KISSsoft 03/2013 – 教程 8

圆柱齿轮副的验证

KISSsoft AG
Rosengartenstrasse 4
8608 Bubikon
Switzerland

Tel: +41 55 254 20 50
Fax: +41 55 254 20 51
info@KISSsoft.AG
www.KISSsoft.AG

SHARING KNOWLEDGE

目录

1 任务

本教程将会介绍如何将已知的数据输入到 KISSsoft 软件中。为此，用户必须执行以下几个步骤以便来准确校核圆柱齿轮副。

- 输入关键的数据到 KISSsoft 中；
- 计算依据 ISO 6336；
- 记录计算结果。

1.1 输入数据

对于下面数据的输入方法，请参阅本教程系列的第二章内容。

1.1.1 工况

功率 [P]	3.5	kW
转速 [n]	2500	1/min (Gear1)
应用系数 [K_A]	1.35	
使用寿命 [H]	750	h

1.1.2 几何

法向模数[m_n]	1.5	mm
分度圆上的螺旋角[ß]	25	°
法向截面的压力角 [α_n]	20	°
齿数[z] Gear1/Gear2	16 / 43	
齿宽[b] Gear1/Gear2	14 / 14.5	mm
中心距 [a]	48.9 ±0.03	mm
变位系数 [x] Gear 1 (小齿轮)	0.3215	

1.1.3 基准齿廓

	齿根高系数 [h^*_{FP}]	齿根圆角半径系数 [ρ^*_{fP}]	齿顶高系数 h^*_{aP}]
Gear 1 (pinion)	1.25	0.3	1.0
Gear 2	1.25	0.3	1.0

1.1.4 其他数据

材料：

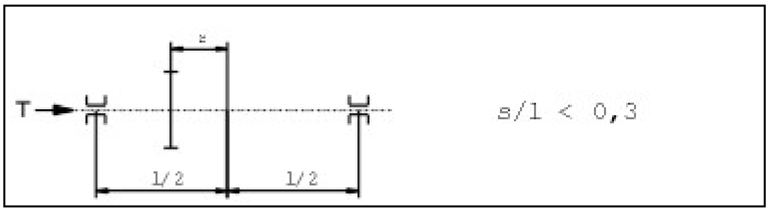
	材料	硬度	σFlim	σHlim
Gear 1 (小齿轮)	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2
Gear 2	15 CrNi 6	case-hardened HRC 60	430 N/mm^2	1500 N/mm^2

润滑：

油液润滑	Microlube GB 00	80 °C

公法线公差范围：

	跨测齿数 [k]	最大公法线长度 [Wkmax]	最小公法线长度[Wkmin]
Gear 1 (小齿轮)	3	11.782 mm	11.758 mm
Gear 2	6	25.214 mm	25.183 mm

精度等级 [Q] (DIN 6336)	8 / 8
齿轮修形	齿端修薄
接触斑点	not verified or inappropriate
小齿轮轴的性质	 轴上负载情况 ISO 6336 图 13a；l = 53 mm; s = 5.9 mm; dsh = 14 mm

2 解决方案

2.1 启动程序

一旦 KISSsoft 安装和激活后，用户可依次点击”开始→程序→KISSsoft 03-2013→KISSsoft”打开程序。进入用户操作界面后，界面如下图所示：

