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KISSsoft Tutorial: Analyzing the Geometry of Worm Gears that have a Globoid Worm Gear

1 Task

1.1 Task

To calculate a worm gear with center distance 100 mm. The worm has 2 teeth, and the worm gear has 41 teeth. The axial/transverse module is 4. The pressure angle at the normal section is 20°. The worm's toothing length is 60 mm. You should select a sensible tooth width for the worm gear. The axis tolerance is js7. The worm's tooth thickness deviation in the normal section is between 0 and -0.04 mm. The tooth thickness deviation for the worm gear is between -0.128 and -0.168. The external diameter of the worm is 44 -0.01 mm. The root diameter is 26.4 -0.110 mm. The effective tip clearance is to be 0.8 mm. The root radius factor is 0.2. The inside radius diameter is 134.4 mm. The tolerance for the external diameter of the worm gear is between 0 and -0.01, for the active root diameter it is between - 0.360 and -0.473. The worm is to be manufactured with accuracy grade 6 as specified in DIN 3974. The worm gear is to be manufactured with quality 7. The lead direction is to the right. The worms flank form is ZI.

1.2 Starting the drive element of a worm gear with a globoid worm wheel.

Once you have installed and activated KISSsoft either as a test or licensed version, follow these steps to call the KISSsoft system. Usually you start the program by clicking "Start→Program Files→KISSsoft 03-2011→KISSsoft". This opens the following KISSsoft user interface:

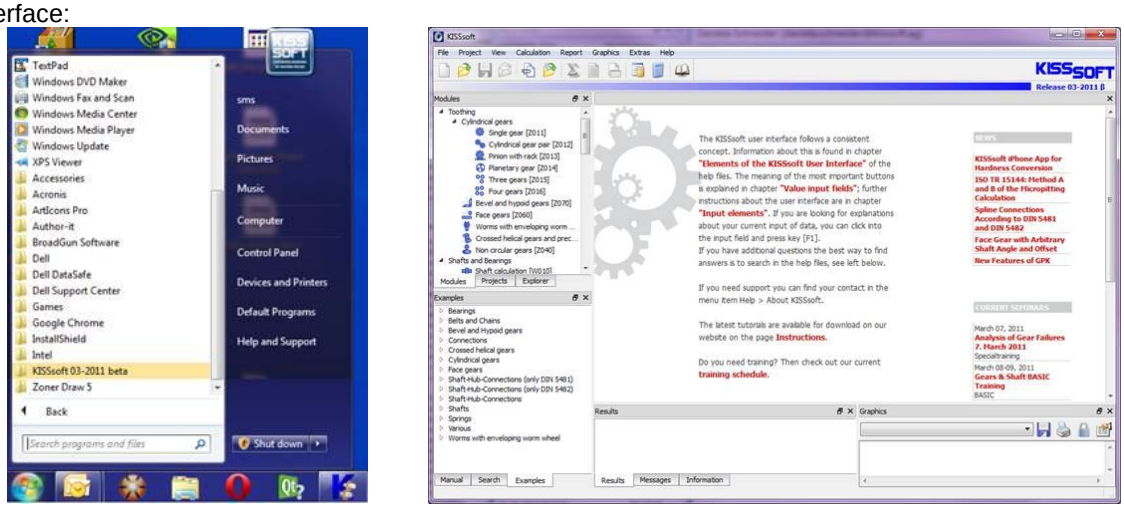

Figure 1.1 Starting KISSsoft, initial window

In the Modules tree window, click the **"Modules"** tab to call the "Worms with enveloping worm wheel" calculation:

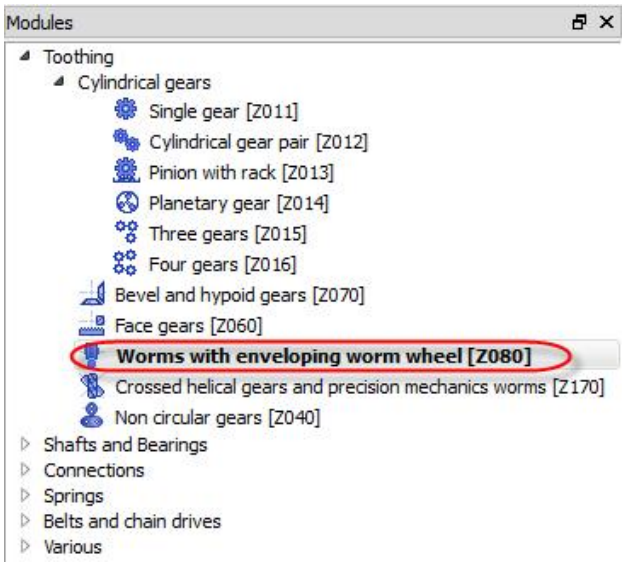

Figure 1.2 Calling the worm gear calculation.

