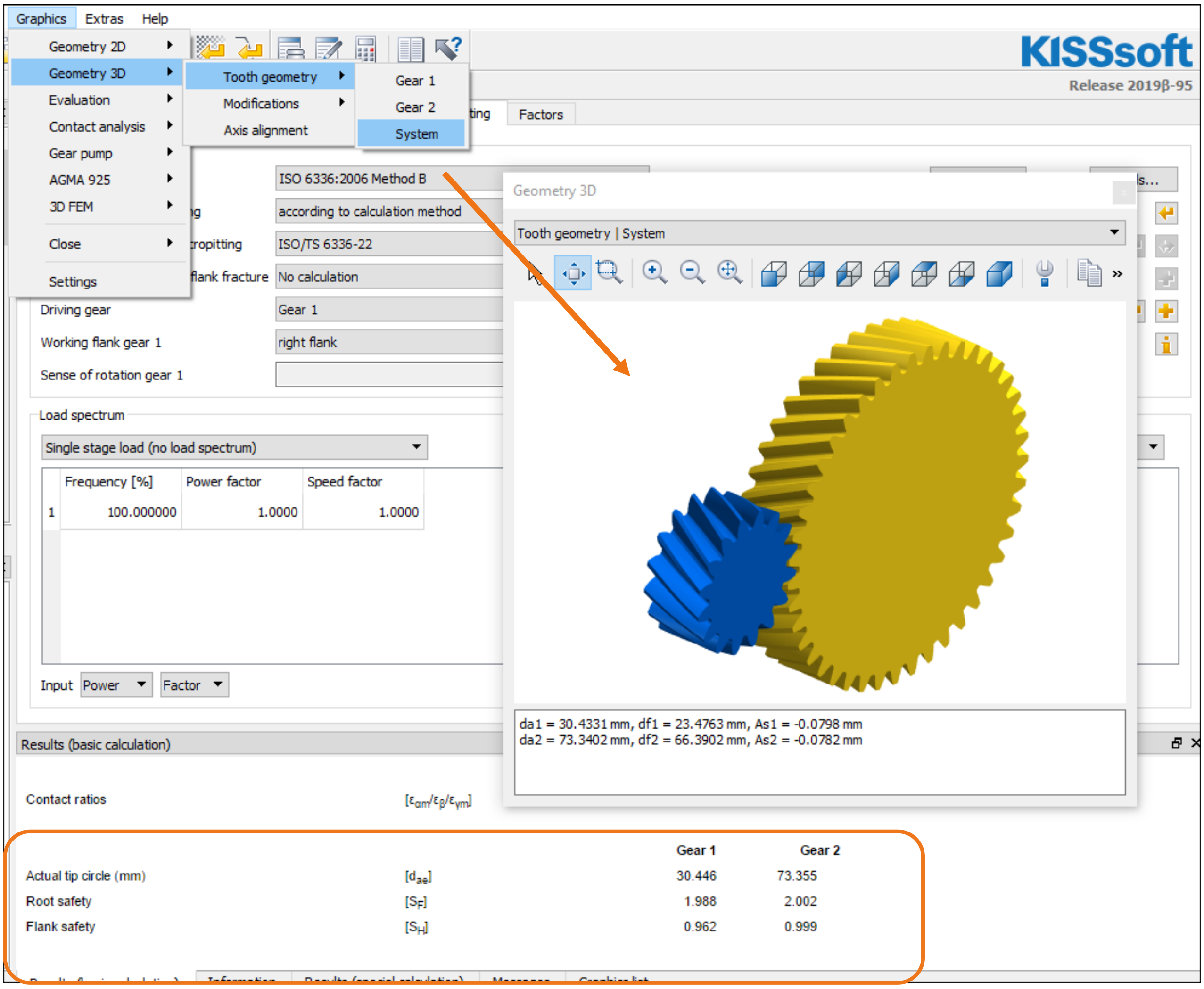


Figure 19. End result of tutorial

2.10 Report

——— KISSsoft Release 2019 &beta ———

KISSsoft-Entwicklungs-Version KISSsoft AG CH-8608 BUBIKON

——— File ———

Name : Tutorial-008

Changed by: KISSsoft on: 17.05.2019 at: 09:13:17

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 KHβ is given for gears with tooth trace modifications.