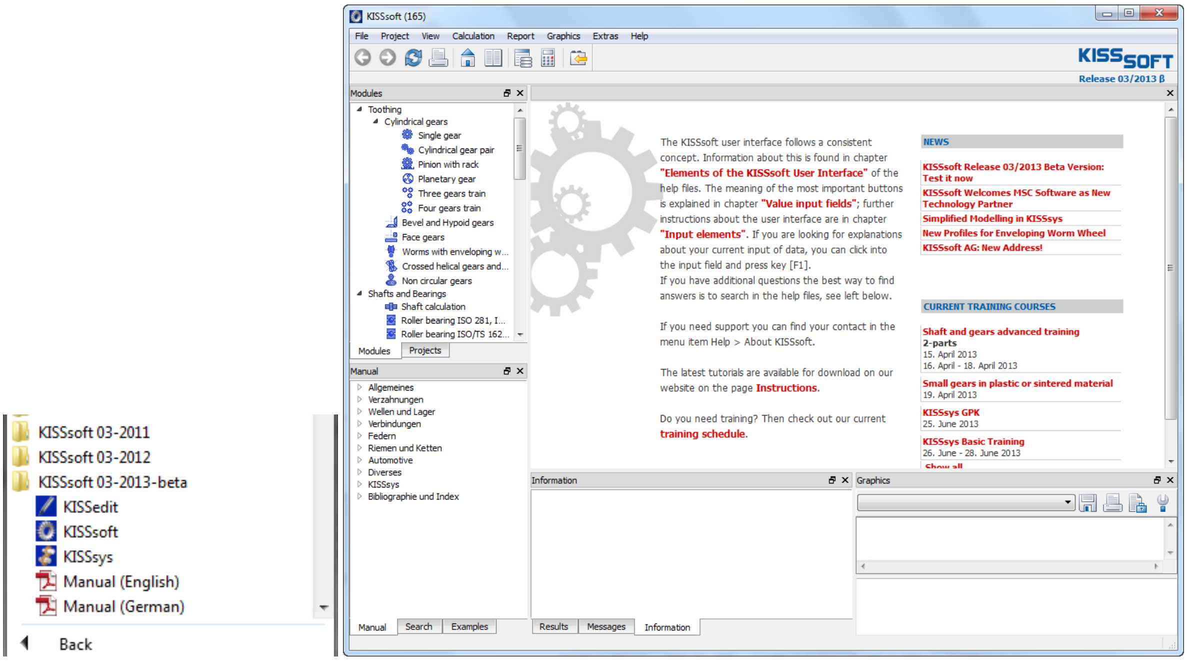


图 1. KISSsoft 的初始界面

2.2 选择计算模块

在模型树里，点击“Modules—> cylindrical gear pairs”打开齿轮副计算模块。

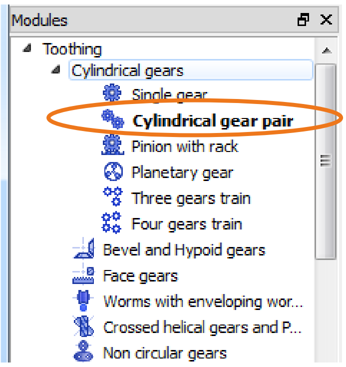


图 2. 打开齿轮副模块

KISSsoft 圆柱齿轮的计算界面如下所示：

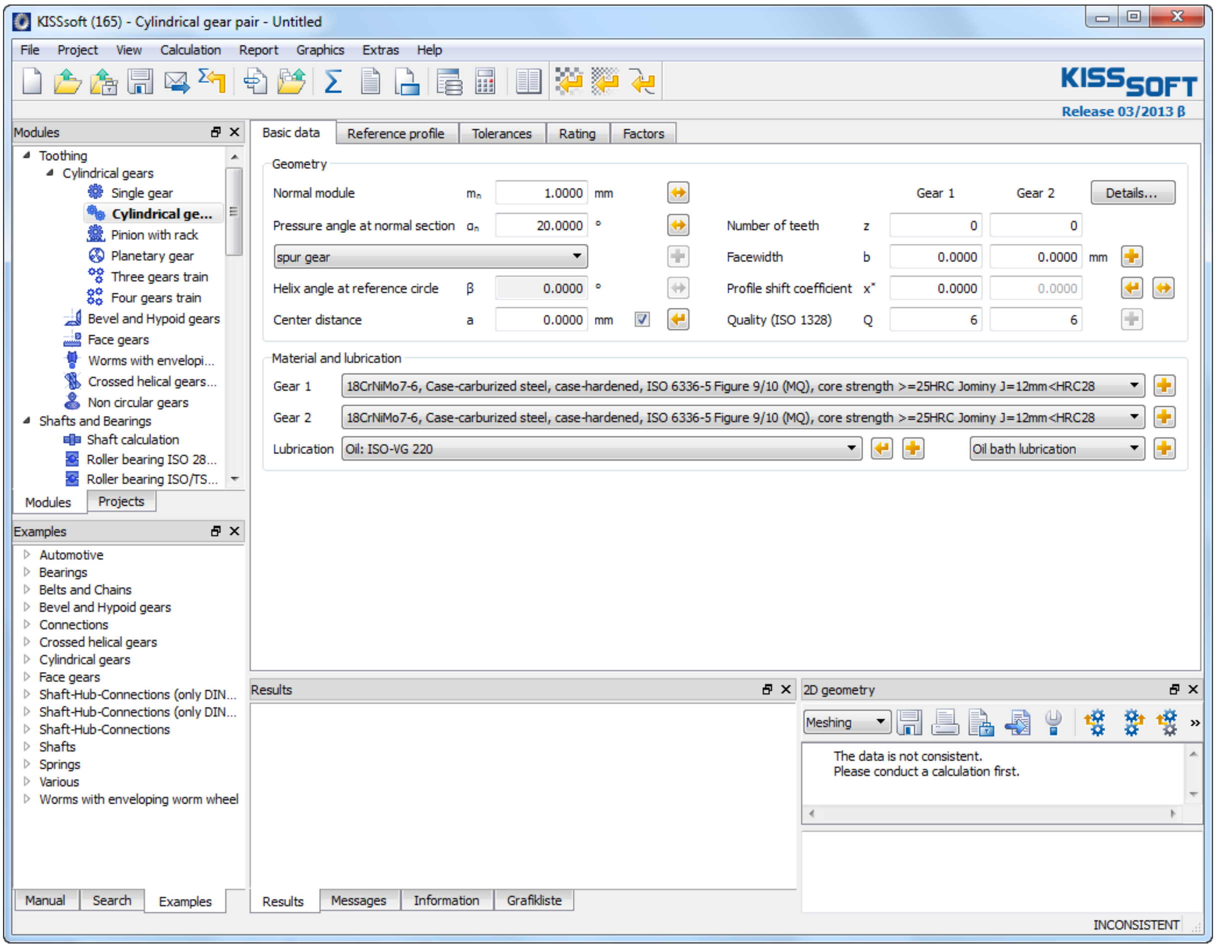


图 3. 圆柱齿轮副数据输入界面

下面的章节将详细介绍如何输入齿轮副参数。

2.3 齿轮副的几何信息

首先，在“Basic data”,—>“Geometry”一栏里，输入法向模数(1.5mm)、压力角(20°)、螺旋角(25°)、中心距(48.9mm)、齿数(16/43)、齿宽(14/14.5mm)、变位系数(0.3215 /…)，精度等级(8 / 8)。在此说明，用户不能直接输入齿轮 2 的变位系数，因为这个值可根据中心距和齿轮 1 的变位系数自动计算出来。然而，用户也可以点击按钮选择符合实际需求的值。还有无论使用哪一种计算方法，都可以设置适合要求的精度等级。