1.3 Inputting data in the main screen

After you call the analysis for a worm gear with a globoid gear, this input screen appears. In the "Strength" group, now select " Only geometry calculation" as the calculation method.

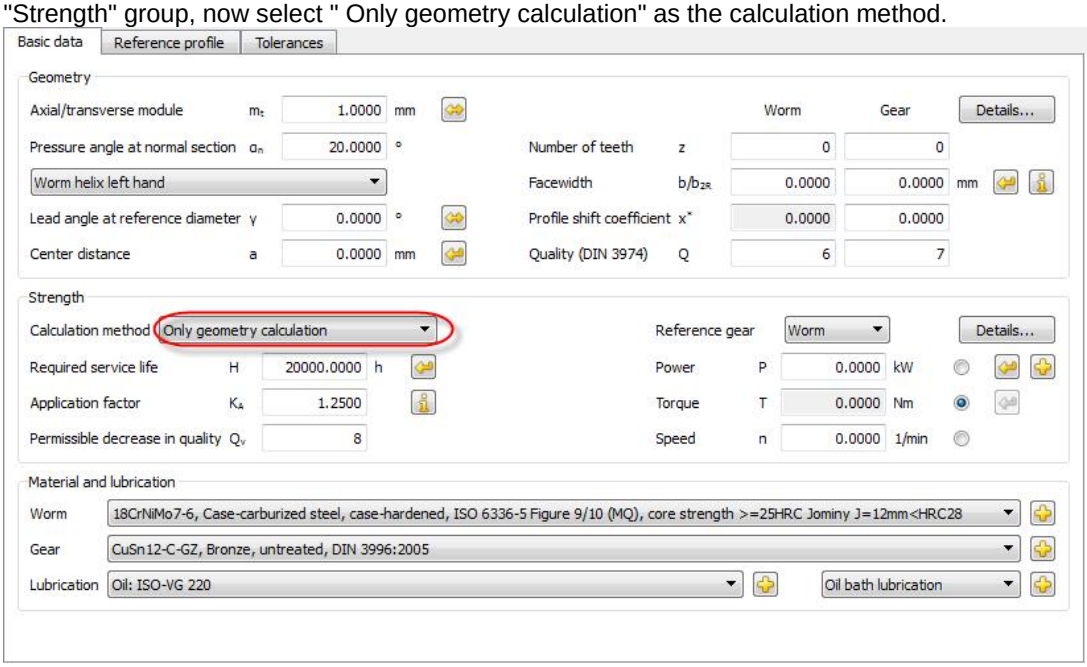

Figure 1.3 Input screen for worms

Input values for the axial/transverse module, number of teeth, quality and worm face width in the **"Basic data"** tab. You must also input the axis distance (1). The subsequent interim value is calculated because only the lead angle needs to be calculated. To do this, click the **"Convert button"**  (2) and then click **"Calculate"** (3) to determine the lead angle. Finally, click Accept (4) to transfer this data to the main screen (see Figure 1.4).

