KISSsoft
Calculation programs for machine design

KISSsoft 03/2013 – 教程 16

包络面蜗轮蜗杆的验证

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SHARING KNOWLEDGE

目录

1. 任务

1.1. 任务

计算中心距为 100 mm 的一对蜗轮蜗杆。蜗杆齿数为 2，蜗轮齿数 41。轴向和切向模数是 4。法向压力角是 20°。蜗杆宽度是 60mm。应该选择一个合适的蜗轮宽度。另外，轴向的公差是 js7。

蜗杆的法向齿厚公差是 0 到-0.04mm，蜗轮齿厚公差是从-0.128 到-0.168，蜗杆外径 44-0.01mm，齿根圆直径 26.4-0.110mm，有效顶隙是 0.8mm，齿根圆角系数为 0.2，内部圆弧直径是 134.4mm。

蜗轮外径公差是 0 到-0.01，有效齿根圆直径公差是从-0.360 到-0.473。蜗杆加工精度等级是 DIN3974 的 6 级，蜗轮的加工精度等级是 7 级，导程方向为向右，蜗杆是 ZI 型。

1.2. 启动包络面蜗轮蜗杆传动装置的设计模块

可以在软件安装并激活后打开 KISSsoft 软件。通常点击"Start→Program Files→KISSsoft 03-2013→KISSsoft"打开程序。打开后用户界面如下所示：

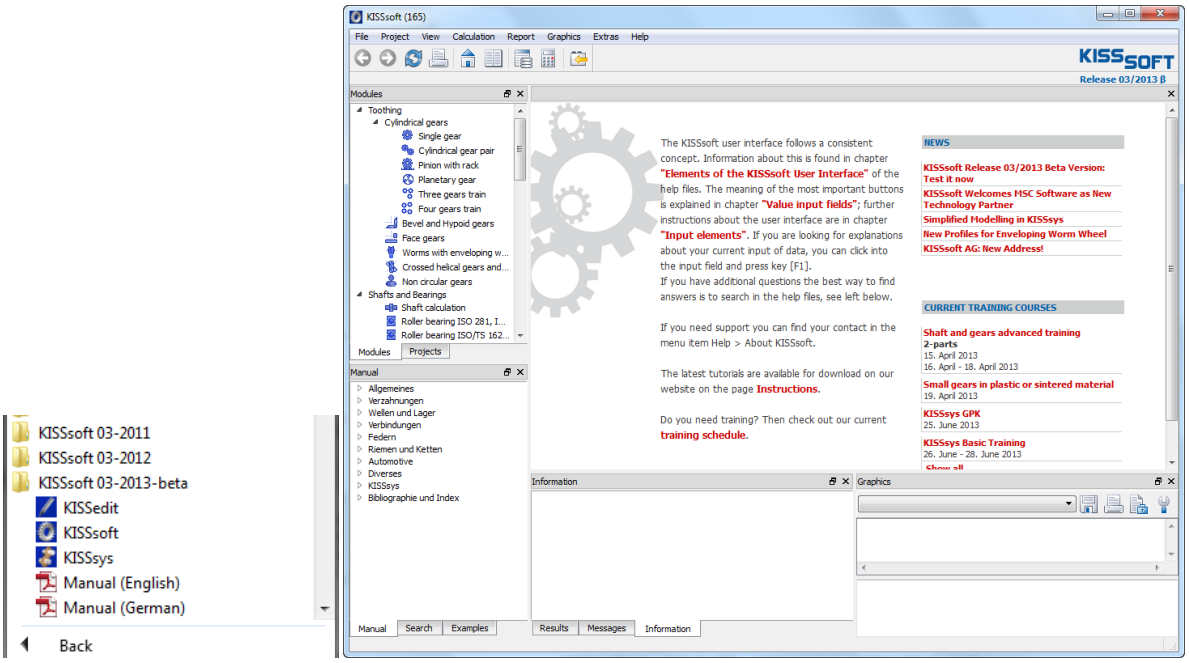

图1. 打开 KISSsoft，初始界面

在模型树窗口中，点击**"Modules"**标签启动 "Worms with enveloping worm wheels" 计算模块。

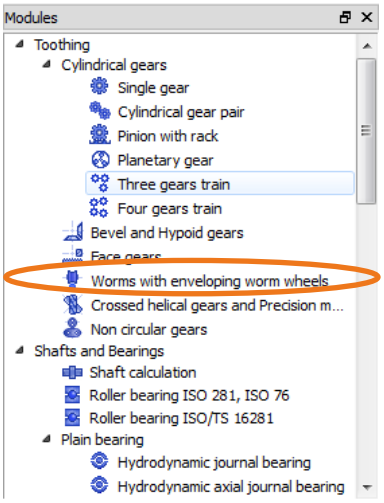

图2. 蜗轮蜗杆的计算模块的启动

1.3. 主界面参数的输入

在打开“Worms with enveloping worm wheels”后，会出现输入参数的主界面。如果只需要执行几何计算部分，可取消菜单选项中的"Calculation -> Rating"。