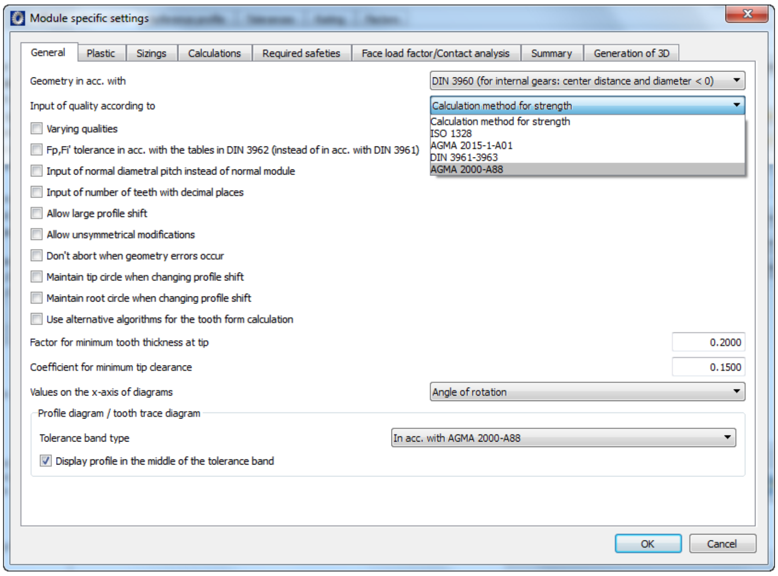


图 4.　　特项参数设置窗口 （精度等级并不依据计算方法来定）

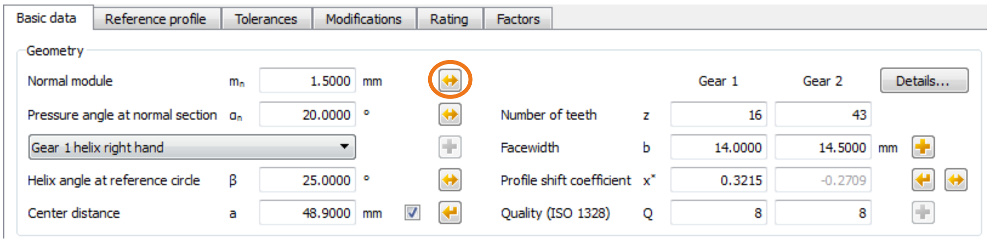


图 5.　　几何参数输入窗口

点击输入框右侧的转换按钮，可以输入其它的参数来求得特定的值。如果需要输入一个角度，可以在角度输入框处右击鼠标来打开小窗口，然后在其中输入角、分、秒，如下图所示：

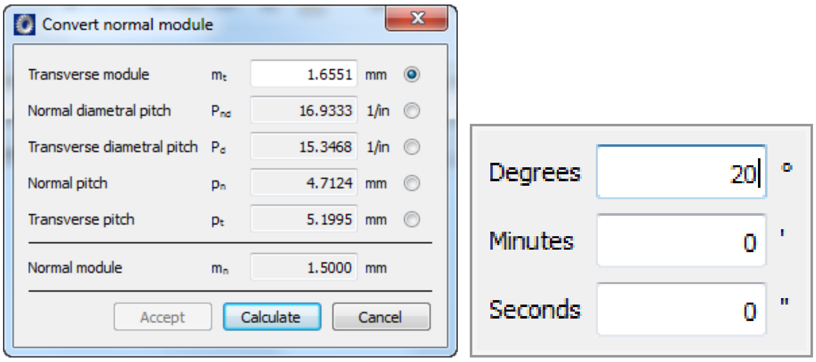


图 6.　　输入其他参数以求特定值

2.4 定义工况以及计算方法

接下来，在“Rating”窗口里，输入功率、扭矩、使用寿命(750 小时)以及应用系数(1.35)。在本案例中，转矩是由功率(3.5 kW)和转速(25001/min)间接求得。然而，在不同的案例中，如果想输入的扭矩同时计算功率的话，只需点击按钮，软件会自动根据扭矩来计算出功率。在“Details”还可以输入更多计算强度的参数。正确地设置参考齿轮 (齿轮 1)的负载，也是同样重要的。在窗口左上角，从计算方法的下拉列表中可以选择合适的计算方法。在本案例中，根据 ISO 6336 方法 B 来计算。

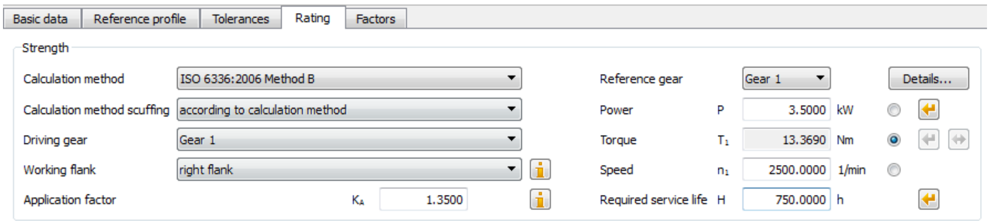


图 7.　　输入工况以及强度

在“Factors”输入窗口里，“Face load factor/contact analysis”一栏下，用户可以直接输入齿面载荷分布系数 $K_{H\beta}$ (在下拉列表里选择“Own Input”)或者点击按钮来定义。用户必须在“Position of contact pattern”的下拉菜单里，选择“not verified or inappropriate”。

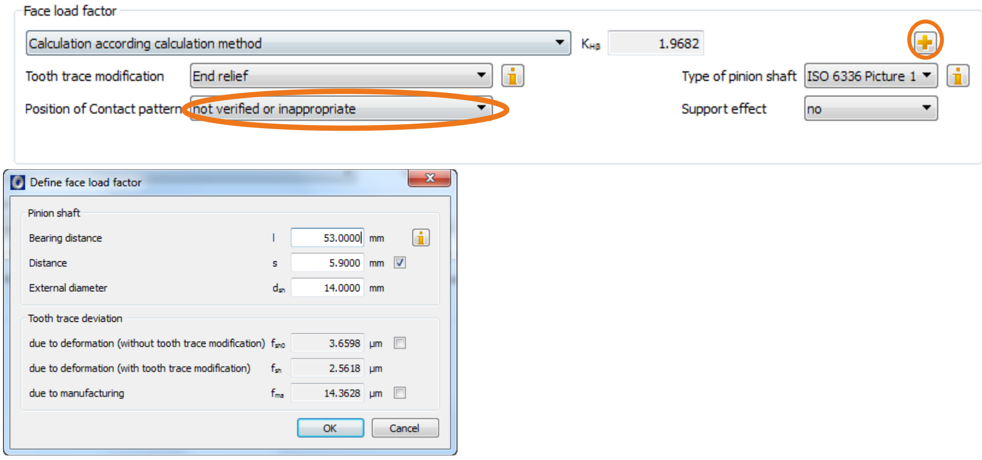


图 8.　　定义齿面载荷分布系数

为计算负载系数，用户必须输入：齿轮修形、轴配置(如图 8)。为此，点击“Type of pinion shaft”右边的按钮，就会看到下图，本案例对应图 9。然后在图 8 所示窗口中选中复选框按钮，用户就可以输入距离 l 和 s 的值。

