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# KISSsoft Tutorial: Analyzing the geometry of worm wheels that have an enveloping worm wheel

## 1 Task

### 1.1 Task

The task is to calculate a worm wheel 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 wheel. 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 wheel is between -0.128 and -0.168. The outside 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 134.4mm. The tolerance for the outside diameter of the worm wheel 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 wheel is to be manufactured with quality 7. The lead direction is to the right. The worm's flank form is ZI.

### 1.2 Start the drive element of a worm wheel with an enveloping worm wheel.

After you have installed and activated the KISSsoft system either as a test or licensed version, follow these steps to call the KISSsoft system. Start the program by clicking "Start/Program Files/KISSsoft 08-2009/KISSsoft". This opens the following KISSsoft user interface:

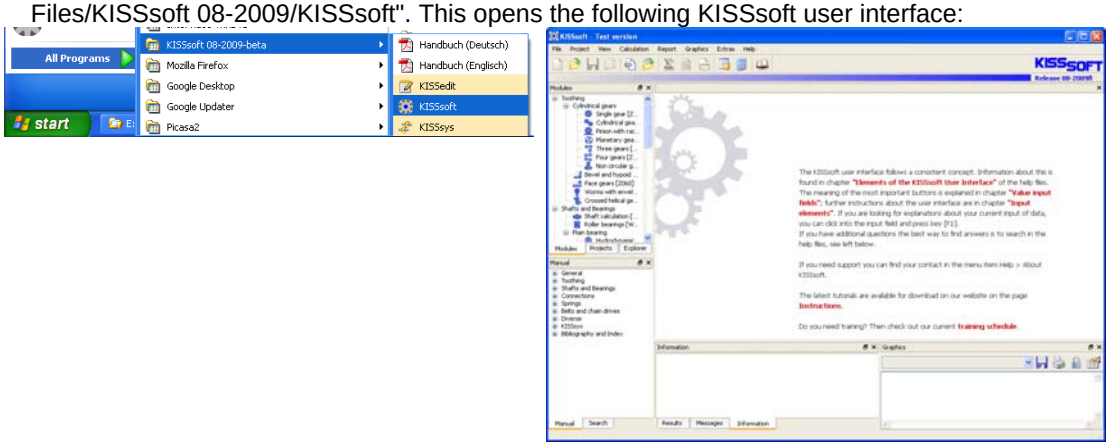


**Figure 1.1** Starting KISSsoft, initial window

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

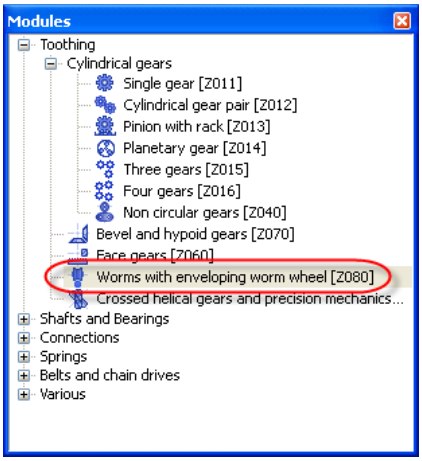


**Figure 1.2** Calling the worm wheel calculation

## 1.3 Input data in main screen

After you call the analysis for a worm wheel with an enveloping worm wheel, this input screen appears. In the "Strength" group, now select "Geometry calculation only" as the calculation method.

