1 Problem definition

1.1 Problem definition

The strength of a helical gear pair is to be analysed according to ISO6336, method B. A load spectrum is used (damage accumulation according to the Miner rule). Resulting safety factors, lifetimes and permissible power rating is to be calculated.

The data for the helical gear pair is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Gear 1</th>
<th>Gear 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module [mm]</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Helix angle [deg]</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Pressure angle [deg]</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>No. of teeth [-]</td>
<td>25</td>
<td>76</td>
</tr>
<tr>
<td>Width [mm]</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>Material</td>
<td>18CrNiMo7-6 case hardened</td>
<td>18CrNiMo7-6 case hardened</td>
</tr>
<tr>
<td>Nominal torque [Nm]</td>
<td>3360</td>
<td>-</td>
</tr>
<tr>
<td>Nominal speed [Rpm]</td>
<td>440</td>
<td>-</td>
</tr>
<tr>
<td>Application factor [-]</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Required lifetime [h]</td>
<td>20’000</td>
<td>20’000</td>
</tr>
</tbody>
</table>

The following load spectra should be used:

<table>
<thead>
<tr>
<th>Frequency [%]</th>
<th>Speed factor [%]</th>
<th>Torque factor [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>30</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
2 Starting KISSsoft

2.1 Starting gear pair calculation

After having installed and released KISSsoft as test or commercial version (see installation instructions), start KISSsoft using „Start/Program Files/KISSsoft 03-2008/KISSsoft“. The following window will appear:

Figure 2.1-1; Start KISSsoft, KISSsoft main window

3 Data input

3.1 Data for load spectra

Once the database tool has been started as shown above, the load spectra database can be opened using „Extras“ -> „Data base tool“ and selecting „Edit“. Now existing load spectra can be modified with „Edit“ or new can be add by selecting “+”.

Figure 3.1-1; Opening the load spectra database
The name, the number of steps in the spectra and the data for the steps is to be given. Furthermore, it should be indicated whether the load spectra is applicable for the torque or power rating, under “Input”. It is also possible to import load spectra from a text file. Once the data has been inserted, the new data set is saved by clicking “OK” and in the next window “Save”. The database tool is closed using “Cancel”. The load spectra are now available for gear analysis as described below. Back in the KISSsoft start window, use “Calculation / Driving-Elements / Spur/Helical gear / Spur/Helical gear pair /Z1)” to start the KISSsoft gear pair analysis as shown in Figure 3.2-1.

### Figure 3.1-3; Defining a load spectra

#### 3.2 Input of gear data

The Cylindrical Gear pair calculation in the KISSsoft main menu is open by using the 2Module tree window” Tab “Modules”, select the Cylindrical Gear pair calculation. Gear data as listed above is now added as shown:
3.3 Defining further parameters

3.3.1 Centre distance
Using the sizing button to the right of the field for the centre distance a, the centre distance can be calculated. At this point, no addendum modification has been defined; the addendum modification sum is hence zero. Using „Calculate“, the centre distance is calculated and available in the main window.

3.3.2 Addendum modification
The addendum modification is to be selected such that balanced / minimal specific sliding is achieved. For this, press „arrow“ to the right of the field profile shift coefficient :
Resulting addendum modifications according to different criteria. In this example problem, the criteria for balanced specific gliding shall be used.

Figure 3.3-3; Sizing of addendum modification

Figure 3.3-4; Resulting addendum modification

The centre distance is not very sensible. It can be changed to 304.2mm manually (type in the new value). The necessary change in addendum modification to achieve this new centre distance is calculated using “Σ” (Calculate). The changes in the addendum modification are minimal and do not change the specific sliding noticeably. Furthermore, the safety factors for root and flank are calculated using the nominal loads as defined in the top right corner of the window. The results are shown in the lower section of the window.

Figure 3.3-5; Gear pair with sensible centre distance, addendum modification and first results using the nominal loads
The specific sliding can be visualised using „Graphics“ -> „Evaluation“ -> ”Specific sliding“:

![Specific sliding visualization](image)

Figure 3.3-6; Calculation of specific gliding, resulting graphic

### 3.3.3 Lubrication

Use the button „Lubrication“ in the main window to get the following dialog where the lubrication parameters can be defined:

![Lubrication parameters](image)

Figure 3.3-7; Lubrication parameters

### 4 Lifetime / strength calculation with load spectra

#### 4.1 Resulting lifetime using required safety factors

In a first step, the lifetime in hours shall be calculated using required safety factors. The required safety factors will automatically calculated by the Software. The safety factors can be defined for different ranges of module, independently for metallic (according to DIN, ISO or AGMA) and plastic gears. These required safety factors can be defined as shown in the figure below (confirm with “Ok“):
Figure 4.1-1 Setting the required safety factors using the module specific settings