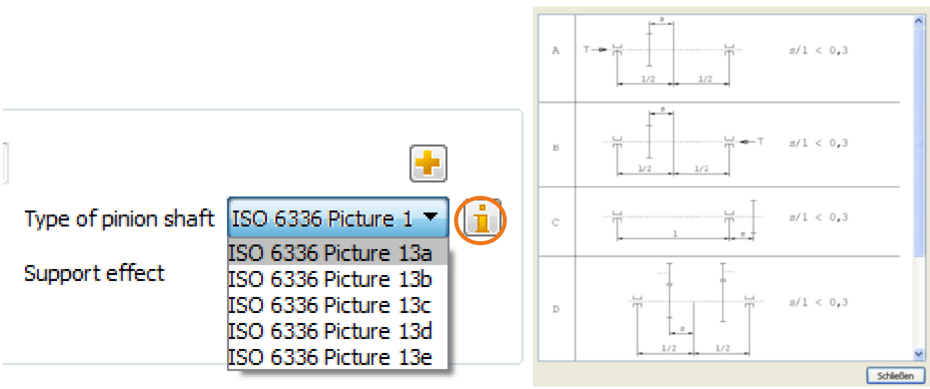


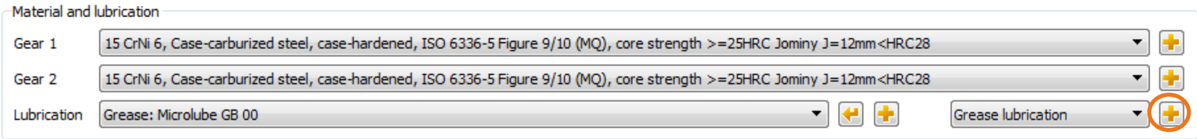
图 9.　　定义齿面载荷分布系数

注意：

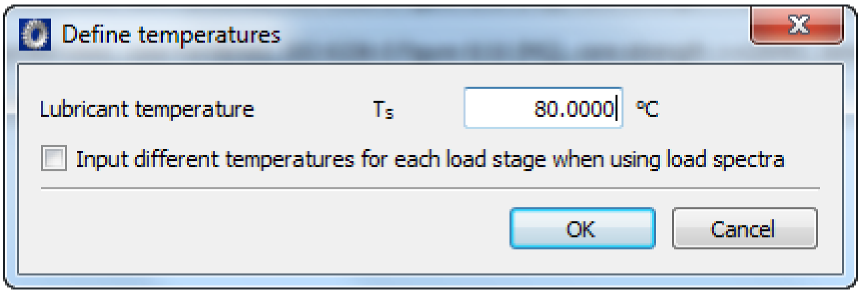
用户需要输入轴的配置来计算齿面载荷分布系数 KHß。ISO 6336(或 DIN 3990)提供了 5 种不同的配置，用户可以选择需要的一种。这些配置分别是从图 A 到 E，如图 9 所示。齿面载荷分布系数 $K_{H\beta}$ 显示了载荷在沿齿宽方向非线性分布的情况。用户也可以从 KISSsoft AG 里获得进一步的教程，请查看文档“kisssoft-anl-072-E-Contact-Analysis-Cylindrical-Gears 圆柱齿轮副接触分析.pdf”。

2.5 材料和润滑

在“Basic data”窗口里，“Material and lubrication”一栏下，从齿轮材料的下拉列表选择所需的材料。15 Cr Ni 6, case-carburized 钢被用于此案例。同时用户也可以选择润滑液以及润滑类型。



点击按钮，可以定义润滑液温度。



2.6 基准齿廓

在“Reference profile”窗口里，用户现在可以输入进一步的数据，比如齿轮 1 和齿轮 2 的基准齿廓形状，包括齿根系数、齿根半径系数和齿顶高系数等。

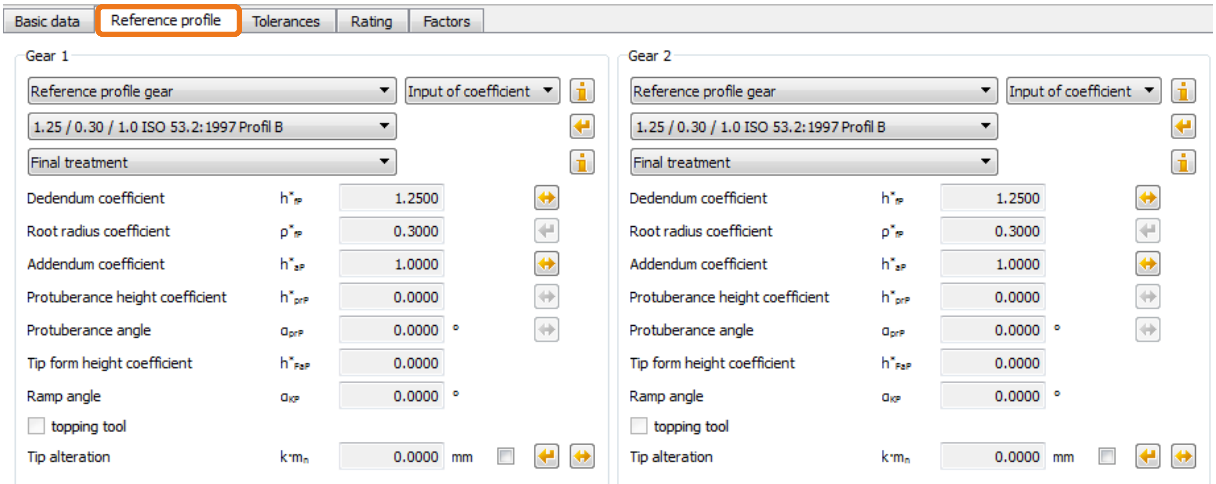


图 10. 基准齿廓输入窗口

2.7 公差

在“Tolerances”窗口里，用户可以定义齿厚偏差。在已验证的案例中，通常只要规定有效公法线长度和齿数的公差。然后输入这两参数，KISSsoft 将自动计算出正确的齿厚公差。在本案例中，用户还可以输入中心距公差（在下拉列表里选择所需标准或者自己输入想要的参数）。