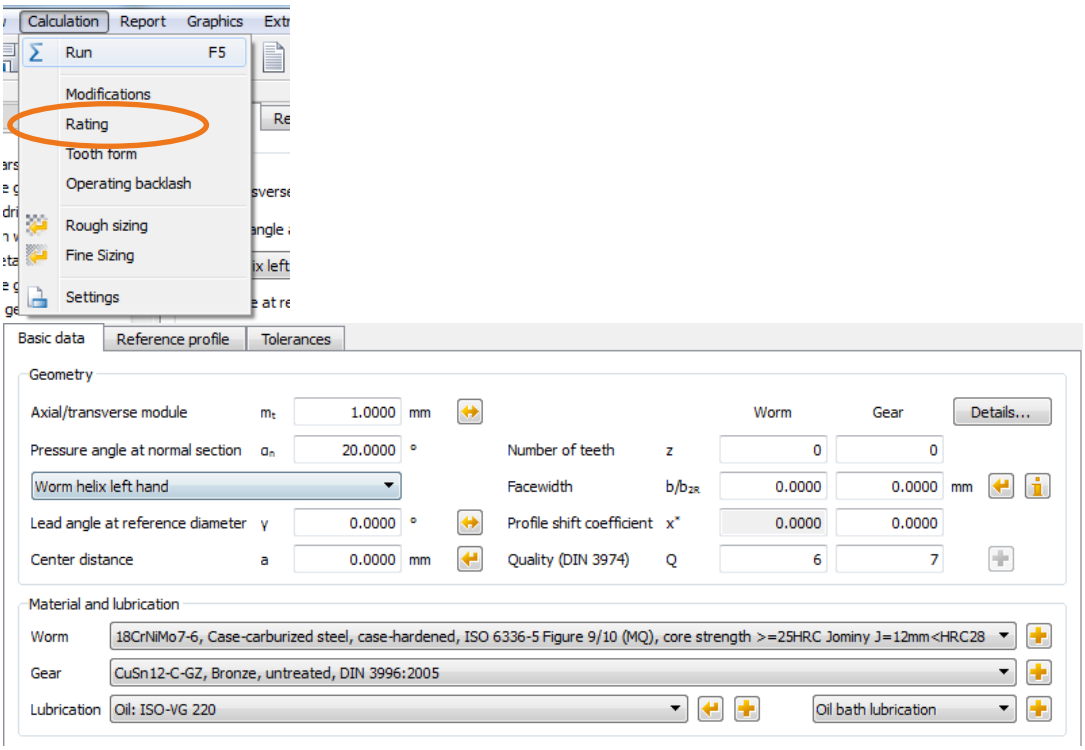

图3. 蜗杆的输入界面

在**"Basic data"**中输入轴向端面模数值、齿数、精度等级和蜗杆宽度。中心距(1)是必须给定的，接下来就可以计算导程角。可点击**"Convert button"** (2)按钮然后点击**"Calculate"** (3)计算得到导程角。最后点击接受(4)将数据导入到主界面（看图 4）。

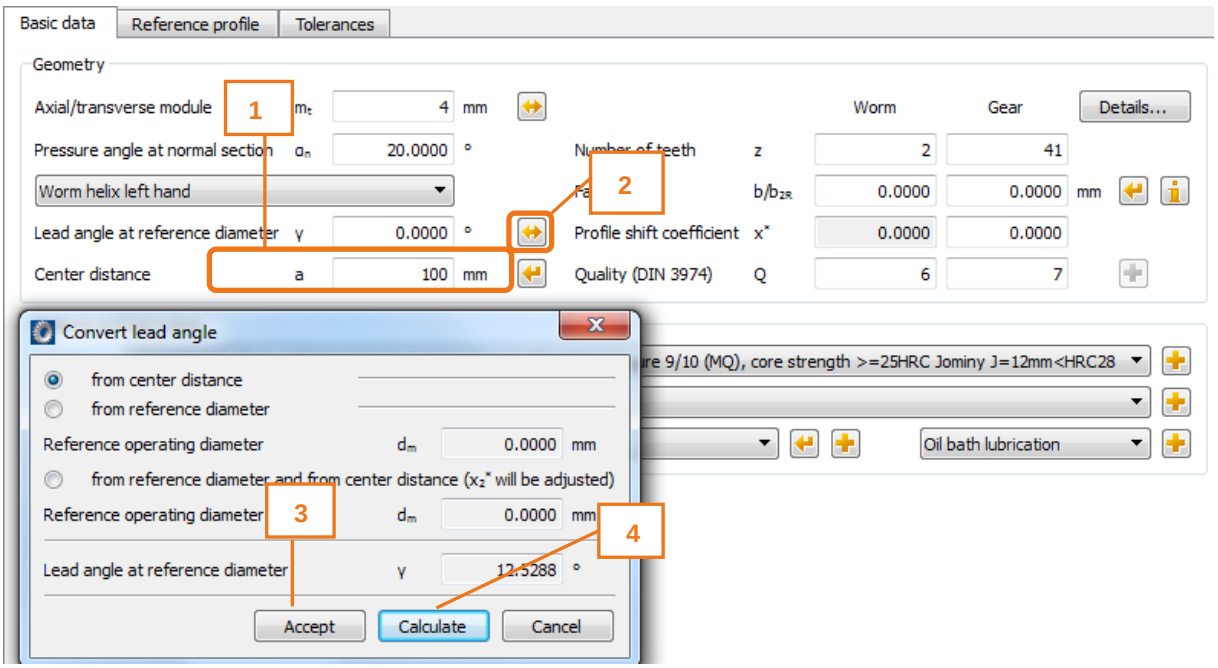

图4. 推荐导程角的临时输入界面

点击**"Details"**按钮，打开"Define details of geometry"子屏幕，然后选择适合的类型ZI。需要输入蜗轮的直径是 134.4mm。