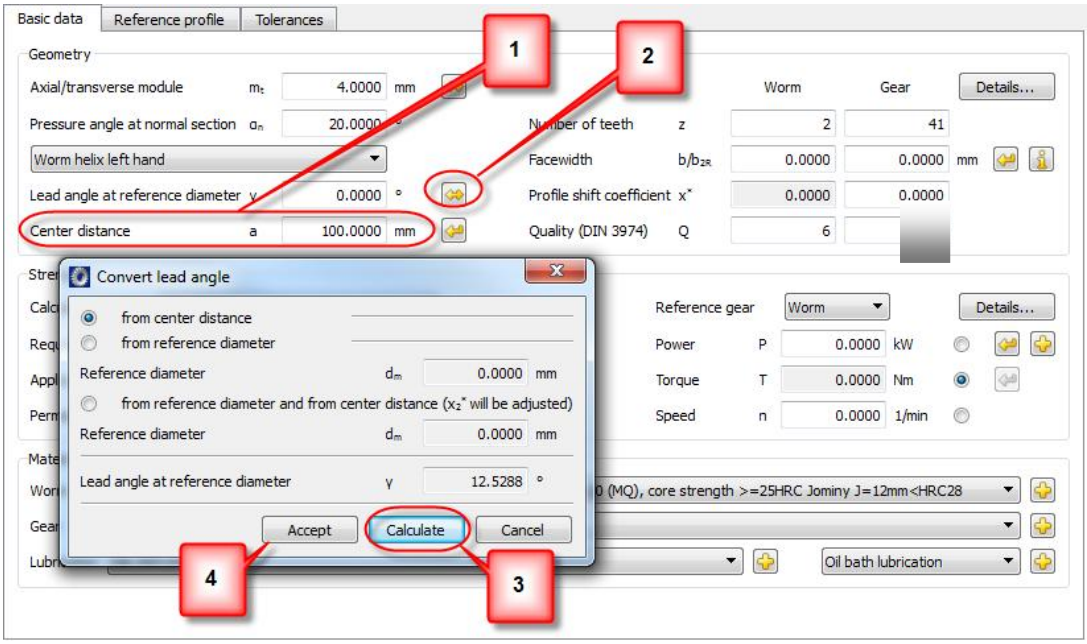

Figure 1.4 Interim state with the Sizing lead angle input screen

Click the **"Details"** button to call the "Define details of geometry" sub-screen and then select the appropriate flank form ZI. You must also input the inside diameter of the worm gear as 134.4 mm.

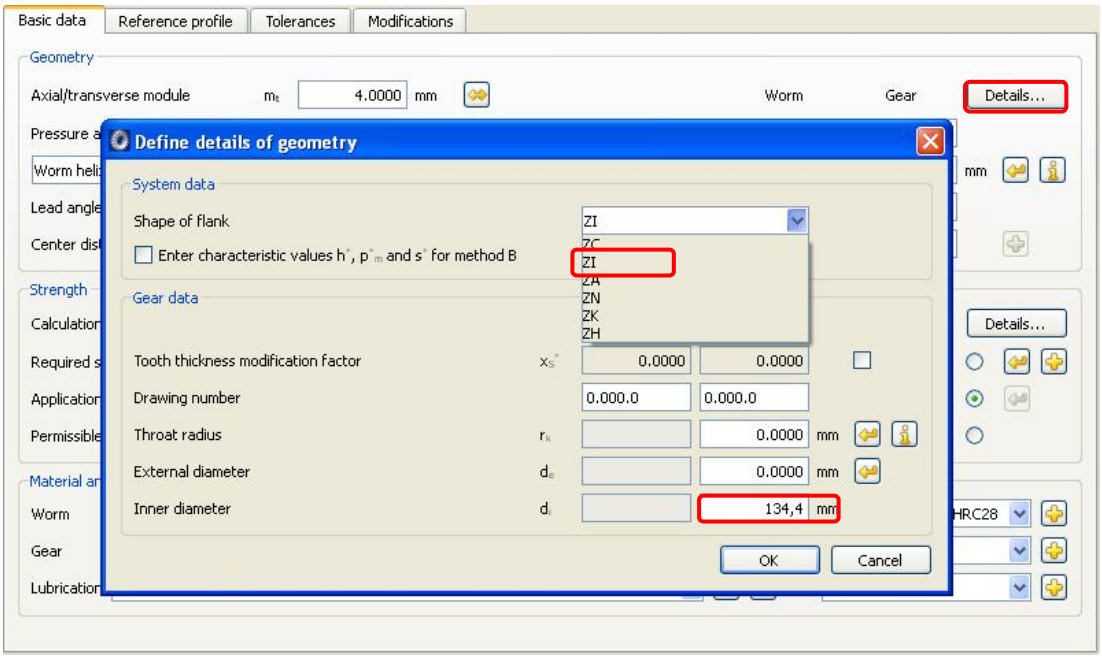

Figure 1.5 Interim status with "Define details of geometry" input screen

1.4 Special features of worm gear teeth flank surfaces

The flank surfaces of a worm gear are defined in a different way from those in cylindrical gears.