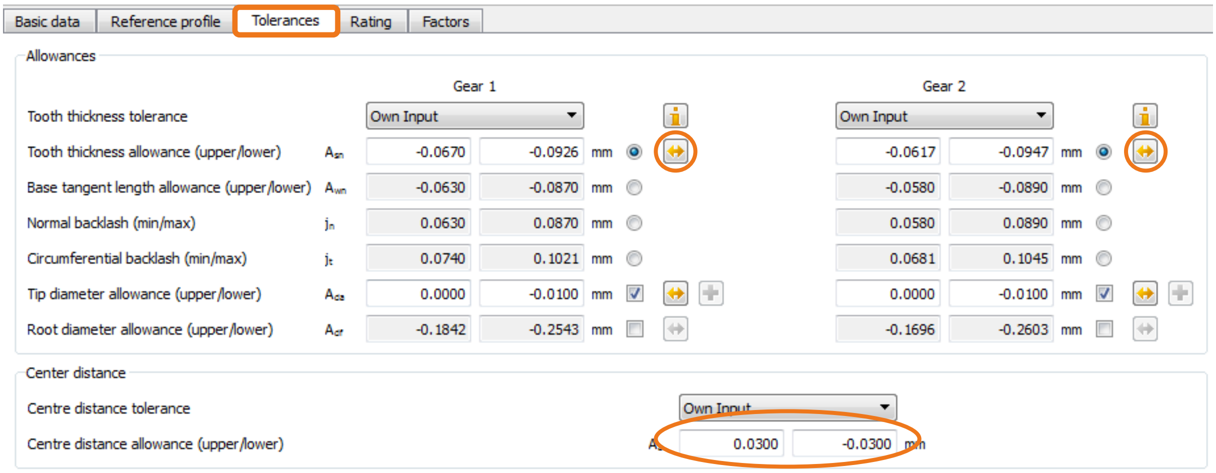


图 11.　　公差输入窗口

在“tolerances”窗口里，点击“tooth thickness tolerances”旁边的 按钮，弹出对话框，然后输入公法线长度的公差区间。

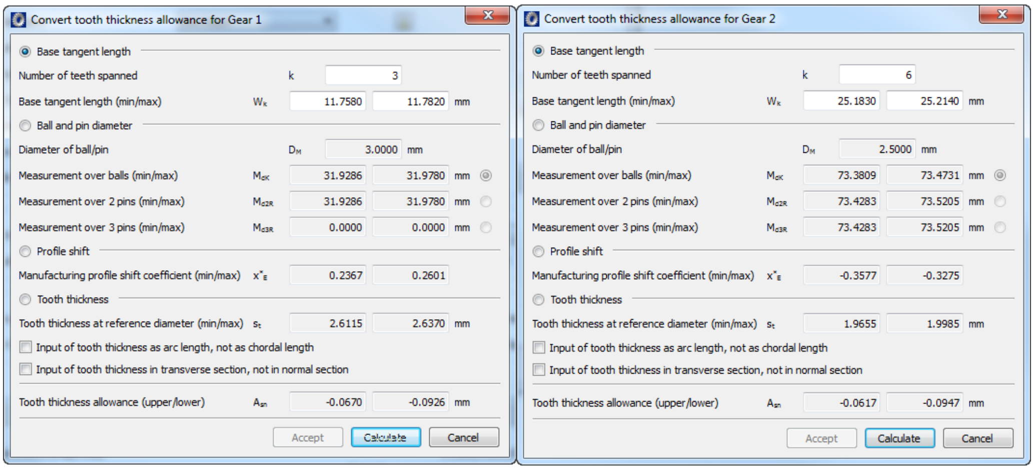


图 12.　　公法线长度的计算

用户现在可以输入跨齿数和公法线长度(最小/最大)。然后点击计算，再点击“Accept”，计算出的数值就会转移到主窗口里。

注意：

1. 在两齿轮的变位定义好之前，不能输入偏差，否则就会得到不正确的值，并且必须重复选型。
2. 用户可以在步骤 2 和 3 之间改变跨齿数。为此，在“Settings”里，点中“Number of teeth spanned” 右侧的复选框，输入数值，或者在转换窗口里直接输入数值。

图 13.　　跨齿数的设置窗口

2.8 润滑

在“Basic data”窗口里，“Material and lubrication”一栏下，可以定义润滑温度以及润滑类型。当输入润滑温度时，用户也可以相应的下拉列表里选择其他润滑类型和润滑液的类型。

在“Lubricant temperature”里输入的数值定义了齿轮的基本温度。出于这个原因，“Lubricant temperature”也是计算有效的润滑剂粘度的重要参数。“Ambient temperature”不影响计算(参见 2.5 材料和润滑)。

“Ambient temperature”输入框只定义在干燥环境下运行的基本温度。在这种情况下，齿轮体的温度将会影响齿轮的计算结果。

注意：

- 蜗杆齿轮：“Ambient temperature”是用于计算温度安全系数
- 塑料齿轮：塑料齿轮的强度计算在很大程度上取决于齿轮体的温度，为此用户必须输入对应的温度。