2-> Mesh gear 1 - 2 :
The face load coefficient is very high.
The formulas for the calculation according ISO or DIN sometimes results
in values that are too high. We recommend that you use the
KISSsoft shaft module to calculate KHβ more accurate.

3-> Hinweis:
Die Berechnung des Fressens wird nicht durchgeführt, da für diesen Schmierstoff keine
Informationen zum Fressen bekannt sind (Fresstest-Verfahren, Laststufe Fresstest).

Calculation of a helical-toothed cylindrical gear pair

Drawing or article number:			
Gear 1:	0.000.0		
Gear 2:	0.000.0		
Calculation method	ISO 6336:2006 Method B		
		------- Gear 1	-------- Gear 2 --
Power (kW)	[P]	3.500	
Speed (1/min)	[n]	2500.0	930.2
Torque (Nm)	[T]	13.4	35.9
Application factor	[KA]	1.35	
Required service life (h)	[H]	750.00	
Gear driving (+) / driven (-)		+	-
Working flank gear 1:	Right flank		
Gear 1 direction of rotation:	Clockwise		

Tooth geometry and material

Geometry calculation according to	ISO 21771:2007, DIN ISO 21771		
		------- Gear 1	-------- Gear 2 --
Center distance (mm)	[a]	48.900	
Center distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	1.5000	
Normal pressure angle (°)	[αn]	20.0000	
Helix angle at reference circle (°)	[β]	25.0000	

Number of teeth	[z]	16	43
Facewidth (mm)	[b]	14.00	14.50
Hand of gear		right	left
Accuracy grade	[Q-ISO 1328:2013]	A 8	A 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

Material treatment according to ISO 6336:2006 Normal, life factors ZNT and YNT >=0.85

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	[ν]	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	[ρfP*]	0.300	(ρfPmax*= 0.472)
Addendum coefficient	[haP*]	1.000	
Tip radius factor	[ρaP*]	0.000	
Protuberance height coefficient	[hprP*]	0.000	
Protuberance angle	[αprP]	0.000	
Tip form height coefficient	[hFaP*]	0.000	
Ramp angle	[αKP]	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	[ρfP*]	0.300	(ρfPmax*= 0.472)
Addendum coefficient	[haP*]	1.000	
Tip radius factor	[ρaP*]	0.000	
Protuberance height coefficient	[hprP*]	0.000	
Protuberance angle	[αprP]	0.000	
Tip form height coefficient	[hFaP*]	0.000	
Ramp angle	[αKP]	0.000	
	not topping		

Summary of reference profile gears:

Dedendum reference profile	[hfP*]	1.250	1.250
Tooth root radius Refer. profile	[ρfP*]	0.300	0.300
Addendum Reference profile	[haP*]	1.000	1.000
Protuberance height coefficient	[hprP*]	0.000	0.000
Protuberance angle (°)	[αprP]	0.000	0.000
Tip form height coefficient	[hFaP*]	0.000	0.000
Ramp angle (°)	[αKP]	0.000	0.000
Type of profile modification:	none (only running-in)		
Tip relief by running in (µm)	[Ca L/R]	2.0 / 2.0	2.0 / 2.0
Lubrication type	Grease lubrication		
Type of grease	Grease: MICROLUBE GB 00		
Lubricant base	Mineral-oil base		
Base oil nominal kinematic viscosity at 40°C (mm²/s)	[v40]	700.00	
Base oil nominal kinematic viscosity at 100°C (mm²/s)	[v100]	35.00	
FZG-Test A/8.3/90 step	[FZGtestA]	0	
Specific density at 15°C (kg/dm³)	[ρ]	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	
Transverse pressure angle (°)	[αt]	21.880	
Working transverse pressure angle (°)	[αwt]	22.100	
	[αwt.e/i]	22.136 / 22.063	
Working pressure angle at normal section (°)	[αwn]	20.199	
Helix angle at operating pitch circle (°)	[βw]	25.034	
Base helix angle (°)	[βb]	23.399	
Reference center distance (mm)	[ad]	48.824	
Sum of profile shift coefficients	[Σxi]	0.0506	
Profile shift coefficient	[x]	0.3215	-0.2709
Tooth thickness, arc, in 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 / 30.421	
(mm)	[da.e/i]		73.355 / 73.325
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.025	
Tip diameter allowances (mm)	[Ada.e/i]		0.000 / -0.030
Tip form diameter (mm)	[dFa]	30.446	73.355
(mm)	[dFa.e/i]	30.446 / 30.421	
(mm)	[dFa.e/i]		73.355 / 73.325
Active tip diameter (mm)	[dNa]	30.446	73.355
	[dNa.e/i]	30.446 / 30.421	
	[dNa.e/i]		73.355 / 73.325
Operating pitch diameter (mm)	[dw]	26.522	71.278
(mm)	[dw.e/i]	26.529 / 26.515	
(mm)	[dw.e/i]		71.296 / 71.260
Root diameter (mm)	[df]	23.696	66.605
Generating Profile shift coefficient	[xE.e/i]	0.2601/ 0.2367	
Generating Profile shift coefficient	[xE.e/i]		-0.3275/ -0.3577
Manufactured root diameter with xE (mm)	[df.e/i]	23.511 / 23.441	
Manufactured root diameter with xE (mm)	[df.e/i]		66.436 / 66.345