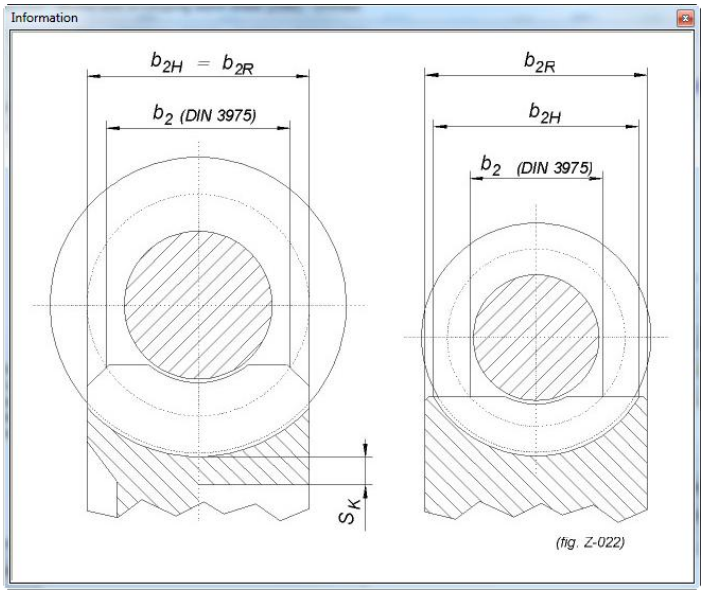

Figure 1.6 Calling the information graphic to describe wheel rim width b2R and wheel width b2H en

Then click the **"Sizing button"** to calculate the gear width  .

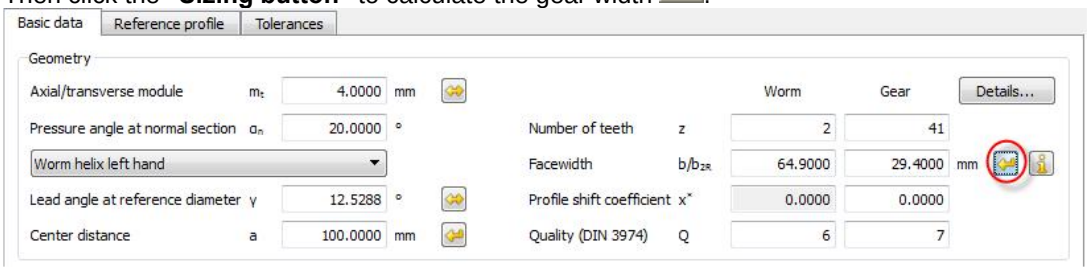

Figure 1.7 Calculated wheel rim width b2R

1.5 Input data for the gear pair

In the **"Reference profile"** tab, select **"Own Input"** as the predefined tool profile. Then click the relevant **"Convert button"** to calculate the addendum and dedendum coefficients for the worm.  Then click Accept to transfer the dedendum and addendum coefficient values to the main screen.

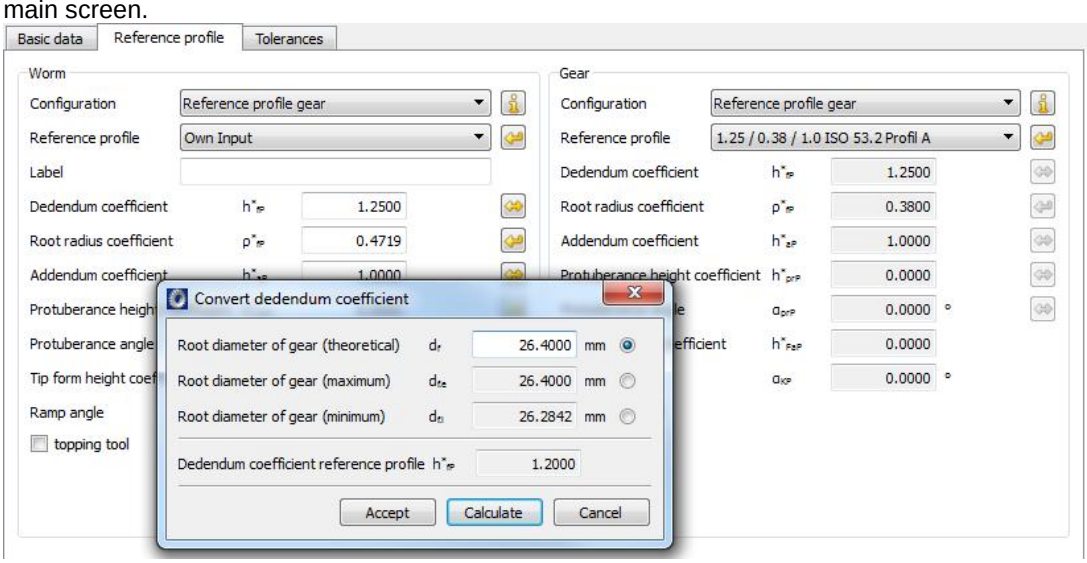

Figure 1.8 Calculating the worm root or tip diameter

Input 0.2 as the root radius factor.