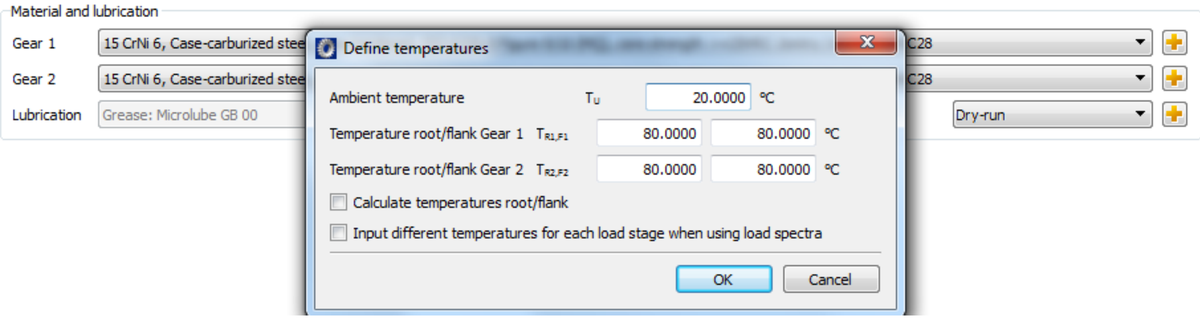


图 14. 干燥环境下运行的温度

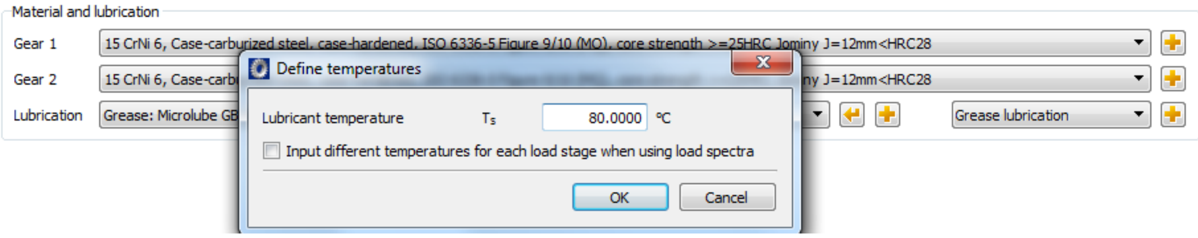


图 15. 润滑油的温度输入

2.9 计算

点击按钮或按“F5”来计算强度结果。结果显示接触斑点不理想，该信息意味着 KHß 值太高。

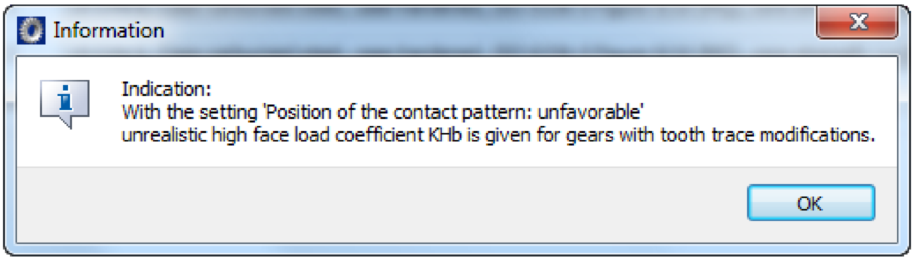


图 16. 计算后弹出的信息框

这也意味着在计算 $K_{Hß}$ 时，是以不真实的接触斑点来计算的。当在车间测试接触斑点时，用户就可以看到这个假设过于保守的或者非现实性。

如果用户已经按教程操作了，计算出的强度值就会如图 17 所示。

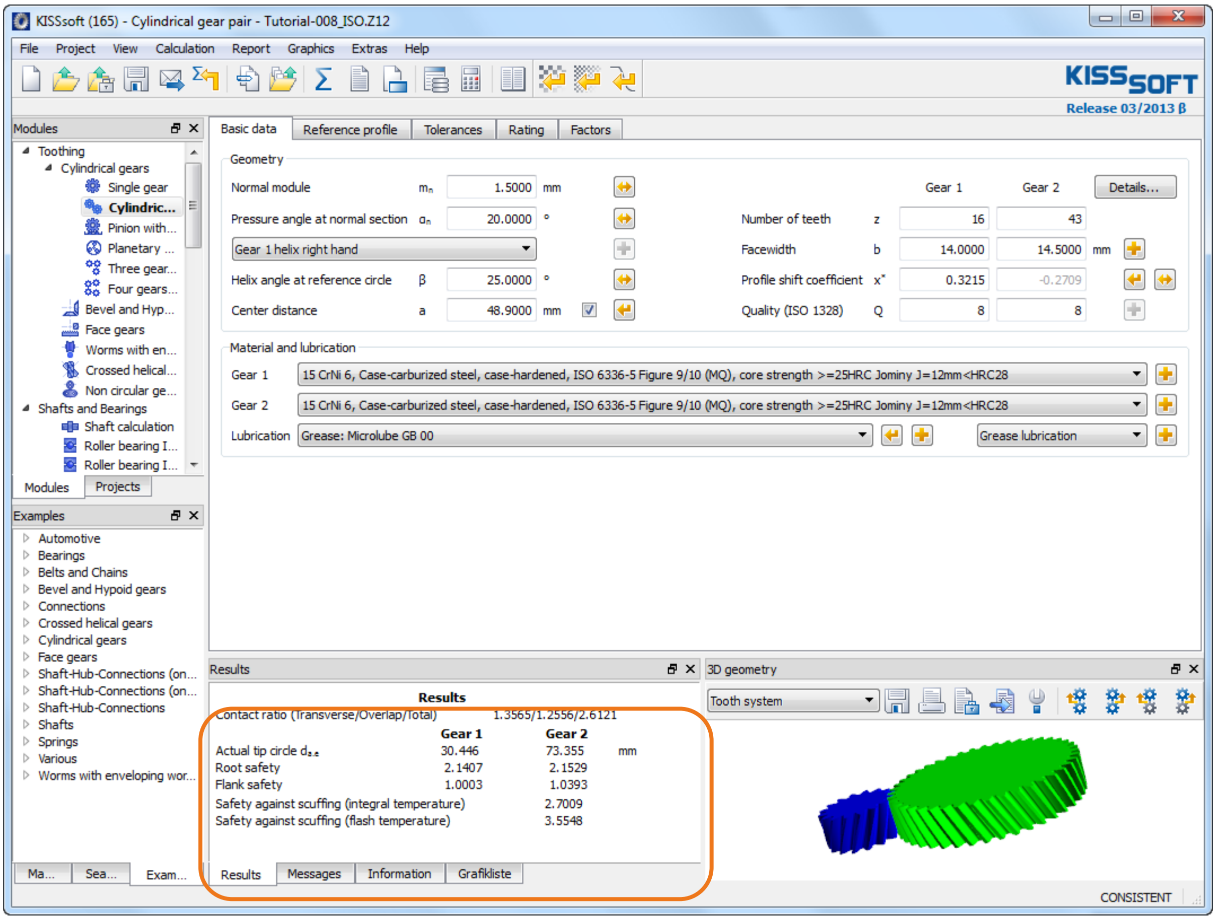


图 17. 教程最后得出的结果

2.10 报告

——— KISSsoft Release 03/2013 ———

KISSsoft-Entwicklungs-Version KISSsoft AG CH-8608 BUBIKON

——— File ———

Name : Tutorial-008_ISO
Description: KISSsoft example
Changed by: ho am: 04.03.2013 um: 08:42:42

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

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

CALCULATION OF A HELICAL GEAR PAIR

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

Calculation method ISO 6336:2006 Method B

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

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
DIN 3960:1987)

		------- GEAR 1 --------	GEAR 2 --
Center distance (mm)	[a]	48.900	
Centre distance allowances (mm)	[Aa.e/i]	0.030 / -0.030	
Normal module (mm)	[mn]	1.5000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	16	43
Facewidth (mm)	[b]	14.00	14.50
Hand of gear	right	left	
Accuracy grade	[Q-ISO 1328:1995]	8	8
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

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

		GEAR 1	GEAR 2
Surface hardness		HRC 60	HRC 60

Material quality according to ISO 6336:2006 Normal (Life factors ZNT and YNT >=0.85)

Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1000.00	1000.00
Yield point (N/mm²)	[Rp]	685.00	685.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.30 / 1.0 ISO 53.2:1997 Profil B

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

not topping

Tool or reference profile of gear 2 :

Reference profile 1.25 / 0.30 / 1.0 ISO 53.2:1997 Profil B

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

not topping

Summary of reference profile gears:

Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.300	0.300
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[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]	0.900

Grease temperature (°C)	[TS]	80.000	

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

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

Base pitch (mm)	[pbt]	4.825
Transverse pitch on contact-path (mm)	[pet]	4.825
Lead height (mm)	[pz]	178.408 479.470
Axial pitch (mm)	[px]	11.150
Length of path of contact (mm)	[ga, e/i]	6.555 (6.635 / 6.456)
Length T1-A, T2-A (mm)	[T1A, T2A]	2.432(2.352/ 2.523) 15.965(15.965/ 15.954)
Length T1-B (mm)	[T1B, T2B]	4.162(4.162/ 4.154) 14.235(14.155/ 14.323)
Length T1-C (mm)	[T1C, T2C]	4.989(4.967/ 5.011) 13.408(13.350/ 13.466)
Length T1-D (mm)	[T1D, T2D]	7.257(7.177/ 7.348) 11.140(11.140/ 11.129)
Length T1-E (mm)	[T1E, T2E]	8.987(8.987/ 8.979) 9.410(9.330/ 9.498)
Length T1-T2 (mm)	[T1T2]	18.397 (18.317 / 18.477)
Diameter of single contact point B (mm)	[d-B]	25.945(25.945/ 25.940) 71.916(71.853/ 71.986)
Diameter of single contact point D (mm)	[d-D]	28.540(28.459/ 28.633) 69.698(69.698/ 69.691)
Addendum contact ratio	[eps]	0.829(0.833/ 0.822) 0.530(0.542/ 0.516)
Minimal length of contact line (mm)	[Lmin]	19.611
Transverse contact ratio	[eps_a]	1.359
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.375 / 1.357 / 1.338
Overlap ratio	[eps_b]	1.256
Total contact ratio	[eps_g]	2.614
Total contact ratio with allowances	[eps_g.e/m/i]	2.631 / 2.612 / 2.594

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 -------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	1009.7
Axial force (N)	[Fa]	470.8
Radial force (N)	[Fr]	405.5
Normal force (N)	[Fnorm]	1185.6
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	72.12
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	1008.1
Axial force (N)	[Faw]	470.8
Radial force (N)	[Frw]	409.4
Circumferential speed pitch d.. (m/sec)	[v]	3.47
Running-in value (µm)	[yp]	1.0
Running-in value (µm)	[yf]	1.0
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	12.156
Meshing stiffness (N/mm/µm)	[cgalf]	15.426
Meshing stiffness (N/mm/µm)	[cgbet]	13.112
Reduced mass (kg/mm)	[mRed]	0.00235
Resonance speed (min-1)	[nE1]	48315
Nominal speed (-)	[N]	0.052
Subcritical range		
Running-in value (µm)	[ya]	1.0
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 16, 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 support effect			
Tooth trace deviation (active) (µm)	[Fby]	15.10	
from deformation of shaft (µm)	[fsh*B1]	2.56	
Tooth trace: with end relief			
Position of Contact pattern: not verified or inappropriate			
from production tolerances (µm)	[fma*B2]	14.36	
Tooth trace deviation, theoretical (µm)	[Fbx]	17.77	
Running-in value (µm)	[yb]	2.67	
Dynamic factor	[KV]	1.050	
Face load factor - flank	[KHb]	1.968	
- Tooth root	[KFb]	1.676	
- Scuffing	[KBb]	1.968	
Transverse load factor - flank	[KHa]	1.338	
- Tooth root	[KFa]	1.338	
- Scuffing	[KBa]	1.338	
Helical load factor scuffing	[Kbg]	1.242	
Number of load cycles (in mio.)	[NL]	112.500	41.860

IF (@UNKNOWN DATADICT)
IF (@UNKNOWN DATADICT)

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
Tooth form factors calculated with manufacturing profile shift xE.e

		------- GEAR 1 --------	GEAR 2 --
Tooth form factor	[YF]	1.37	1.67
Stress correction factor	[YS]	2.15	1.84
Working angle (°)	[alfFen]	21.64	18.97
Bending lever arm (mm)	[hF]	1.52	1.84
Tooth thickness at root (mm)	[sFn]	3.14	3.15
Tooth root radius (mm)	[roF]	0.65	0.82

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

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	0.792	
Deep tooth factor	[YDT]	1.000	
Gear rim factor	[YB]	1.000	1.000
Effective facewidth (mm)	[beff]	14.00	14.50
Nominal stress at tooth root (N/mm²)	[sigF0]	112.30	113.33
Tooth root stress (N/mm²)	[sigF]	357.19	360.47

Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	0.999	0.994
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	1.000	1.000
Finite life factor	[YNT]	0.930	0.949
	[YdrelT*YRrelT*YX*YNT]	0.889	0.902
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	860.00	860.00
Limit strength tooth root	[sigFG]	764.63	776.06
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	588.17	596.97

Required safety	[SFmin]	1.30	1.30
Safety for Tooth root stress	[SF=sigFG/sigF]	2.14	2.15
Transmittable power (kW)	[kWRating]	5.76	5.80

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.291	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.858	
Helix angle factor	[Zbet]	1.050	
Effective facewidth (mm)	[beff]	14.00	
Nominal flank pressure (N/mm²)	[sigH0]	757.63	
Surface pressure at operating pitch circle (N/mm²)			
	[sigHw]	1464.09	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	1464.09	1464.09
Lubrication coefficient at NL	[ZL]	1.096	1.093
Speed coefficient at NL	[ZV]	0.974	0.975
Roughness coefficient at NL	[ZR]	0.937	0.939
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	0.975	1.014
	[ZL*ZV*ZR*ZNT]	0.976	1.014
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm²)	[sigHG]	1464.48	1521.64
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1541.56	1601.73
Safety for surface pressure at operating pitch circle			
	[SHw]	1.00	1.04
Required safety	[SHmin]	0.95	0.95
Transmittable power (kW)	[kWRating]	3.88	4.19
Safety for stress at single tooth contact	[SHBD=sigHG/sigH]	1.00	1.04
(Safety regarding nominal torque)	[(SHBD)^2]	1.00	1.08

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

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

5. STRENGTH AGAINST SCUFFING

Calculation method according to
ISO TR 13989:2000

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

Lubrication coefficient (for lubrication type)	[XS]	1.200
Multiple meshing factor	[Xmp]	1.000
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]	6.31	
Effective facewidth (mm)	[beff]	14.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	269.330	
(Kbg = 1.242, wBt*Kbg = 334.533)			
Pressure angle factor (eps1: 0.829, eps2: 0.530)	[Xalfbet]	0.990	