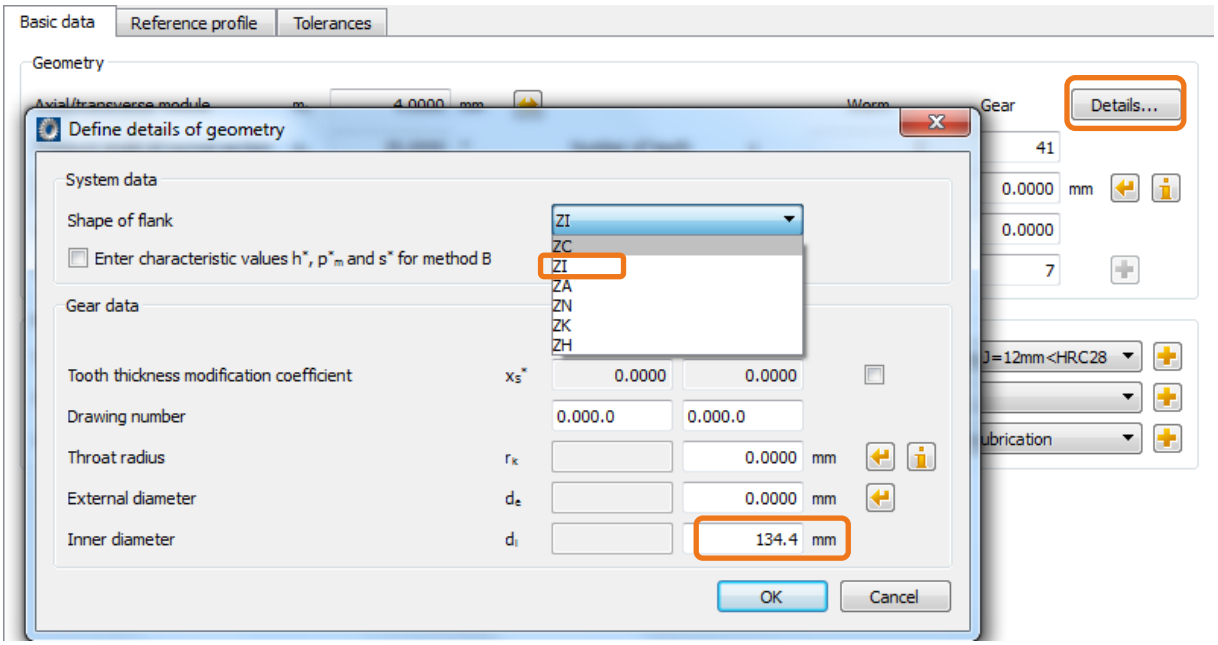

图5. "Define details of geometry"细节几何参数数据的临时输入框

1.4. 蜗轮齿面的特质

蜗轮几何齿廓在标准中定义的概念，和圆柱齿轮有很大的区别。

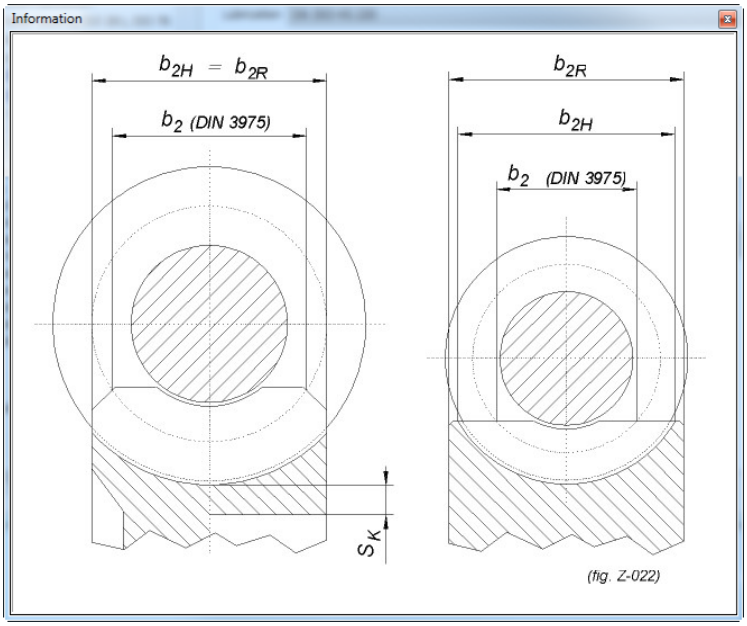

图6. 信息显示图中描述了轮毂宽 b2R 和轮宽 b2H

点击**"Sizing"** 按钮选型出一组合理的齿宽值。

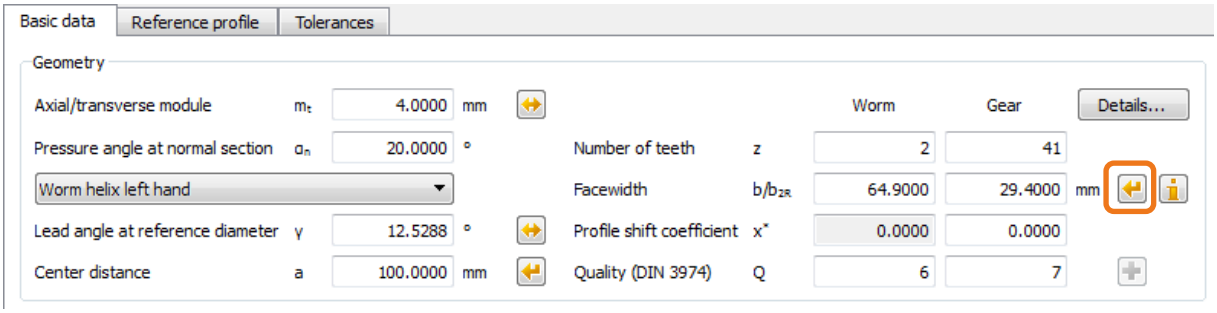

图7. 计算轮毂宽 b2R

1.5. 齿轮副参数输入

在**"Reference profile"**标签下，选择**"Own Input"**作为预定义的刀具齿廓。然后点击**Convert** 按钮，计算蜗杆的齿顶圆直径、齿顶高系数和齿根高系数。当点击接受后，这些参数值会转移到主屏幕上。