Theoretical tip clearance (mm)	[c]	0.375	0.375
Effective tip clearance (mm)	[c.e/i]	0.530 / 0.447	
Effective tip clearance (mm)	[c.e/i]		0.529 / 0.454
Active root diameter (mm)	[dNf]	25.050	68.670
(mm)	[dNf.e/i]	25.077 / 25.037	
(mm)	[dNf.e/i]		68.700 / 68.652
Root form diameter (mm)	[dFf]	24.894	67.921
(mm)	[dFf.e/i]	24.820 / 24.794	
(mm)	[dFf.e/i]		67.816 / 67.761
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.141 / 0.109	
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]		0.470 / 0.418
Involute length (mm)	[l_dFa-l_dFf]	3.125	2.906
Addendum, $m_n(h_{aP}*+x+k)$ (mm)	[ha]	1.982	1.094
(mm)	[ha.e/i]	1.982 / 1.970	
(mm)	[ha.e/i]		1.094 / 1.079
Dedendum (mm)	[hf=mn*(hfP*-x)]	1.393	2.281
(mm)	[hf.e/i]	1.485 / 1.520	
(mm)	[hf.e/i]		2.366 / 2.412
Roll angle at dFa (°)	[χ_dFa.e/i]	41.909 / 41.810	
Roll angle at dFa (°)	[χ_dFa.e/i]		27.702 / 27.642
Roll angle to dNa (°)	[χ_dNa.e/i]	41.909 / 41.810	
Roll angle to dNa (°)	[χ_dNa.e/i]		27.702 / 27.642
Roll angle to dNf (°)	[χ_dNf.e/i]	11.657 / 11.186	
Roll angle to dNf (°)	[χ_dNf.e/i]		16.422 / 16.270
Roll angle at dFf (°)	[χ_dFf.e/i]	8.135 / 7.696	
Roll angle at dFf (°)	[χ_dFf.e/i]		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]	0.815 / 0.771	
(mm)	[san.e/i]		1.174 / 1.127
Normal tooth thickness at tip form circle (mm)	[sFan]	0.874	1.225
(mm)	[sFan.e/i]	0.815 / 0.771	
(mm)	[sFan.e/i]		1.174 / 1.127
Normal space width at root circle (mm)	[efn]	0.000	1.352
(mm)	[efn.e/i]	0.000 / 0.000	
(mm)	[efn.e/i]		1.388 / 1.409
Max. sliding velocity at tip (m/s)	[vga]	1.436	0.919
Specific sliding at the tip	[ζa]	0.610	0.591
Specific sliding at the root	[ζf]	-1.443	-1.567
Mean specific sliding	[ζm]	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	11.150
Length of path of contact (mm)	[ga, e/i]	6.555 (6.588 / 6.466)	
Length T1-A (mm)	[T1A]	2.432 (2.399 / 2.500)	
Length T2-A (mm)	[T2A]		15.965 (15.965 / 15.931)
Length T1-B (mm)	[T1B]	4.162 (4.162 / 4.141)	
Length T2-B (mm)	[T2B]		14.235 (14.202 / 14.289)
Length T1-C (mm)	[T1C]	4.989 (4.980 / 4.998)	
Length T2-C (mm)	[T2C]		13.408 (13.384 / 13.432)
Length T1-D (mm)	[T1D]	7.257 (7.224 / 7.325)	
Length T2-D (mm)	[T2D]		11.140 (11.140 / 11.106)