The effective tip clearance is then used to determine the root or tip diameter for the worm gear. The active root diameter is calculated from (center distance tip diameter of worm/2 tip

clearance)*2 =(100 – 44/2 – 0.8)*2=154.4 mm. The tip diameter is calculated from (center distance active root diameter of worm/2 tip clearance)*2=(100 – 26,4/2 – 0.8)*2=172 mm.

Once again, click the relevant **"Convert button"**  to convert the dedendum and addendum coefficient at the worm wheel. Then click Accept to transfer the values to the main screen.

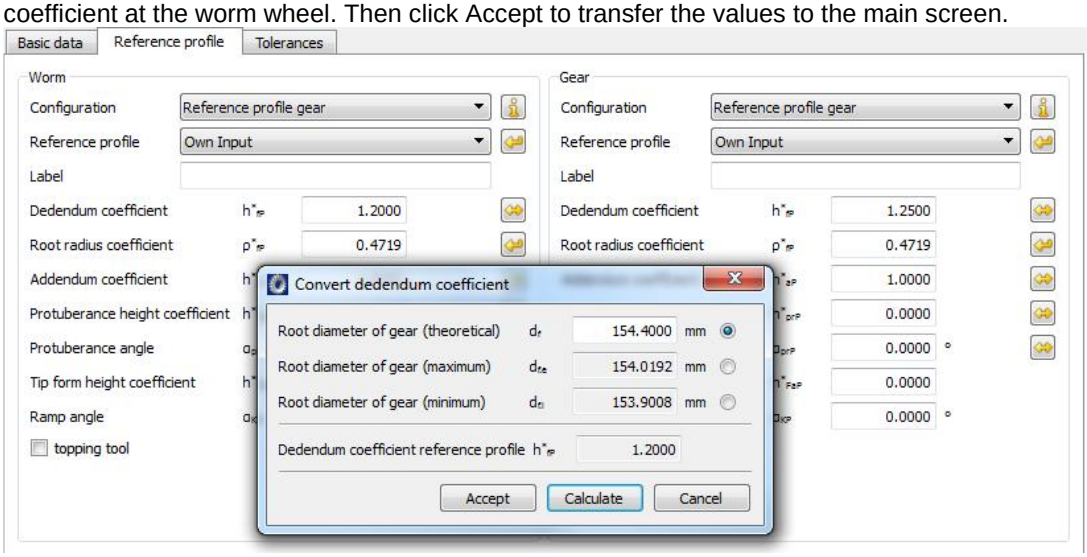

Figure 1.9 Calculating the worm wheel root or tip diameter

Explanation: When you call the worm gear calculation, the system already provides predefined basic settings. However, the default profile 1.25/ 0.38/ 1 ISO 53 A does not match what we want. The software already shows that it has calculated the tip diameter detailed above.
The particular geometry of globoid worm gears also means you need to calculate the tip gorge radius and the external diameter d_{e2}.

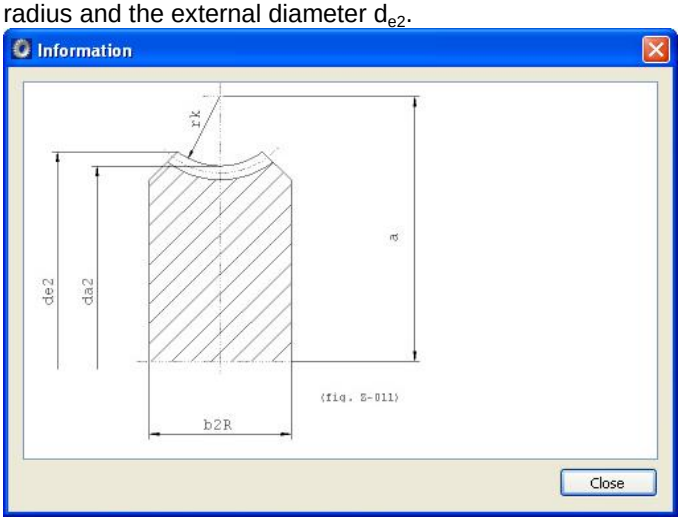

Figure 1.10 Geometry of globoid worm gears

In the "Basic data" tab, click the **"Details"** button to display the "Define details of geometry" sub-screen and then click the relevant "Sizing" button to perform the required calculation of the tip gorge radius r_k and the external diameter d_{e2} über in den