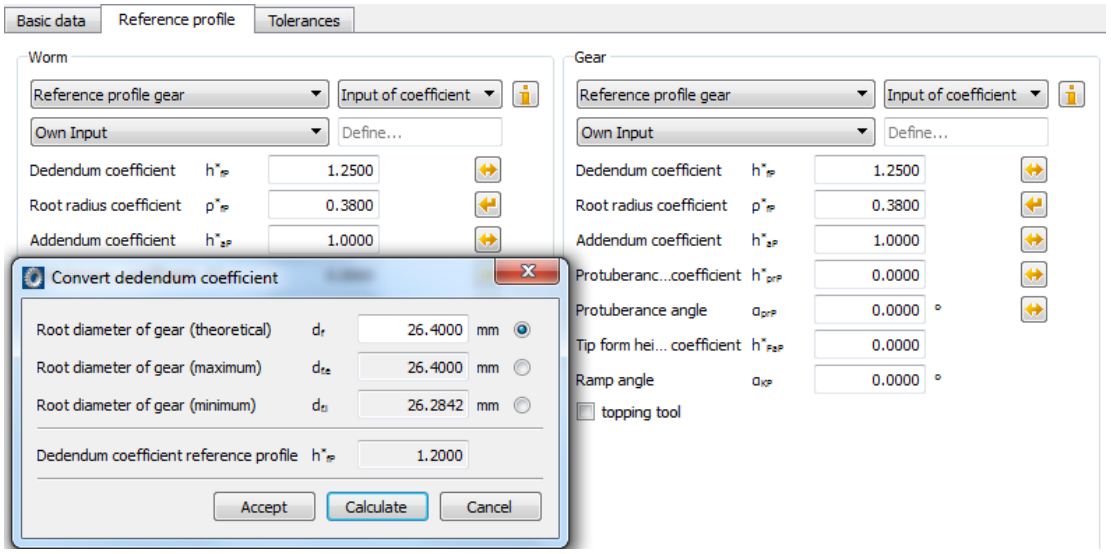

图8. 计算蜗杆齿根或齿顶直径

输入齿根圆角系数为 0.2。

有效顶隙决定了蜗轮的齿根或齿顶圆直径。有效齿根圆计算公式（中心距-蜗杆齿顶圆直径/2-顶隙）*2=（100-44/2-0.8）*2=154.4mm。齿顶圆直径的计算公式是（中心距-蜗杆有效齿根圆直径/2-顶隙）*2=172mm。

再次点击相关**"Convert"**扩展按钮 计算出蜗轮的齿根高和齿顶高系数，然后点击接受将值转移到主界面中。

注释：当打开蜗轮计算时，系统已经提供了与定义的基本设置。这些默认的齿廓参数 1.25/ 0.38/ 1 ISO 53 A 并不符合设计的需要。软件已经在以上窗口中显示出计算的详细齿顶圆直径。

圆柱蜗杆的详细几何参数还包括喉圆半径和外圆直径 d_{e2}。

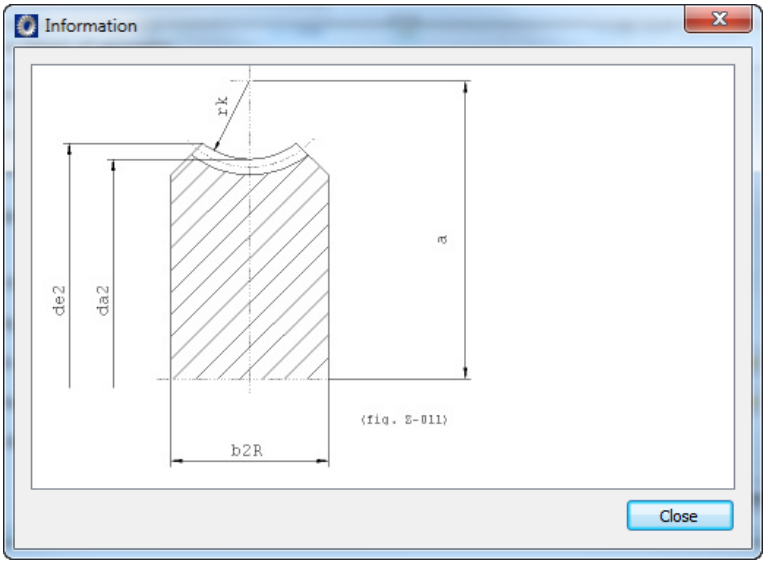

图9. 圆柱蜗轮的几何参数

在"Basic data"标签下，点击**"Details"**按钮打开子窗口。然后点击选型按钮计算出所需的喉圆半径 r_k 和外圆直径 d_{e2}。更多信息看图 10。