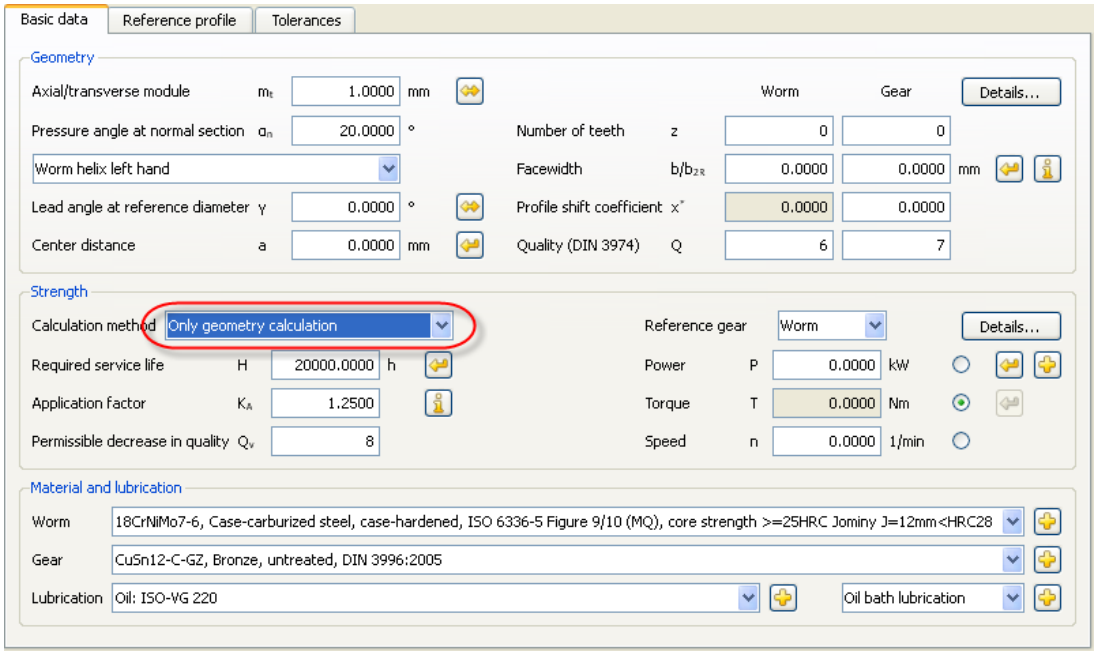


**Figure 1.3** Input screen for worm wheels

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 "**Conversion 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**).

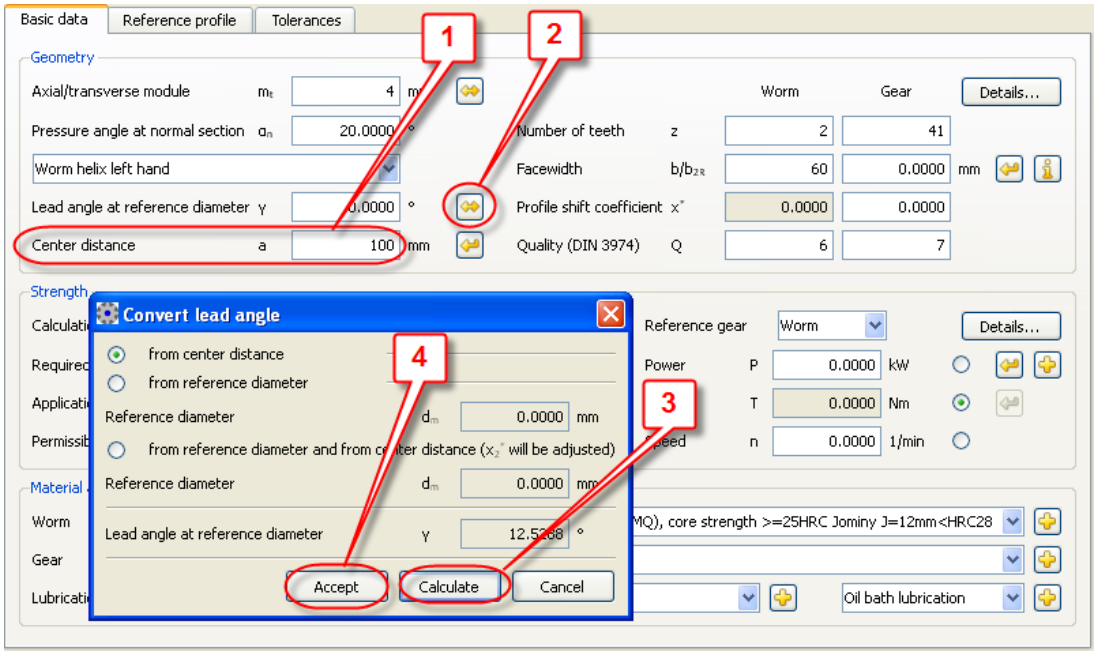


**Figure 1.4** Interim state with the converting lead angle input screen

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 wheel as 134.4mm.