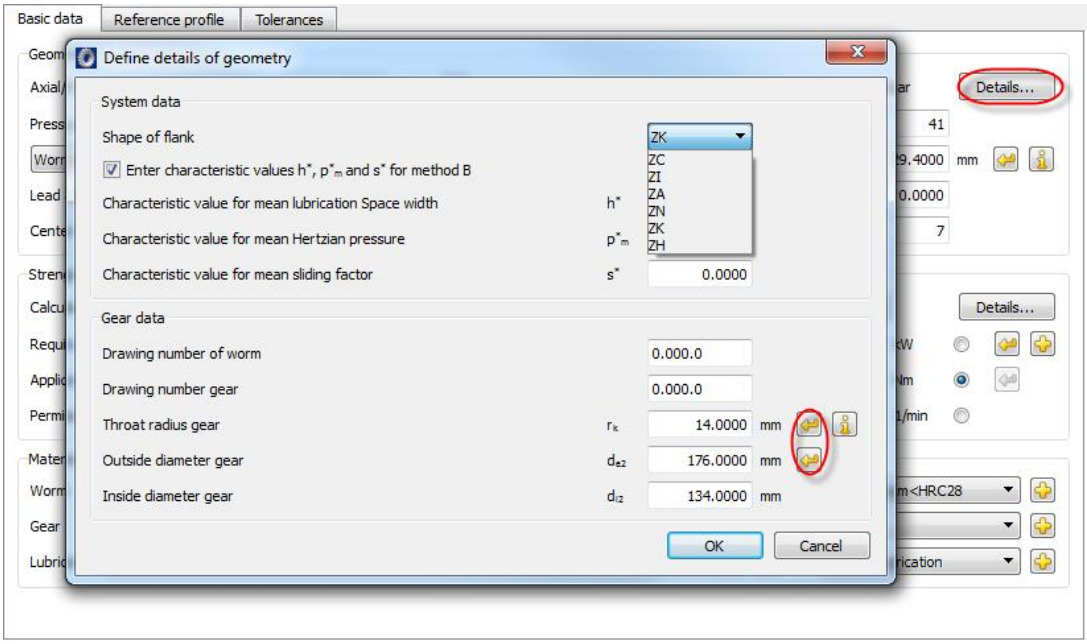

Figure 1.11 Calculating tip gorge radius r_k and the external diameter

1.6 Inputting tolerances

In the **"Tolerances"** tab, select **"Own Input"** instead of using the predefined dimensions. Then input the tooth thickness deviation in accordance with the default values and the entry for the tip diameter deviation.

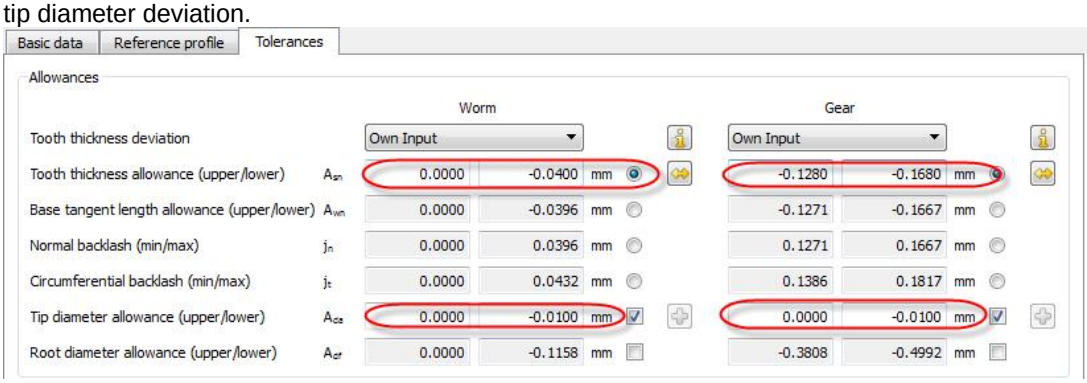

Figure 1.12 Inputting tooth thickness tolerance and tip diameter allowances

Then check the tip diameter deviation and modify it if necessary.