Flash temperature-criteria		
Lubricant factor	[XL]	0.812
Tooth mass temperature (°C)	[theMi]	93.82
theM = theoil + XS*0.47*Xmp*theflm	[theflm]	24.50
Scuffing temperature (°C)	[theS]	343.17
Coordinate gamma (point of highest temp.)	[Gamma]	0.788
[Gamma.A]=-0.513 [Gamma.E]=0.801		
Highest contact temp. (°C)	[theB]	154.03
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Approach factor	[XJ]	1.000
Load sharing factor	[XGam]	0.920
Dynamic viscosity (mPa*s)	[etaM]	64.01 (80.0 °C)
Coefficient of friction	[mym]	0.074
Required safety	[SBmin]	2.000
Safety factor for scuffing (flash-temp)	[SB]	3.555

Integral temperature-criteria		
Lubricant factor	[XL]	1.000
Tooth mass temperature (°C)	[theM-C]	98.75
theM-C = theoil + XS*0.70*theflaint	[theflaint]	22.32
Integral scuffing temperature (°C)	[theSint]	357.16
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Running-in factor (well run in)	[XE]	1.000
Contact ratio factor	[Xeps]	0.282
Dynamic viscosity (mPa*s)	[etaOil]	64.01 (80.0 °C)
Averaged coefficient of friction	[mym]	0.101
Geometry factor	[XBE]	0.364
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.261
Integral tooth flank temperature (°C)	[theint]	132.24
Required safety	[SSmin]	1.800
Safety factor for scuffing (intg.-temp.)	[SSint]	2.701
Safety referring to transferred torque	[SSL]	5.306

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		Own Input	Own Input
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.067 / -0.093	-0.062 / -0.095
Number of teeth spanned	[k]	3.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	11.845	25.272
Actual base tangent length ('span') (mm)	[Wk.e/i]	11.782 / 11.758	25.214 / 25.183
Diameter of contact point (mm)	[dMWk.m]	26.843	69.973
Theoretical diameter of ball/pin (mm)	[DM]	2.789	2.496
Eff. Diameter of ball/pin (mm)	[DMeff]	3.000	2.500

Theor. dim. centre to ball (mm)	[MrK]	16.053	36.846
Actual dimension centre to ball (mm)	[MrK.e/i]	15.989 / 15.964	36.760 / 36.714
Diameter of contact point (mm)	[dMMr.m]	27.596	70.166
Diametral measurement over two balls without clearance (mm)			
	[MdK]	32.107	73.644
Actual dimension over balls (mm)	[MdK.e/i]	31.978 / 31.929	73.473 / 73.381
Diametral measurement over rolls without clearance (mm)			
	[MdR]	32.107	73.691
Actual dimension over rolls (mm)	[MdR.e/i]	31.978 / 31.929	73.520 / 73.428
Dimensions over 3 rolls without clearance (mm)	[Md3R]	0.000	73.691
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	73.520 / 73.428
Chordal tooth thickness (no backlash) (mm)	['sn]	2.704	2.060
Actual chordal tooth thickness (mm)	['sn.e/i]	2.637 / 2.611	1.998 / 1.965
Reference chordal height from da.m (mm)	[ha]	2.037	1.103
Tooth thickness (Arc) (mm)	[sn]	2.707	2.060
(mm)	[sn.e/i]	2.640 / 2.615	1.999 / 1.966
Backlash free center distance (mm)	[aControl.e/i]	48.723 / 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
Centre distance allowances (mm)	[Aa.e/i]	0.030 / -0.030	
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.024 / -0.024	
Radial clearance (mm)	[jr]	0.289 / 0.147	
Circumferential backlash (transverse section) (mm)			
	[jt]	0.231 / 0.118	
Torsional angle for fixed gear 1 (°)		0.3725 / 0.1899	
Normal backlash (mm)	[jn]	0.197 / 0.100	

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to ISO 1328:1995:			
Accuracy grade	[Q-ISO1328]	8	8
Single pitch deviation (µm)	[fpt]	14.00	15.00
Base circle pitch deviation (µm)	[fpb]	13.00	13.90
Cumulative circular pitch deviation over k/8 pitches (µm)			
	[Fpk/8]	19.00	24.00
Profile form deviation (µm)	[ffa]	11.00	13.00
Profile slope deviation (µm)	[fHa]	9.50	11.00
Total profile deviation (µm)	[Fa]	15.00	17.00
Helix form deviation (µm)	[ffb]	14.00	15.00
Helix slope deviation (µm)	[fHb]	14.00	15.00
Total helix deviation (µm)	[Fb]	20.00	21.00
Total cumulative pitch deviation (µm)	[Fp]	41.00	52.00
Concentricity deviation (µm)	[Fr]	32.00	42.00
Total radial composite deviation (µm)	[Fi"]	45.00	55.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	13.00	13.00
Total tangential composite deviation (µm)	[Fi']	61.00	74.00
Tangential tooth-to-tooth composite deviation (µm)			
	[fi']	21.00	22.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, 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 centre distance (eps_a=1.0)	[aMAX]	49.577	
Torsional stiffness (MNm/rad)	[cr]	0.0	0.2
Mean coeff. of friction (acc. Niemann)	[mum]	0.098	
Wear sliding coef. by Niemann	[zetw]	0.819	
Power loss from gear load (kW)	[PVZ]	0.061	
(Meshing efficiency (%)	[etaz]	98.254)	
Weight - calculated with da (g)	[Mass]	79.80	479.82
Total weight (g)	[Mass]	559.63	
Moment of inertia (System referenced to wheel 1):			
Calculation taking into account the exact tooth-shape			
single gears (da...di) (kg*m²)	[TraeghMom]	5.984e-006	0.000269
System (da...df) (kg*m²)	[TraeghMomDaDf]	9.971e-006	
System (da...di) (kg*m²)	[TraeghMom]	4.322e-005	

Indications for the manufacturing by wire cutting:

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

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :

Calculation of Gear 1

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

Calculation of Gear 2

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

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Calculation of Zbet according Corrigendum 1 ISO 6336-2:2008 with Zbet = 1/(COS(beta)^0.5)
- 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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