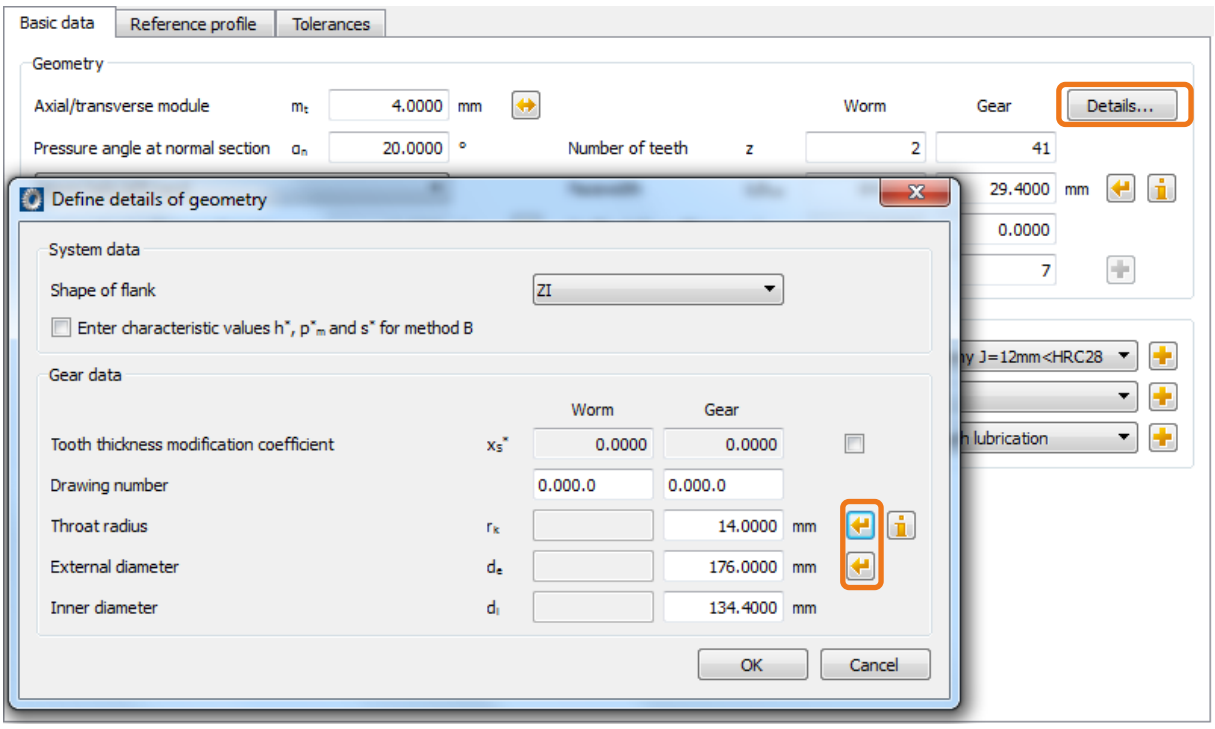

图10. 计算喉圆半径 r_k 和外圆直径 d_{e2}

1.6. 公差输入

在**"Tolerances"**标签下，选择**"Own Input"**来替代预定义的尺寸。然后根据默认值输入齿厚公差和齿顶圆直径公差。

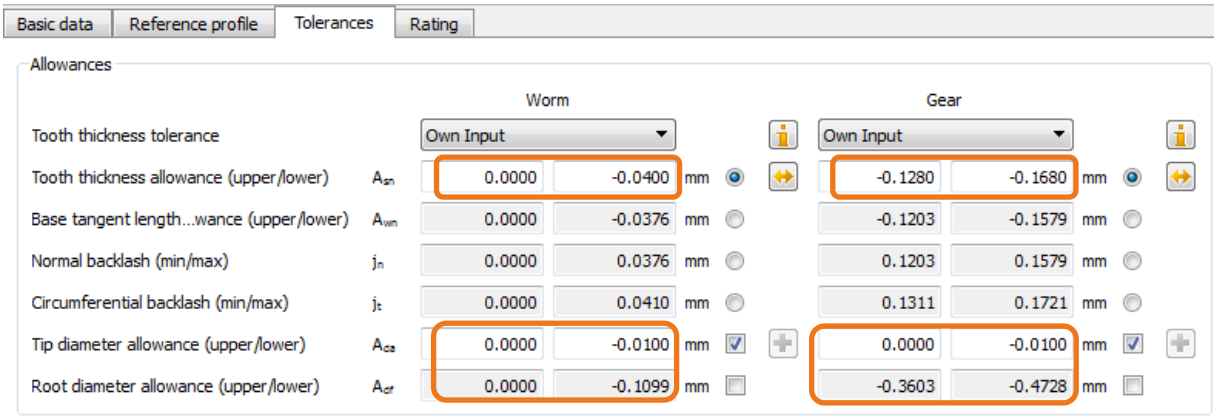

图11. 输入齿厚公差和齿顶圆直径公差

检查齿根圆直径公差，必要时可以修改。

选择中心距公差。

图12. 输入中心距公差

在执行强度计算前，需要设置以下参数：蜗杆宽度为 60mm，增加蜗轮宽度 b_{2R} 到 31mm，外圆直径 d_{e2} 到 181.41mm。

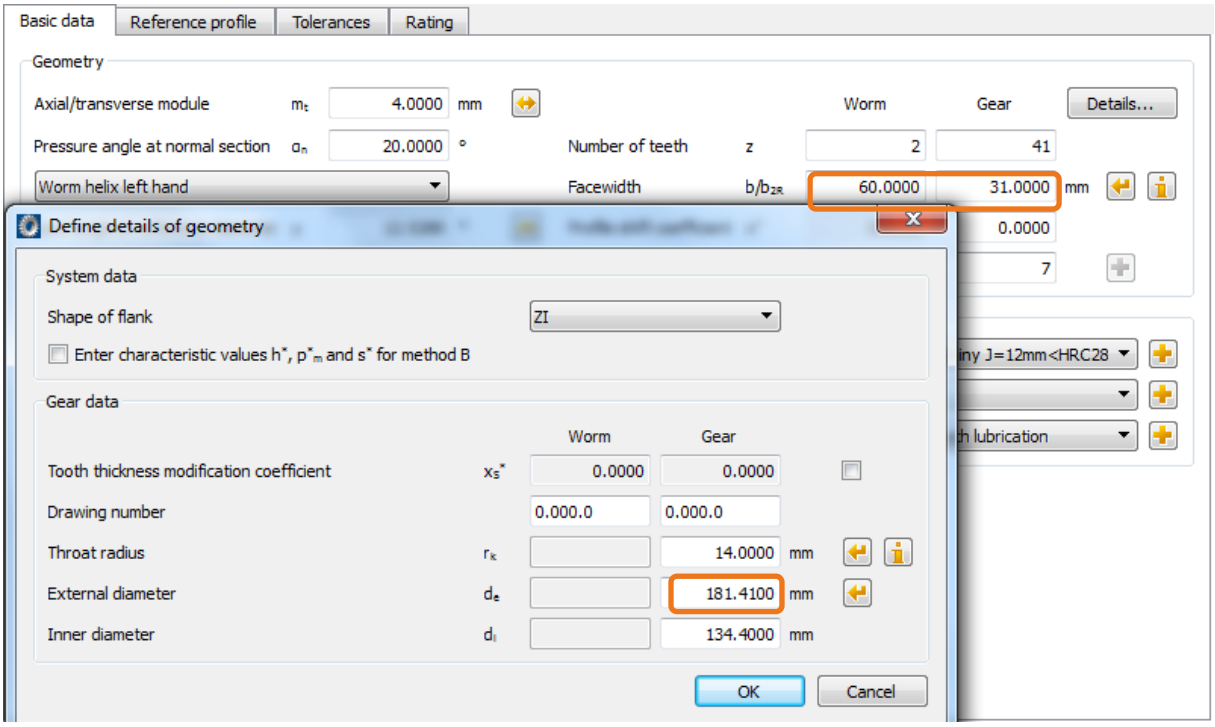

图13. 最终输入

这些被作为结果在软件中计算出来。

2. 强度校核

各种不同的算法已经都以文件的方式集成到手册中（章节 16）。如果有任何问题可以参照注释说明。通过点击"File→Open"并选择"WormGear 1 (DIN3996 Example 1)"，打开以及集成好的案例教程。