Length T1-E (mm)	[T1E]	8.987 (8.987 / 8.966)	
Length T2-E (mm)	[T2E]		9.410 (9.377 / 9.464)
Length T1-T2 (mm)	[T1T2]	18.397 (18.364 / 18.430)	
Diameter of single contact point B (mm)	[d-B]	25.945 (25.945 / 25.932)	
Diameter of single contact point B (mm)	[d-B]		71.916 (71.890 / 71.960)
Diameter of single contact point D (mm)	[d-D]	28.540 (28.506 / 28.609)	
Diameter of single contact point D (mm)	[d-D]		69.698 (69.698 / 69.676)
Addendum contact ratio	[ε]	0.829 (0.830 / 0.822)	
Addendum contact ratio	[ε]		0.530 (0.535 / 0.518)
Minimal length of contact line (mm)	[Lmin]	19.611	

Transverse contact ratio	[εα]	1.359
Transverse contact ratio with allowances	[εα.e/m/i]	1.365 / 1.353 / 1.340
Overlap ratio	[εβ]	1.256
Total contact ratio	[εγ]	2.614
Total contact ratio with allowances	[εγ.e/m/i]	2.621 / 2.608 / 2.596

General influence factors

		------- 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]	1.2
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']	12.156
Meshing stiffness (N/mm/µm)	[cγα]	15.426
Meshing stiffness (N/mm/µm)	[cγβ]	13.112
Reduced mass (kg/mm)	[mRed]	0.00235
Resonance speed (min-1)	[nE1]	48315
Resonance ratio (-)	[N]	0.052
Subcritical range		
Running-in value (µm)	[yα]	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 in accordance with Figure 13, ISO 6336-1:2006	[-]	0
0:a), 1:b), 2:c), 3:d), 4:e)		
Coefficient K' according to Figure 13, ISO 6336-1:2006	[K']	0.80
Without stiffening		
Tooth trace deviation (active) (µm)	[Fβy]	16.38
from deformation of shaft (µm)	[fsh*B1]	2.58
fsh (µm) = 3.68 , B1=0.70 , fHβ5 (µm) = 5.50		

Tooth trace:	with end relief		
Position of contact pattern:	not verified or inappropriate		
from production tolerances (µm)	[fmα*B2]	15.84	
B2=			
0.70			
Tooth trace deviation, theoretical (µm)	[Fβx]	19.27	
Running-in value (µm)	[yβ]	2.89	
Dynamic factor	[Kv]	1.057	
Face load factor - flank	[KHβ]	2.043	
- Tooth root	[KFβ]	1.725	
- Scuffing	[KBβ]	2.043	
Transverse load factor - flank	[KHα]	1.385	
- Tooth root	[KFα]	1.385	
- Scuffing	[KBα]	1.385	
Number of load cycles (in mio.)	[NL]	112.500	41.860

Tooth root load capacity

Calculation of Tooth form coefficients according method: B

		------- Gear 1 --------	Gear 2 --
Calculated with generating profile shift coefficient	[xE.e]	0.2601	-0.3275
Tooth form factor	[YF]	1.38	1.68
Stress correction factor	[YS]	2.14	1.84
Load application angle (°)	[αFen]	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)	[ρF]	0.65	0.82
Bending moment arm (-)	[hF/mn]	1.021	1.231
Tooth thickness at root (-)	[sFn/mn]	2.093	2.102
Tooth root radius (-)	[ρF/mn]	0.431	0.545
Load application diameter (mm)	[d_{en}]	32.728	84.649
Calculation cross section diameter (mm)	[d_{sFn}]	23.995	67.030
Tangents on calculation cross section (°)	[α_{sFn}]	30.000	30.000
Notch parameter	[q_s]	2.426	1.930
Helix angle factor	[Yβ]	0.792	
Deep tooth factor	[YDT]	1.000	
Gear rim factor	[YB]	1.00	1.00
Effective facewidth (mm)	[beff]	14.00	14.50
Nominal stress at tooth root (N/mm²)	[σF0]	112.82	113.68
Tooth root stress (N/mm²)	[σF]	384.69	387.60
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]	0.930	0.949
$Y_C*Y_{drelT}*Y_{RrelT}*Y_X*Y_{NT}$		0.889	0.902
Alternating bending factor, mean stress influence coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*σFlim (N/mm²)	[σFE]	860.00	860.00