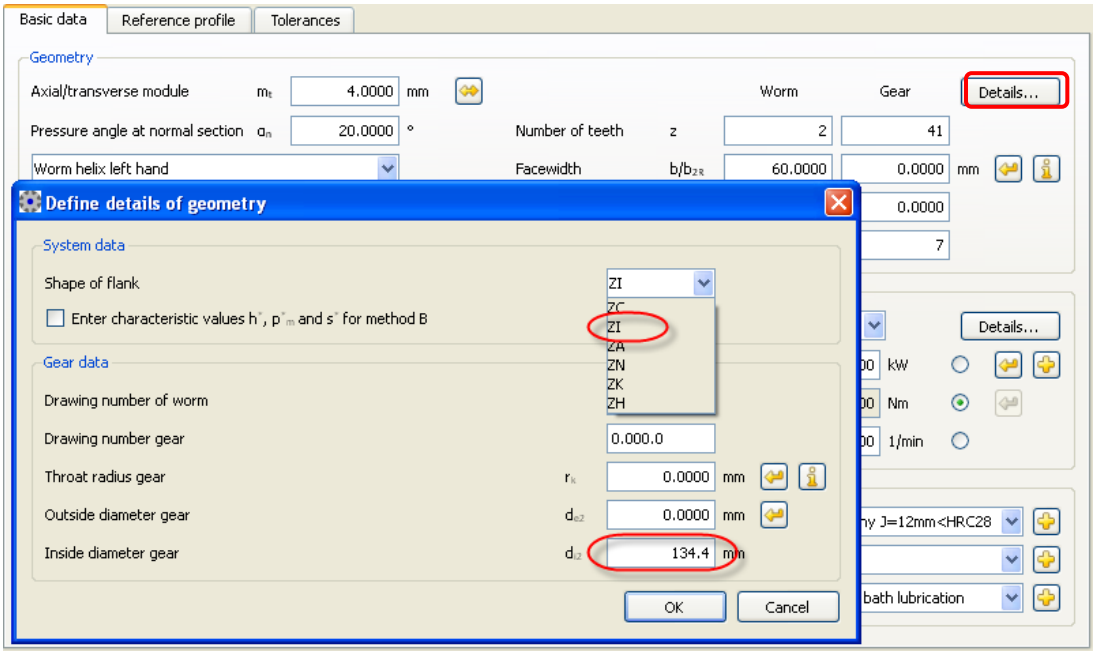


**Figure 1.5** Interim status with "Define details of geometry" input screen

## 1.4 Special features of worm wheel teeth flank surfaces

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

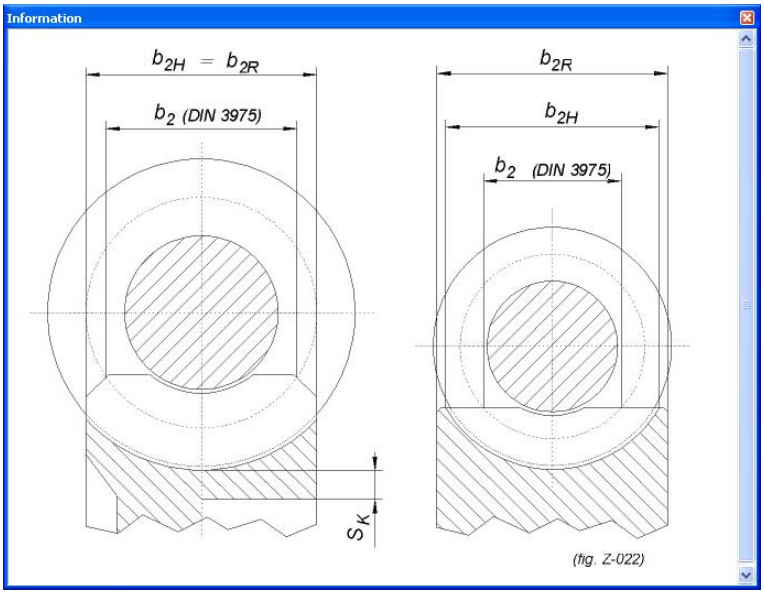


**Figure 1.6** Calling the information graphic to describe wheel flange width b2R and wheel width b2H

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

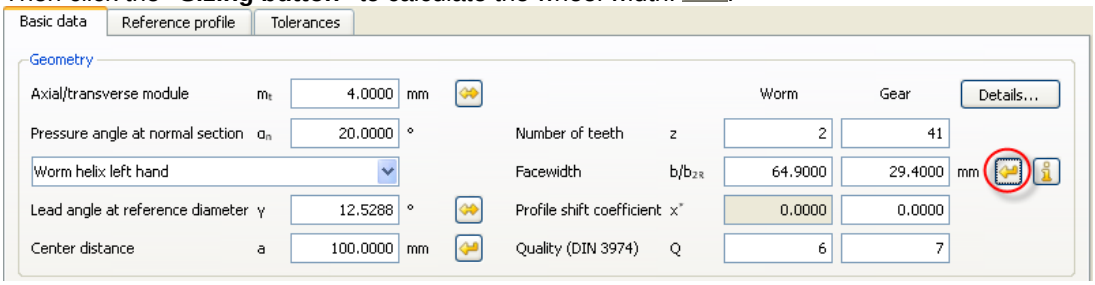


**Figure 1.7** Calculated wheel flange width b2R

## 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 **"conversion 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.