The calculation of the resulting lifetime can now be executed from the main window using the plus button:

![Interface for setting safety factors](image)

**Figure 4.1-2; Starting the lifetime calculation using a load spectra**

In the following dialog, the load spectra can be selected (press „Plus“ button), see Figure 4.1-2. The required safety factors as defined above are shown using “Nominal safeties”, see Figure 4.1-2. The application factor should be set to 1.00, since a load spectra is used (may be higher than 1.00 depending on the application). Different modifications of Miners rule may be chosen, use “F1” to get more information on this topic from the manual. Then, the calculation is executed by using “Σ” (or the button “F5”):

![Dialog for selecting load spectra](image)

**Choose type of Miner rule**

**Choose load spectra**

**Overview of load spectra**

*Figure 4.1-3; Lifetime analysis, main window*

With „Report“ -> „Lifetime“ can be generate the results in a report.
Figure 4.1-4, generate report

File

Name : Tutorial-010
Description: KISSsoft Data Set
Changed by : ho on: 26.03.2008 at: 11:36:07

Calculation of life

Load spectrum
Nominal Power [P]  200.0000  kW
Application factor [KA]  1.00
Load spectrum : Tutorial10
Number of element in the load spectrum: 4
Reference gear: 1

Element Frequency (%)  Power (kW)  Nominal Speed (rpm)  Torque (Nm)
1     10.00000      8.00     88.00     868.12
2     20.00000     30.00    220.00    1302.18
3     40.00000    144.00    352.00    3906.53
4     30.00000   200.00    440.00    4340.59

Woehler-curve at the fatigue stress according: Miner

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation all the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Notice:
Calculation with methods ISO6336 and AGMA 2001 results in a reduction
of resistance in the domain of fatigue resistance
(from circa 10^7 to 10^10 cycles with a reduction of circa 15).
The lifetime calculation takes this into account
(also with the Woehler Curve of the Miner type).

Required safety root: 1.400
Required safety flank: 1.000

Results

Life (h) root :  347.380  899.381
Life (h) flank :  5451.834  18885.620

Life (h) system: 347.380

Element no.  Damage(%)  
1  0.00000e+000  
2  0.00000e+000  
3  0.7134  
4  99.2866

Safety scuffing (I.):  2.84
Safety scuffing (B.):  2.95

(Safety against scuffing is indicated for the weakest element of the load spectrum.)

End report lines: 66

Figure 4.1-5; Report for load spectra analysis
Figure 4.1-6; display minimum Lifetime

To see intermediate results with further details for each step in the load spectra you can see in the file Z18-H1.tmp. Saved in file directory C:\Document and settings\user\local settings\TMP\KISS_???. You will obtain a listing like this:

Figure 4.1-7; Report with information on each step of the analysis.

### 4.2 Resulting safety factors for a required lifetime

After input a required lifetime in the group ‘Strength’ the calculation is executes by a load spectrum calculation. The same settings as described above should be made. However, instead of the required safety factors, a required lifetime should be defined. Using ‘Σ’ (or the button ‘F5’), the calculation of the safety factors taking into account the load spectra is executed. The results are shown in the “Results window”.

Figure 4.2-1; resulting safety factors based on a required lifetime and a load spectra

### 4.3 Calculation of the permissible torque

In the same manner, using the sizing button „Calculation / Sizing of torque / Torque with duty cycle “, the maximum torque can be calculated such that the required safety factors and lifetime are achieved. Again, load spectra can be taken into account.
5 Further calculation modules

5.1 Safety against scuffing

In the lower section of the main window, the safety against scuffing (flash or integral temperature criteria) is shown:

![Safety factors against scuffing](image)

The course of the flash temperature can be shown using „Calculation / Flash temperature course“, see Figure 5.1-2. Using „Calculation / Profile Corrections Z15“ (see Figure 5.1-3) a tip relief can be added to the tooth form (here using 90% of the nominal load). The modified tooth form can be accepted using „Take over data“. The messages shown in Figure 5.1-4 will appear, indicating that the reference profile has changed. The tip relief will result in an improved course of the flash temperature, see Figure 5.1-7.

![Flash temperature course for the un-modified tooth form](image)
Press “Calculate F5” in the main window again and the new safety factors against scuffing will be shown. Note that they have increased (compare Figure 5.1-1 with Figure 5.1-6.).