Now select the center distance tolerance.

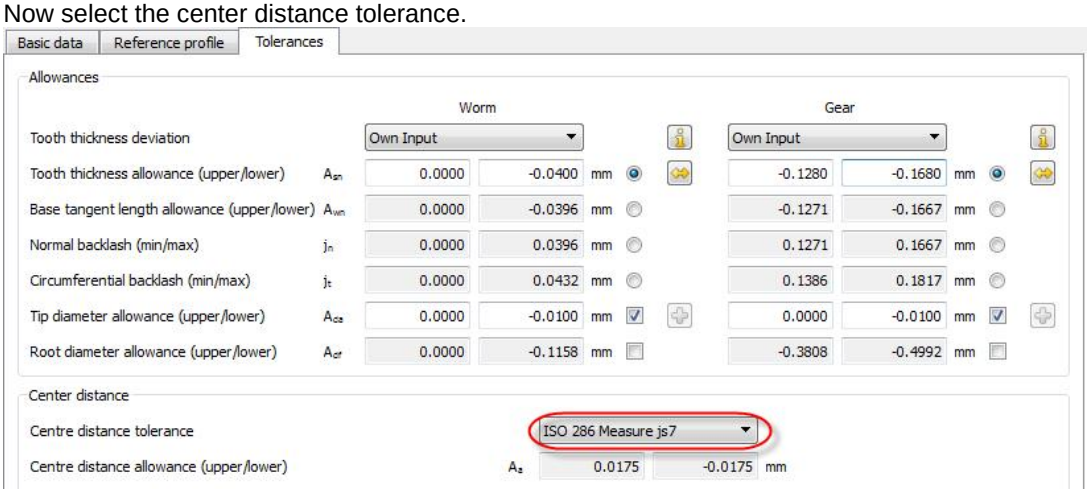

Figure 1.13 Input axis tolerance

The following changes must be now be made so you can perform the strength calculation later on:

Increase the required face width of the worm gear b_{2R} to 31 mm and the external diameter d_{e2} to 181.41 mm.

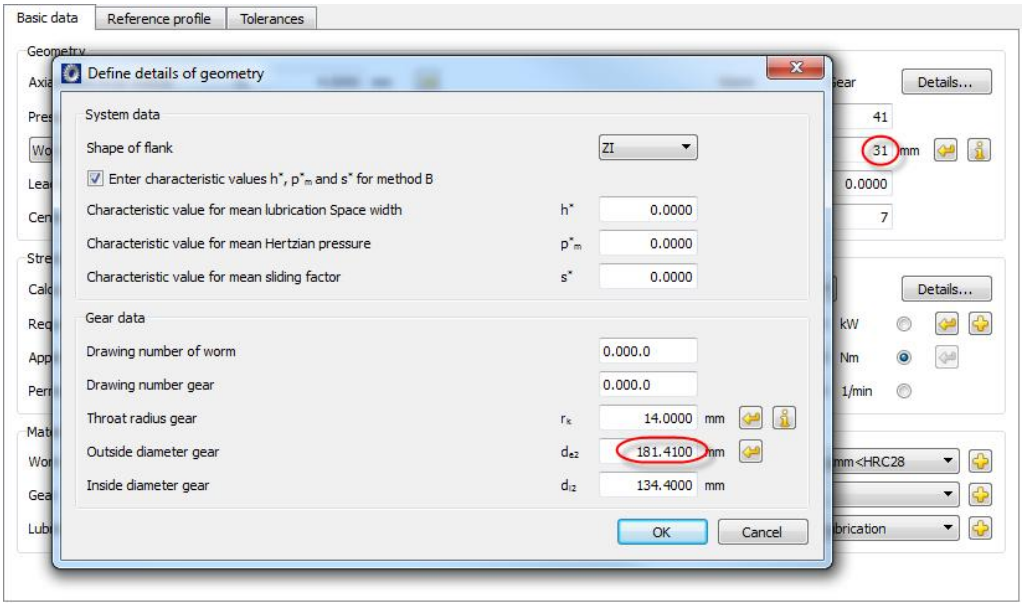

Figure 1.14 Final inputs

These are the results of the calculation.