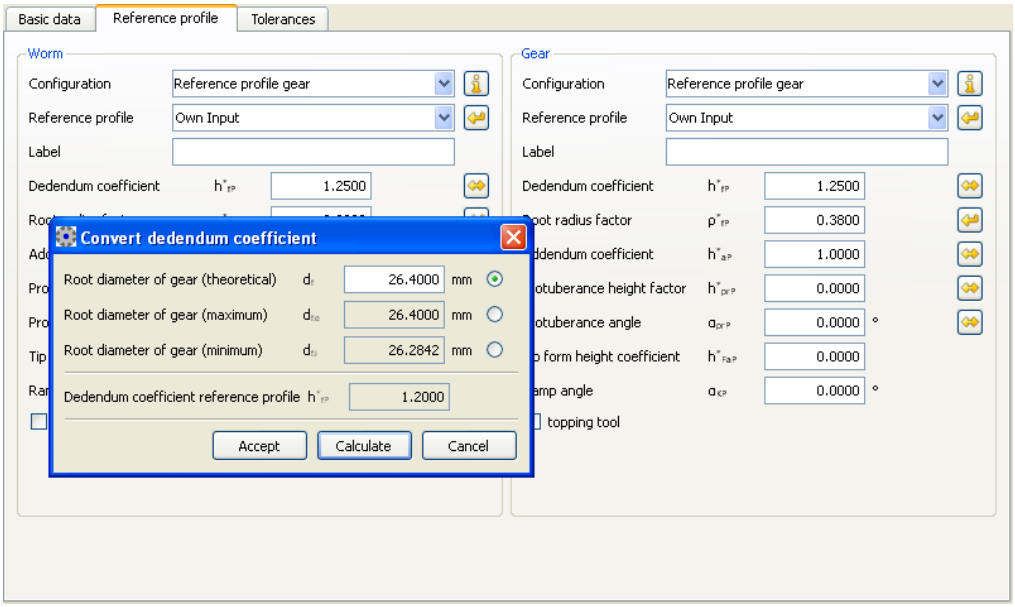


**Figure 1.8** Calculating the root or tip diameter for the worm

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 wheel. 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 **"conversion button"**  to convert the dedendum and addendum coefficient at the worm wheel. Then click Accept to transfer the values to the main screen.