If the calculation of the flash temperature course is executed again using „Calculation / Flash temperature course“, the graphic below will be generated. Note that the flash temperature at the tip of the tooth has decreased considerably and that the overall temperature is lower:
5.2 Hardening depth

The necessary hardening depth can be estimated using the course of the shear stress level over the depth of the tooth (shear stress due to Hertzian contact stress). Use “Graphics/ Evaluation/ Hardening depth“ to get the stress distribution. The necessary hardness depth is estimated at twice the depth of the shear stress maximum. If the gear is grinded after hardening, the grinding depth has to be added to the recommended value for the hardening depth.

Figure 5.1-7: Course of flash temperature for modified tooth (with tip relief).

Figure 5.2-1: Shear stress over tooth depth, recommended hardening depth
1 Problem definition

1.1 Problem definition

The strength of a helical gear pair is to be analysed according to ISO6336, method B. A load spectrum is used (damage accumulation according to the Miner rule). Resulting safety factors, lifetimes and permissible power rating is to be calculated.

The data for the helical gear pair is as follows:

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<tr>
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</tr>
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<tbody>
<tr>
<td>Module [mm]</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Helix angle [deg]</td>
<td>5</td>
<td>5</td>
</tr>
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<td>18CrNiMo7-6 case hardened</td>
</tr>
<tr>
<td>Nominal torque [Nm]</td>
<td>3360</td>
<td>-</td>
</tr>
<tr>
<td>Nominal speed [Rpm]</td>
<td>440</td>
<td>-</td>
</tr>
<tr>
<td>Application factor [-]</td>
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<td>20'000</td>
</tr>
</tbody>
</table>

The following load spectra should be used:

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</thead>
<tbody>
<tr>
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<td>50</td>
<td>30</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>30</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
2 Starting KISSsoft

2.1 Starting gear pair calculation

After having installed and released KISSsoft as test or commercial version (see installation instructions), start KISSsoft using „Start/Program Files/KISSsoft 03-2008/KISSsoft“. The following window will appear:

Figure 2.1-1; Start KISSsoft, KISSsoft main window

3 Data input

3.1 Data for load spectra

Once the database tool has been started as shown above, the load spectra database can be opened using „Extras“ -> “Data base tool“ and selecting “Edit”. Now existing load spectra can be modified with “Edit” or new can be add by selecting “+”:

Figure 3.1-1; Opening the load spectra database
Creating a new data base

The name, the number of steps in the spectra and the data for the steps is to be given. Furthermore, it should be indicated whether the load spectra is applicable for the torque or power rating, under “Input”. It is also possible to import load spectra from a text file. Once the data has been inserted, the new data set is saved by clicking “OK” and in the next window “Save”. The database tool is closed using “Cancel”. The load spectra are now available for gear analysis as described below. Back in the KISSsoft start window, use “Calculation / Driving-Elements / Spur/Helical gear / Spur/Helical gear pair /Z1)” to start the KISSsoft gear pair analysis as shown in Figure 3.2-1.

Input of gear data

The Cylindrical Gear pair calculation in the KISSsoft main menu is open by using the 2Module tree window” Tab “Modules”, select the Cylindrical Gear pair calculation. Gear data as listed above is now added as shown:
3.3 Defining further parameters

3.3.1 Centre distance

Using the sizing button to the right of the field for the centre distance $a$, the centre distance can be calculated. At this point, no addendum modification has been defined; the addendum modification sum is hence zero. Using „Calculate“, the centre distance is calculated and available in the main window.

3.3.2 Addendum modification

The addendum modification is to be selected such that balanced / minimal specific sliding is achieved. For this, press „arrow“ to the right of the field profile shift coefficient :
Resulting addendum modifications according to different criteria. In this example problem, the criteria for balanced specific gliding shall be used.

Figure 3.3-3: Sizing of addendum modification

The centre distance is not very sensible. It can be changed to 304.2mm manually (type in the new value). The necessary change in addendum modification to achieve this new centre distance is calculated using \( \Sigma \) (Calculate). The changes in the addendum modification are minimal and do not change the specific sliding noticeably. Furthermore, the safety factors for root and flank are calculated using the nominal loads as defined in the top right corner of the window. The results are shown in the lower section of the window.