Permissible tooth root stress σFG/SFmin (N/mm²)	[σFP]	588.17	596.97
Limit strength tooth root (N/mm²)	[σFG]	764.63	776.05
Required safety	[SFmin]	1.30	1.30
Safety for tooth root stress	[SF=σFG/σF]	1.99	2.00
Transmittable power (kW)	[kWRating]	5.35	5.39

Flank safety

		------- Gear 1	-------- Gear 2 --
Zone factor	[ZH]	2.291	
Elasticity factor (√N/mm²)	[ZE]	189.812	
Contact ratio factor	[Zε]	0.858	
Helix angle factor	[Zβ]	1.050	
Effective facewidth (mm)	[beff]	14.00	
Nominal contact stress (N/mm²)	[σH0]	757.63	
Contact stress at operating pitch circle (N/mm²)	[σHw]	1522.46	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Contact stress (N/mm²)	[σHB, σHD]	1522.46	1522.46
Lubrication factor for NL	[ZL]	1.096	1.093
Speed factor for NL	[ZV]	0.974	0.975
Roughness factor for NL	[ZR]	0.937	0.939
Material hardening factor for NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	0.975	1.014
	[ZL*ZV*ZR*ZNT]	0.976	1.014
Limited pitting is permitted: No			
Size factor (flank)	[ZX]	1.000	1.000
Permissible contact stress, σHG/SHmin (N/mm²)	[σHP]	1541.56	1601.73
Pitting stress limit (N/mm²)	[σHG]	1464.48	1521.64
Required safety	[SHmin]	0.95	0.95
Safety factor for contact stress at operating pitch circle	[SHw]	0.96	1.00
Safety against pressure, σHG/σHBD Single contact	[SHBD]	0.96	1.00
Safety regarding transmittable torque	[(SHBD)^2]	0.93	1.00
Transmittable power (kW)	[kWRating]	3.59	3.87

Micropitting according to **ISO/TS 6336-22-1:2018**

Calculation has not been carried out, lubricant: Load stage micropitting test not known

Measurements for tooth thickness

		------- Gear 1	-------- Gear 2 --
Tooth thickness deviation		Own Input	Own Input
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.067 /-0.093	-0.062 /-0.095
Number of teeth spanned	[k]	3.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	11.845	25.272
Actual base tangent length ('span') (mm)	[Wk.e/i]	11.782 / 11.758	25.214 / 25.183
(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, transverse, 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]	2.639 / 2.614	1.999 / 1.966
Reference chordal height from da.m (mm)	[ha]	2.033	1.098
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]	0.013 / -0.013	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.010 / -0.010	
Radial backlash (mm)	[jrw.e/i]	0.272 / 0.165	
Circumferential backlash (transverse section) (mm)	[jtw.e/i]	0.217 / 0.132	
Normal backlash (mm)	[jn.e/i]	0.185 / 0.112	
Torsional angle on input with output fixed:			
Total torsional angle (°)	[j.tSys]	0.9382/0.5710	