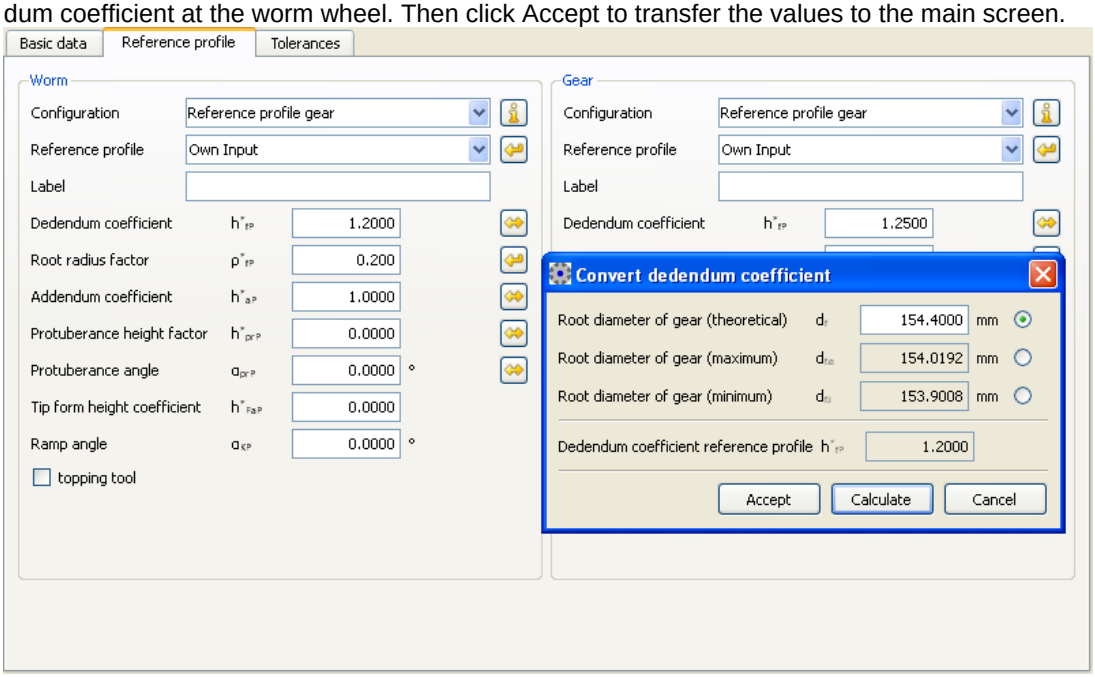


**Figure 1.9** Calculating the root or tip diameter of a worm wheel

Explanation: When you call the worm wheel calculation, the system already provides predefined base 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 shown above.

The particular geometry of enveloping worm wheels also means you need to calculate the tip gorge radius and the outside diameter $d_{e2}$.

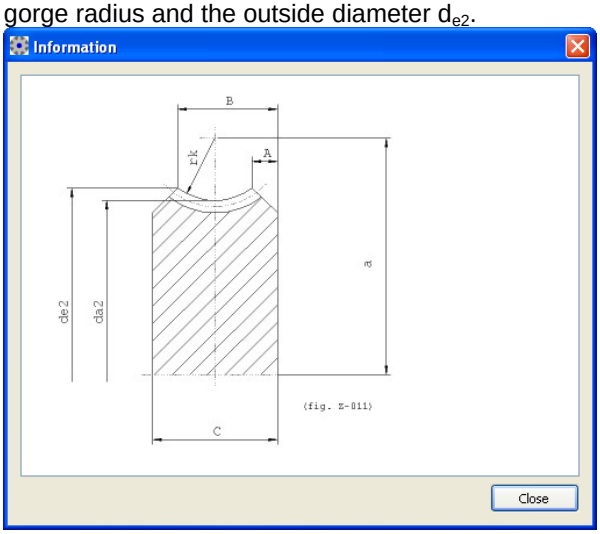


**Figure 1.10** Geometry of enveloping worm wheels

In the "Basic data" tab, click the **"Details"** button to display the "Define details of geometry" subscreen and then click the relevant "Sizing" button" to perform the required calculation of the tip gorge radius $r_k$ and the outside diameter $d_{e2}$.

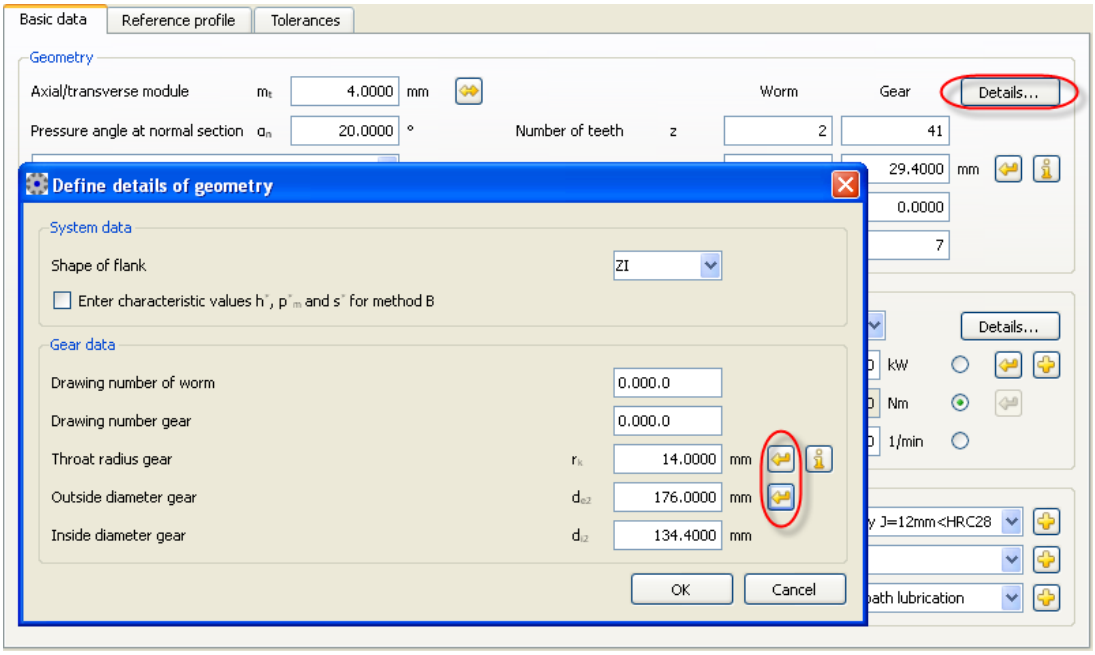


**Figure 1.11** Calculating the tip gorge radius rk and the outside diameter

## 1.6 Inputting tolerances

In the **"Tolerances"** tab, set the selection of predefined dimensions to **"Own input"**. Then input the tooth thickness deviation in accordance with the default values and the input for the tip diameter deviation.