2 Strength calculation

The various different calculation methods are documented in the manual (Chapter 16). Please refer to the notes if you have any questions. To open the prepared example used in this tutorial, click "File/→Open" and select "WormGear (DIN3996 Example 1)".

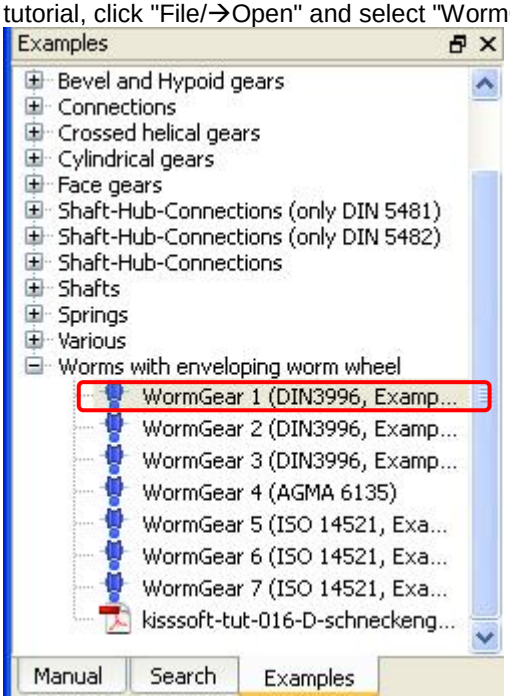

Figure 2.1 Opening the calculation example file

2.1 Results of the geometry calculation

KISSsoft - Release 03-2011
KISSsoft-Entwicklungs-Version KISSsoft AG CH-8634 HOMBRECHTIKON

File
Name : WormGear 1 (DIN3996, Example 1)
Description: KISSsoft example
Changed by : ho on: 01.02.2011 at: 09:24:05

WORMGEAR ANALYSIS

Drawing or article number:
Worm: 0.000.0
Gear: 0.000.0

Calculation method Only geometry calculation
(Geometry: ISO 14521)
Geometry calculation from axial module

1. TOOTH GEOMETRY AND MATERIAL

Shape of flank: ZI

		------- WORM	---------- WHEEL ----
Center distance (mm)	[a]	100.000	
Centre distance tolerance		ISO 286 Measure js7	
Axis 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: CuSn12Ni2-C-GZ, Bronze, untreated
DIN 3996:2005

		------- WORM	---------- WHEEL ----
Surface hardness		HRC 59	HBW 95
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
Pulsating shear strength (N/mm²)	[tauFlim]	430.00	90.00
Dauerfestig. Hertzsche Pressung (N/mm²)	[sigHlim]	1500.00	520.00
Average 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
Material Coefficient YW	[YW]		0.95
Material lubrication coefficient	[WML_PolyG]		1.75

Tool or reference profile of gear 1 :

Reference profile 1.20 / 0.20 / 1.0 DIN 867

Addendum coefficient	[haP*]	1.000
Dedendum coefficient	[hfP*]	1.200
Tip radius factor	[rhoaP*]	0.000
Root radius factor	[rhofP*]	0.200
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

Addendum coefficient	[haP*]	1.000
Dedendum coefficient	[hfP*]	1.200
Tip radius factor	[rhoaP*]	0.000
Root radius factor	[rhofP*]	0.200
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 (module)	[hfP*]	1.200	1.200
Tooth root radius Refer. profile (module)	[rofP*]	0.200	0.200
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Buckling root flank height (module)	[hFaP*]	0.000	0.000
Buckling root flank angle (°)	[alfKP]	0.000	0.000

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

Indications for the manufacture of the worm wheel according to DIN 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 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

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 ISO14521/DIN 3975.)

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 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 chamfer / tip rounding (mm)	[hK]	0.000	0.000
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
Normal Tooth thickness at Tip cyl. (mm)	[san]	0.000	2.907
(mm)	[san.e/i]	0.000 / 0.000	2.778 / 2.731

Lead height (mm)	[pz]	25.133
Axial pitch (mm)	[px]	12.566

Transverse contact ratio (approximate value following Thomas-Charchut) [eps_a] 0.000

For ZI-worms:

Base diameter (mm)	[db]	18.431
Base lead angle (°)	[gamb]	23.463
Basecylinder pitch (mm)	[pb]	11.527

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. Messkörperdurchmesser (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 DIN 3974:			
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