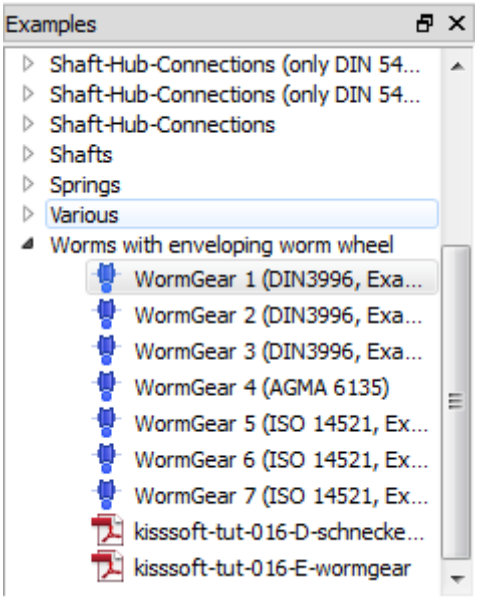

图14. 打开计算案例

2.1. 强度和几何计算校核结果

KISSsoft Release 03/2013

KISSsoft-Entwicklungs-Version KISSsoft AG CH-8608 BUBIKON

File

Name : WormGear 1 (DIN3996 Example 1)
Description: KISSsoft example
Changed by: ho am: 04.03.2013 um: 16:08:10

WORMGEAR ANALYSIS

Drawing or article number:
Worm: 0.000.0
Gear: 0.000.0

Calculation method DIN 3996:2012
(Geometry: DIN 3975:2002)
Geometry calculation from axial module

		------- WORM----------	WHEEL ----
Power (kW)	[P]	4.500	
Worm driving			
Power (kW)	[P]	5.302	4.500
Speed (1/min)	[n]	1500.0	73.2
Application factor	[KA]	1.00	
Torque (Nm)	[T]	33.754	587.282
Required service life	[H]	25000.00	
Number of starts (1/h)	[Ns]	0.00	

1. TOOTH GEOMETRY AND MATERIAL

Shape of flank: ZI

		------- WORM----------	WHEEL ----
Center distance (mm)	[a]	100.000	
Centre distance tolerance		ISO 286:2010 Measure js7	
Shaft angle (°)	[Sigma]	90.0000	
Transverse module (mm)	[mt]		4.0000
Normal module (mm)	[mn]	3.9047	
Axial module (mm)	[mx]	4.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Mean lead angle (°)	[gamma]	12.5288	
Hand of gear		left	left
Number of teeth	[z]	2	41
Facewidth (mm)	[b1]	60.00	
Wheel rim width b2R (mm)	[b2R]		31.00
Wheel width b2H (mm)	[b2H]		31.00
Facewidth for calculation (mm)	[b1, b2]	60.00	30.83
Accuracy grade (manufacturing)	[Vqual]	6	7
Internal diameter gearbody (mm)	[di]	0.00	134.40

Material
Worm: 16 MnCr 5 (1), Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28

Gear 2: CuSn12Ni2-C-GZ, Bronze, untreated
DIN 3996:2005

		------- WORM	---------- WHEEL ----
Surface hardness		HRC 59	HBW 95
Pulsating shear strength (N/mm²)	[tauFlim]	430.00	90.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	520.00
Material Coefficient YW	[YW]		0.95
Material lubrication coefficient	[WML_PolyG]		1.75
Tensile strength (N/mm²)	[Rm]	1000.00	280.00
Yield point (N/mm²)	[Rp]	695.00	150.00
Young's modulus (N/mm²)	[E]	206000	98100
Poisson's ratio	[ny]	0.300	0.350
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.50	2.00
Mean roughness height, Rz, flank (µm)	[RZH]	3.00	8.00
Mean roughness height, Rz, root (µm)	[RZF]	3.00	8.00

Tool or reference profile of gear 1 :
Reference profile 1.20 / 0.20 / 1.0 DIN 867:1986

Dedendum coefficient	[hfP*]	1.200
Root radius factor	[rhofP*]	0.200
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 1.20 / 0.20 / 1.0 DIN 867:1986

Dedendum coefficient	[hfP*]	1.200
Root radius factor	[rhofP*]	0.200
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*]	1.200	1.200
Root radius reference profile (in module)	[rofP*]	0.200	0.200
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]	0.0	0.0

Lubrication type	oil bath lubrication
Type of oil (Own input)	Öl: ISO-VG 220

Lubricant base		Synthetic oil based on Polyglycol	
Kinem. viscosity	oil at	40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity		oil at 100 °C (mm²/s)	[nu100]	37.00
FZG test A/8.3/90 (| ISO 14635-1:2006)	[FZGtestA]	13	
Specific density at 15 °C (kg/dm³)		[roOil]	1.020	
Oil temperature (°C)		[TS]	73.226	

		------- WORM	---------- WHEEL ----
Generating angle (°)	[alfa0]	20.000	
Pressure angle at normal section (°)	[alfn]	20.000	

Indications for the manufacture of the worm wheel according to ISO 14521:
(Only valid for worm wheels which are manufactured with a hob similar to the worm.)

Mean lead angle of the worm (°)	[gamma]		12.5288	
Transverse module (mm)	[mt]		4.0000	
Reference diameter (mm)	[d]		164.000	
Reference operating diameter	(mm)		[dm]	164.000
External diameter (mm)	[de]		181.410	
Throat radius (mm)	[rk]		14.000	
Profile shift coefficient	[x-worm]		0.0000	
Pitch on reference circle (mm)	[p2]		12.566	

Indications for the manufacture of the worm wheel as a cylindrical gear
(This specification is only a suggestion. It is necessary to do a calculation of the exact geometry using the crossed-helical calculation!)