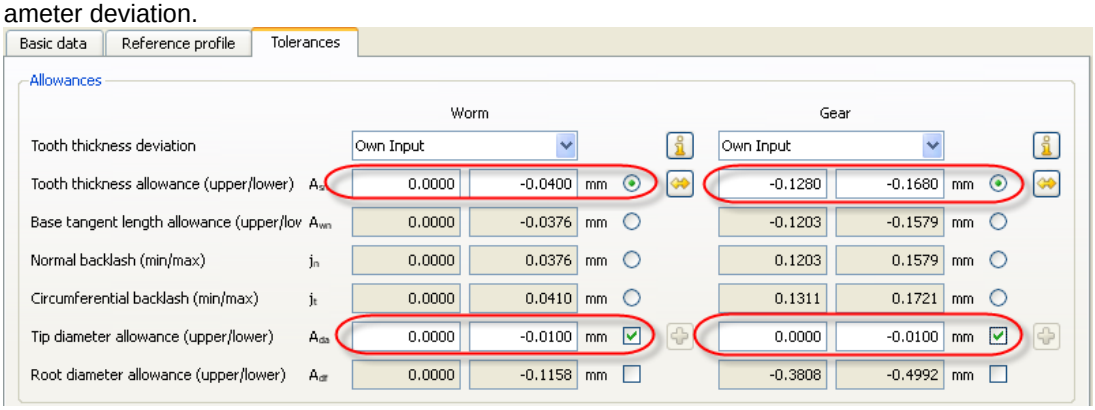


**Figure 1.12** Inputting a tooth thickness tolerance and tip diameter deviation

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

Now select the center distance tolerance.

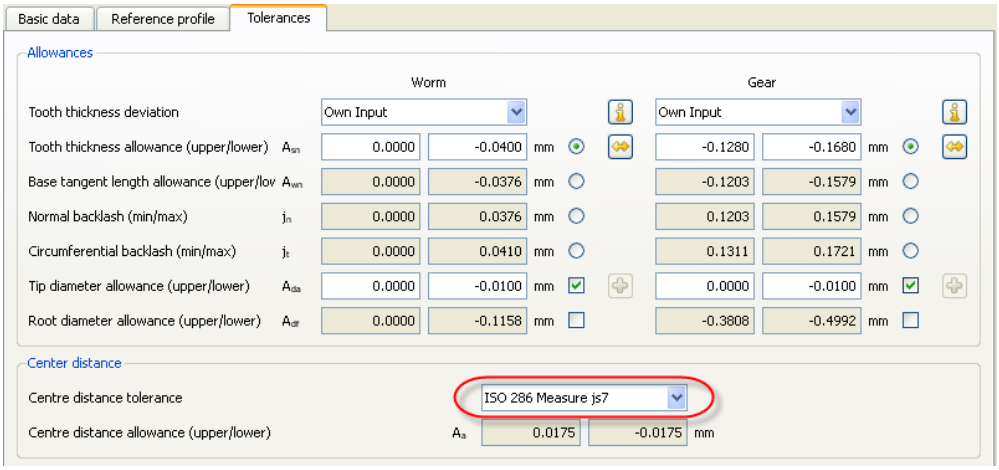


**Figure 1.13** Input center distance tolerance

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 wheel $b_{2R}$ to 31mm and the outside diameter $d_{e2}$ to 181.41 mm.