Toothing tolerances

		------- Gear 1	-------- Gear 2 --
According to ISO 1328-1:2013, ISO 1328-2:1997			
Accuracy grade	[Q-ISO1328:2013]	A8	A8
Single pitch deviation (µm)	[fptT]	16.00	16.00
Base circle pitch deviation (µm)	[fpbT]	14.80	14.90
Sector pitch deviation over k/8 pitches (µm)	[Fpk/8T]	30.00	32.00
Profile form deviation (µm)	[ffαT]	16.00	16.00
Profile slope deviation (µm)	[fHαT]	13.00	13.00
Total profile deviation (µm)	[FαT]	21.00	21.00
Helix form deviation (µm)	[ffβT]	17.00	18.00
Helix slope deviation (µm)	[fHβT]	16.00	16.00
Total helix deviation (µm)	[FβT]	23.00	24.00
Total cumulative pitch deviation (µm)	[FpT]	45.00	50.00
Adjacent pitch difference (µm)	[fuT]	23.00	23.00
Runout (µm)	[FrT]	41.00	45.00
Single flank composite, total (µm)	[FisT]	61.00	66.00
Single flank composite, tooth-to-tooth (µm)	[fisT]	16.00	16.00
Radial composite, total (µm)	[FidT]	45.00	55.00

Radial composite, tooth-to-tooth (µm)	[fidT]	13.00	13.00

FidT (Fi''), fidT (fi'') according to ISO 1328:1997 calculated with the geometric mean values for mn and d

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

Maximum value for deviation error of axis (µm)	[fΣβ]	45.43	(Fβ=	24.00	)
Maximum value for inclination error of axes (µm)	[fΣδ]	90.86			

Modifying and defining the tooth form

Data for the tooth form calculation :

Calculation of Gear 1

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

haP*= 1.069, hfP*= 1.250, ρfP*= 0.300

Calculation of Gear 2

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

haP*= 1.067, hfP*= 1.250, ρfP*= 0.300

Supplementary data

Maximal possible center distance (eps_a=1.0)	[aMAX]	49.577	
Mass (g)	[m]	63.09	436.69
Total mass (g)	[mGes]	499.78	
Moment of inertia for system, relative to the input:			
calculation without consideration of the exact tooth shape			
Single gears, (da+df)/2...di (kg*m²)	[J]	5.779e-06	0.0002673
System (da+df)/2...di (kg*m²)	[J]	4.279e-05	
Torsional stiffness at driving gear with fixed driven gear:			
Torsional stiffness (MNm/rad)	[cr]	0.028	
Torsion when subjected to nominal torque (°)	[δcr]	0.028	
Mean coefficient of friction (as defined in Niemann)	[μ_m]	0.098	
Wear sliding coef. by Niemann	[ζw]	0.819	
Gear power loss (kW)	[PVZ]	0.061	
Meshing efficiency (%)	[ηz]	98.257	
Sound pressure level according to Masuda, without contact analysis			
	[dB(A)]	50.7	

Indications for the manufacturing by wire cutting:			
Deviation from theoretical tooth trace (µm)	[WireErr]	400.3	149.6
Permissible deviation (µm)	[Fb/2]	11.5	12.0

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]	1126	
Tooth root service life (h)	[HFatt]	1e+06	1e+06
Tooth flank service life (h)	[HHatt]	1126	3027

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	0.0000	66.5837	24.7753

Damage calculated on basis of system service life [Hatt] (1126.4 h)

F1%	F2%	H1%	H2%
0.00	0.0000	100.0000	37.2093

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

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

Gear		fac	b	t0	T	R(H)%
1	Tooth root	150000	1.7	9.654e+29	1.484e+30	100.00
1	Tooth flank	150000	1.3	1.523e+08	7.256e+08	100.00
2	Tooth root	55814	1.7	9.654e+29	1.484e+30	100.00
2	Tooth flank	55814	1.3	1.523e+08	7.256e+08	100.00

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

Remarks:

- Specifications with [.e/i] imply: Maximum [e] and minimum value [i] for
  Taking all tolerances into account
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness allowance

are taken into account.
The maximum and minimum clearance according to
the largest or smallest allowances are defined..

The calculation is performed for the operating pitch circle.

- Calculation of Zbet according to Corrigendum 1 ISO 6336-2:2008 with Zbet = 1/(COS(beta)^0.5)
- Details of calculation method:
  cγ according to Method B
  Kv according to Method B
  KHβ and KFβ according to Method C
  fmα according to Equation 64, fsh according to 57/58, Fβx according to 52/53/54
  KHα, KFα according to Method B
- The logarithmically interpolated value taken from the values for the fatigue strength and the static strength, based on the number of load cycles, is used for coefficients ZL, ZV, ZR, ZW, ZX, YdrelT, YRrelT and YX..

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