Pressure angle at Transverse section (°)	[alft]	(59.205)	20.448	
Pressure angle at axial section (°)	[alfx]	(20.448)	59.205	
Helix angle at reference circle (°)	[beta]	(77.471)	12.529	
Lead angle at reference diameter (°)	[gamma]	(12.529)	77.471	
Transverse module (mm)	[mt]	(18.000)	4.000	
Axial module (mm)	[mx]	(4.000)	18.000	
Helix angle at operating pitch circle (°)	[betas]	(77.471)	12.529	
Operating pitch diameter (mm)	[dw]	(36.000)	164.000	
Profile shift coefficient	[x-DIN3960]	(0.0000)	0.0000	

Overall transmission ratio	[itot]	-20.500		
Gear ratio	[u]	20.500		
Base helix angle (°)	[betab]		11.762	
Reference centre distance (mm)	[ad]	100.000		
Diametral factor q	[q]	9.000		
Sum of profile shift coefficients	[Summexi]	0.0000		
Profile shift coefficient	[x-worm]	0.0000	0.0000	
Profile shift (x*m) (mm)	[x*mx]	0.0000	0.0000	

(The profile shift is related to the axial module of the worm subject to ISO TR 14521:2010/DIN 3975:2002.)

Tip alteration (mm)	[k*mn]	0.000	0.000	
Theoretical tip clearance (mm)	[c]	0.800	0.800	
Effective tip clearance (mm)	[c.e/i]	1.059/ 0.963	0.877/ 0.782	
Reference operating diameter	(mm)	[dm]	36.000	164.000
Reference diameter (mm)	[d]		164.000	
Base diameter (mm)	[db]		153.666	
Tip diameter (mm)	[da]	44.000	172.000	
Tip form diameter (mm)	[dFa]	44.000	172.000	
(mm)	[dFa.e/i]	44.000/ 43.990	172.000/ 171.990	
Tip diameter allowances (mm)	[Ada.e/i]	0.000/ -0.010	0.000/ -0.010	
Root diameter (mm)	[df]	26.400	154.400	
Generating Profile shift coefficient	[xE.e/i]		-0.0450/ -0.0591	

Manufactured root diameter with xE (mm)	[df.e/i]	26.400/ 26.290	154.040/ 153.927

Lead height (mm)	[pz]	25.133
Axial pitch (mm)	[px]	12.566
Transverse contact ratio (approximate value following Thomas-Charchut)		
	[eps_a]	1.911

For ZI-worms:		
Base diameter (mm)	[db]	18.431
Base lead angle (°)	[gamb]	23.463
Basecylinder pitch (mm)	[pb]	11.527

2. FACTORS OF GENERAL INFLUENCE

		------- WORM	---------- WHEEL ----	
Nominal circum. force at pitch circle (N)	[Ft]	1875.2	7162.0	
Axial force (N)	[Fa]	-7162.0	-1875.2	
Radial force (N)	[Fr]	2847.3	-2847.3	
Normal force (N)	[Fn]	8343.7		
Circumferential speed pitch d.. (m/sec)	[v]	2.827	0.628	
Sliding velocity an mean circle (m/s)	[vgm]	2.896		
Number of load cycles (in mio.)	[NL]	2249.999	109.756	
Data of reference gearbox:				
Equivalent Young's modulus (N/mm²)	[EredT]	150622.00		
Surface roughness of worm (µm)	[RaT]	0.500		
Center distance (mm)	[aT]	100.000		
Transmission ratio	[uT]	20.500		
Reference operating diameter	(mm) [dm1T]		36.000	164.000
Characteristic value for mean Hertzian pressure	[pmT*]	0.962		
Characteristic value for mean lubricant gap thickness	[hT*]	0.070		
Characteristic value for mean sliding path	[sT*]	30.800		
Physical characteristic values:				
Characteristic value for mean lubrication Space width	[h*]	0.0692		
Characteristic value for mean Hertzian pressure	[pm*]	0.9470		
Characteristic value for mean sliding path	[s*]	30.2850		
Efficiency according method C:				
Roller bearing with set support				
Bearing loss-power (kW)	[PVLP]	0.126		
Number of sealings (worm-shaft)	[nVD]	2		
Sealing loss power (kW)	[PVD]	0.046		
Idle loss power (kW)	[PV0]	0.153		
Base friction number	[muOT]	0.0245		
Size coefficient	[YS]	1.000		
Geometry factor	[YG]	1.006		
Roughness factor	[YR]	1.000		
Material Coefficient YW	[YW]	0.950		
Mean tooth friction number	[muzm]	0.0234		
Tooth friction angle (°)	[roz]	1.341		
Meshing efficiency (%)	[etaz]	90.002		
Mesh loss power (kW)	[PVZ]	0.477		
Total loss power (kW)	[PV]	0.802		
Total efficiency (%)	[etaGes]	84.872		

Wheel bulk temperature:

Lubrication type	oil bath lubrication	
Worm submerges into lubricant		
Cooling area of wheel-pair (cm²)	[AR]	50.840
Heat-transfer coefficient wheels (W/m²/K)	[alfL]	24439.990
Wheel bulk temperature (°C)	[theM]	77.1
Oil sump temperature (°C)	[theS]	73.2

3. WEAR SUPPORT CAPABILITY ACCORDING METHOD B,C

Mean lubricant gap thickness (µm)	[hminm]	0.2480
(hminm calculated with etaOM= 0.0642 Ns/m2 theM=77.1°)		
Pressure factor	[WH]	1.0000
Factor for lubricant structure	[WS]	2.6140
Factor for start	[WNS]	1.0000
Characteristic value	[Kw]	0.6484
Wear intensity	[JOT]	5.10181e-010
Wear intensity	[Jw]	8.92817e-010
Wear path (m)	[sWm]	815829
Wear removal (mm)	[delWn]	0.728
Permissible tooth thickness reduction (coefficient in module)	[DeltaS]	0.300
Permissible mass decrease (kg)		
Normal tooth thickness at tip cyl. (mm)	[san]	2.907
(mm) [san.e/i]	2.778/ 2.731	
Boundary value for flank-removal (mm)	[delWlimn]	1.171
Limited by: Permissible tooth thickness decrease		
Safety against wear	[SW]	1.608
Required safety	[SWmin]	1.100
As information:		
Achievable service life (with SW = 1.100) (h)	[Lh]	36551.07