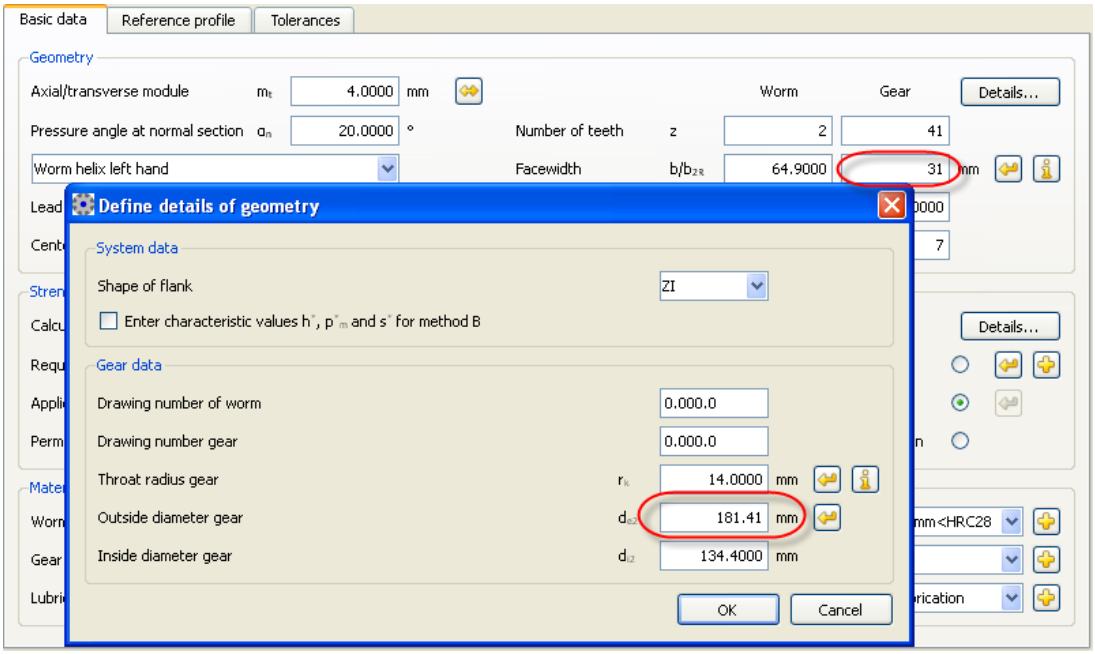


**Figure 1.14** Concluding entries

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)".

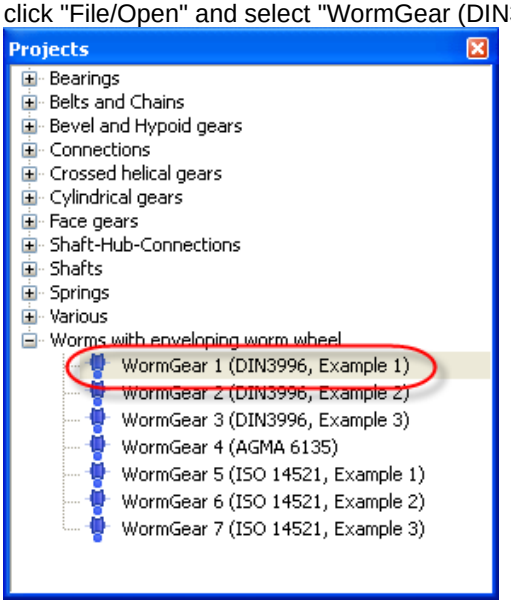


**Figure 2.1** Opening the example calculation

## 2.1 Results of the geometry calculation

KISSsoft - Release 08-2009ß
KISSsoft evaluation

File
Name : Unnamed
Changed by : David on: 20.07.2009 at: 23:10:57

**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 ---- |
|---|---|---|---|
| Centre 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 | |
| Helix | | left | left |
| Number of teeth | [z] | 2 | 41 |
| Face width (mm) | [b1] | 64.90 | |
| Wheel rim width b2R (mm) | [b2R] | | 31.00 |
| Wheel width b2H (mm) | [b2H] | | 31.00 |
| Face width for calculation (mm)[B1] | | 64.90 | 30.83 |
| Accuracy grade (manufacturing) | [Vqual] | 6 | 7 |
| Internal diameter gearbody (mm) | [di] | 0.00 | 134.40 |

Material
worm: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28
Gear: CuSn12-C-GZ, Bronze, untreated
DIN 3996:2005

| | | ------- WORM | ---------- WHEEL ---- |
|---|---|---|---|
| Surface hardness | | HRC 61 | HBW 95 |
| Yield point (N/mm²) | [sigs] | 850.00 | 150.00 |
| Young's modulus (N/mm²) | [E] | 206000 | 88300 |
| Poisson's ratio | [ny] | 0.300 | 0.350 |
| Fatigue str. tooth root tension (N/mm²) | [tauFlim] | 430.00 | 92.00 |
| Fatigue str. Hertzian stress (N/mm²) | [sigHlim] | 1500.00 | 425.00 |
| Average roughness, Ra, tooth flank (µm) | [RAH] | 0.60 | 1.30 |
| Mean roughness height, Rz, flank (µm) | [RZH] | 4.80 | 0.00 |
| Mean roughness height, Rz, root (µm) | [RZF] | 20.00 | 0.00 |
| Material Coefficient YW | [YW] | | 1.00 |
| Material lubrication coefficient | [WML_Min] | | 1.60 |

Tool or reference profile of gear 1 :

| Reference Profile (Own input) | | |
|---|---|---|
| Addendum factor | [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 (Own input) | | |
|---|---|---|
| Addendum factor | [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 |

| Sum 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 gear according to DIN3975:**
**(Only valid for worm gears 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 |
| Meancircle diameter (mm) | [dm] | 164.000 |
| Outside diameter (mm) | [de] | 181.410 |
| Tip groove mean radius (mm) | [rk] | 14.000 |
| Profile shift coefficient | [x-DIN3975] | 0.0000 |
| Pitch (mm) | [p2] | 12.566 |

**Indications for the manufacture of the worm wheel as a cylindrical gear**
**(This specification is only a suggestion. You must calculate the exact geometry using the crossed-cylindrical calculation!)**

| | | | |
|---|---|---|---|
| Pressure angle at Transverse section (°) | [alft] | (59.205) | 20.444 |
| Pressure angle at axial section (°) | [alfx] | (20.448) | 59.324 |
| Helix angle at reference diameter (°) | [beta] | (77.471) | 12.469 |
| Lead angle at pitch diameter (°) | [gamma] | (12.529) | 77.531 |
| Transverse module (mm) | [mt] | (18.000) | 3.999 |
| Axial module (mm) | [mx] | ( 4.000) | 18.000 |
| Helix angle at operating pitch diameter (°) | [betas] | (77.528) | 12.472 |
| Operating pitch diameter (mm) | [dw] | (36.171) | 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 |
| Shape number q | [q] | 9.000 |
| Sum of the Addendum modification | [Summexi] | 0.0000 |

| | | | |
|---|---|---|---|
| Profile shift coefficient | [x-DIN3975] | 0.0000 | 0.0000 |
| Profile shift coefficient (x*m) (mm) | [x*mx] | 0.0000 | 0.0000 |

(The addendum modification is related to the axial module of the worm subject to DIN3975)

| | | | |
|---|---|---|---|
| Modification of tip diam. (mm) | [k] | 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 |
| Meancircle 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 circle (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 acc. to Thomas-Charchut)
[eps_a] 0.000

For ZI worms:

| | | |
|---|---|---|
| Base diameter (mm) | [dB] | 18.431 |
| Base lead angle (°) | [gamb] | 23.463 |
| Base cylinder pitch (mm) | [pb] | 11.527 |

## 8. MEASURES FOR TOOTH THICKNESS

Tooth thickness tolerance
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 |
| Axial distance without backlash (mm) | [aControl] | 99.820/ 99.707 | |
| Backlash free center distance, tolerances (mm) | [jta] | -0.180/-0.293 | |
| No. of teeth over which to measure | [k] | | 5.000 |
| Base tangent length ('span') (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 |
| Theoretical dim. center to ball (mm) | [MrK] | | 87.190 |
| Actual dimension center to ball (mm) | [MrK.e/i] | 87.034/86.985 | |
| Diameter of contact point (mm) | [dMMr.m] | 37.166 | 164.455 |
| Theoretical dimension over two balls (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 gap in axial cut (mm) | [emx] | 6.283 | |
| Actual tooth gap (mm) | [emx.e/i] | 6.283/6.324 | |
| 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. TOLERANCES

| | | ------- WORM | ---------- WHEEL ---- |
|---|---|---|---|
| According to DIN 3974: | | | |
| Accuracy grade | [Vqual] | 6 | 7 |
| Single normal 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 angular deviation (µm) | [fHa] | 7.50 | 11.00 |
| Profile deviation (µm) | [ffa] | 11.00 | 15.00 |
| Profile total deviation (µm) | [Fa] | 13.00 | 19.00 |
| Runout tolerance (µm) | [Fr] | 18.00 | 35.00 |
| Total tangential composite deviation (µm) | [Fi'] | 29.00 | 56.00 |
| Tooth-to-tooth tangential composite deviation (µm) | [fi'] | 15.00 | 22.00 |