4.PITTING SUPPORT CAPABILITY ACCORDING METHOD B,C

		------- WORM---------- WHEEL ----
Equivalent Young's modulus (N/mm²)	[Ered]	149673.38
Mean flank pressure (N/mm²)	[sigHm]	367.36
Life coefficient	[ZH]	1.000
Speed factor	[ZV]	0.851
Size coefficient	[ZS]	1.000
Lubrication factor	[Zoil]	1.000
Ratio factor	[Zu]	1.000
Boundary value of average flank pressure (N/mm²)	[sigHG]	442.766
Safety for surface pressure on flank	[SH]	1.205
Required safety	[SHmin]	1.000
As information:		
Achievable service life (with SHmin = 1.000) (h)	[Lh]	76640.67

5. BENDING SAFETY

Bearing distance l1 (mm)	[l1]	150.000
Distance l11 (mm)	[l11]	75.000
Deflection (mm)	[delm]	0.030
Boundary value bending (mm)	[dellim]	0.080
Safety for bending	[Sdel]	2.632
Required safety	[Sdelmin]	1.000

6. TOOTH-ROOT SUPPORT CAPABILITY ACCORDING METHOD C

		------- WORM---------- WHEEL ----
Calculation taking into account the decrease of the tooth thickness due to wear (with minimum (delWn, delWlimn))		
Tooth thickness at root (mm)	[sft2]	9.663
Tooth form factor	[YF2]	1.200
Contact ratio factor	[Yeps]	0.500
Lead coefficient	[Ygam]	1.024
Rim thickness (mm)	[sk2]	10.000
Rim thickness coefficient	[YK2]	1.000
Nominal shear stress at tooth root (N/mm²)	[tauF2]	35.51
No Quality reduction by small plastic deformation is accepted.		
Life coefficient	[YNL]	1.000
Boundary value of shear stress at tooth root (N/mm²)	[tauFG]	90.00
Safety for Tooth root stress	[SF]	2.534
Required safety	[SFmin]	1.100

7. TEMPERATURE SAFETY ACCORDING METHOD C

Housing with cooler		
Ambient temperature (°C)	[TU]	20.0
Oil temperature (°C)	[theOil]	73.2
Boundary value oil temperature (°C)	[theSlim]	100.0
Temperature safety	[ST=theSlim/theOil]	1.366
Required safety	[STmin]	1.100
Oil sump temperature (°C)	[theS]	73.2
(Safety	[theSlim/theS]	1.366)

8. ALLOWANCES FOR TOOTH THICKNESS

Tooth thickness deviation

Worm:	Own Input
Gear:	Own Input

		------- WORM---------- WHEEL ----	
Tooth thickness allowance (normal section) (mm)	[As.e/i]	0.000/ -0.040	-0.128/ -0.168
Backlash free center distance (mm)	[aControl]	99.820/ 99.707	
Backlash free center distance, allowances (mm)	[jta]	-0.180/ -0.293	
Number of teeth spanned	[k]		5.000
Base tangent length (no backlash) (mm)	[Wk]		54.275
Actual base tangent length ('span') (mm)	[Wk.e/i]		54.155/ 54.117
Diameter of contact point (mm)	[dMWk.m]		162.549
Base tangent length (span): Can only be measured, if the worm-wheel is manufactured like a cylindrical gear!			
Theoretical diameter of ball/pin (mm)	[dm]	6.545	6.615
Eff. Diameter of ball/pin (mm)	[DMeff]	7.000	7.000
Theor. dim. centre to ball (mm)	[MrK]		87.190
Actual dimension centre to ball (mm)	[MrK.e/i]	87.034/ 86.985	
Diameter of contact point (mm)	[dMMr.m]	37.166	164.455
Diametral measurement over two balls without clearance (mm)	[MdK]		174.257

Actual dimension over balls (mm)	[MdK.e/i]		173.946/173.848
Theoretical dim. over 3 wires (mm)	[Md3R]	46.559	
Actual dim. over 3 rolls (mm)	[Md3R.e/i]	46.559/46.452	
Tooth thickness (chordal) in pitch diameter (mm)	['sn]	6.133	6.132
Actual chordal tooth thickness (mm)	['sn.e/i]	6.133/6.093	6.004/5.964
Tooth thickness on axial cut (mm)	[smx]	6.283	
Actual tooth thickness (mm)	[smx.e/i]	6.283/6.242	
Tooth space in axial cut (mm)	[emx]	6.283	
Actual tooth space (mm)	[emx.e/i]	6.283/6.324	
Reference chordal height from da.m (mm)	[ham1, ha2]	3.997	4.052

Centre distance allowances (mm)	[Aa.e/i]	0.018/-0.018
Circumferential backlash (transverse section) (mm)	[jt]	0.226/0.118
Normal backlash (mm)	[jn]	0.207/0.108

9. GEAR ACCURACY

		------- WORM	---------- WHEEL ----
According to DIN 3974:1995:			
Accuracy grade	[Vqual]	6	7
Single pitch deviation (µm)	[fpx, fp2]	8.50	13.00
Difference between adjacent pitches (µm)	[fux, fu2]	11.00	16.00
Total deviation of the slope (µm)	[Fpz]	11.00	
Total cumulative pitch deviation (µm)	[Fp2]		51.00
Profile slope deviation (µm)	[fHa]	7.50	11.00
Profile form deviation (µm)	[ffa]	11.00	15.00
Total profile deviation (µm)	[Fa]	13.00	19.00
Concentricity deviation (µm)	[Fr]	18.00	35.00
Total tangential composite deviation (µm)	[Fi']	29.00	56.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	15.00	22.00

10. ADDITIONAL DATA

Weight - calculated with da (kg)	[Mass]	0.714		2.455
Start under load:				
Tooth friction number (acc. Niemann)	[muzm_S]		0.140	
Torque (Nm)	[T1_S]	48.195		587.282

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
- The specification of circumferential backlash (as well as the backlash-free distance for the tooth thickness check) is not yet fully checked, and serves only as a The details of the chordal tooth thickness are imprecise and merely an indication (The calculation is done according to ISO TR 14521:2010/DIN 3975:2002, without taking into account the exact shape of flank.).
- In ISO14521 and DIN3996, the necessary data for each material are not always complete. In such a case you get the message: "Not calculated (material data missing)'

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