Figure 3.3-4: Resulting addendum modification

Figure 3.3-5: Gear pair with sensible centre distance, addendum modification and first results using the nominal loads
The specific sliding can be visualised using „Graphics“-> „Evaluation“ ->”Specific sliding“:

![Figure 3.3-6; Calculation of specific gliding, resulting graphic](image)

### 3.3.3 Lubrication

Use the button „Lubrication“ in the main window to get the following dialog where the lubrication parameters can be defined:

![Figure 3.3-7; Lubrication parameters](image)

#### 4 Lifetime / strength calculation with load spectra

##### 4.1 Resulting lifetime using required safety factors

In a first step, the lifetime in hours shall be calculated using required safety factors. The required safety factors will automatically calculated by the Software. The safety factors can be defined for different ranges of module, independently for metallic (according to DIN, ISO or AGMA) and plastic gears. These required safety factors can be defined as shown in the figure below (confirm with “Ok”):
Figure 4.1-1 Setting the required safety factors using the module specific settings

The calculation of the resulting lifetime can now be executed from the main window using the plus button:

Figure 4.1-2; Starting the lifetime calculation using a load spectra

In the following dialog, the load spectra can be selected (press „Plus“ button), see Figure 4.1-2. The required safety factors as defined above are shown using “Nominal safeties”, see Figure 4.1-2. The application factor should be set to 1.00, since a load spectra is used (may be higher than 1.00 depending on the application). Different modifications of Miners rule may be chosen, use “F1” to get more information on this topic from the manual. Then, the calculation is executed by using “Σ” (or the button “F5”):

Choose type of Miner rule
Choose load spectra
Overview of load spectra

Figure 4.1-3; Lifetime analysis, main window

With „Report“ -> „Lifetime“ can be generate the results in a report.
Figure 4.1-4, generate report

**File**

**Name**: Tutorial-010  
**Description**: KISSsoft Data Set  
**Changed by**: ho  
**on**: 26.03.2008  
**at**: 11:36:07

**Calculation of life**

**Load spectrum**

- **Nominal Power (P)**: 200.0000 kW
- **Application factor (KA)**: 1.00
- **Load spectrum**: Tutorial10
- **Number of element in the load spectrum**: 4
- **Reference gear**: 1

<table>
<thead>
<tr>
<th>Element Frequency (%)</th>
<th>Power (kW)</th>
<th>Nominal Speed (rpm)</th>
<th>Torque (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.00000</td>
<td>8.00</td>
<td>888.12</td>
</tr>
<tr>
<td>2</td>
<td>20.00000</td>
<td>30.00</td>
<td>1302.18</td>
</tr>
<tr>
<td>3</td>
<td>40.00000</td>
<td>144.00</td>
<td>3906.53</td>
</tr>
<tr>
<td>4</td>
<td>30.00000</td>
<td>200.00</td>
<td>4340.59</td>
</tr>
</tbody>
</table>

Woehler-curve at the fatigue stress according: Miner

**Notice:**
- Calculation method according to:  
  - ISO 6336, part 6
- During the calculation all the load coefficients (ISO6336: KV, KHB, KFB; AGMA2001: Knu, Km, ..) for each load spectrum element are calculated separately.

**Notice:**
- Calculation with methods ISO6336 and AGMA 2001 results in a reduction of resistance in the domain of fatigue resistance (from circa 10^7 to 10^10 cycles with a reduction of circa 15).
- The lifetime calculation takes this into account (also with the Woehler Curve of the Miner type).

**Required safety root**: 1.400  
**Required safety flank**: 1.000

**Results**

- **Gear 1**
  - **Life (h) root**: 347.380  
  - **Life (h) flank**: 5451.834

- **Gear 2**
  - **Life (h) root**: 899.381  
  - **Life (h) flank**: 18885.620

**Life (h) system**: 347.380

**Element no. Damage (%)**

- 1: 0.0000e+000
- 2: 0.0000e+000
- 3: 0.7134
- 4: 99.2866

**Safety scuffing (I.)**: 2.84  
**Safety scuffing (B.)**: 2.95

(Safety against scuffing is indicated for the weakest element of the load spectrum.)

**End report**

**lines**: 66

Figure 4.1-5; Report for load spectra analysis
To see intermediate results with further details for each step in the load spectra you can see in the file Z18-H1.tmp. Saved in file directory C:\Document and settings\user\local settings\TMP\KISS_???\KISS_???. You will obtain a listing like this:

4.2 Resulting safety factors for a required lifetime

After input a required lifetime in the group ‘Strength’ the calculation is executes by a load spectrum calculation. The same settings as described above should be made. However, instead of the required safety factors, a required lifetime should be defined. Using “Σ” (or the button “F5”), the calculation of the safety factors taking into account the load spectra is executed. The results are shown in the “Results window”.

4.3 Calculation of the permissible torque

In the same manner, using the sizing button „Calculation / Sizing of torque / Torque with duty cycle “, the maximum torque can be calculated such that the required safety factors and lifetime are achieved. Again, load spectra can be taken into account.
5 Further calculation modules

5.1 Safety against scuffing

In the lower section of the main window, the safety against scuffing (flash or integral temperature criteria) is shown:

![Safety factors against scuffing](image)

Figure 5.1-1: Safety factors against scuffing

The course of the flash temperature can be shown using „Calculation / Flash temperature course“, see Figure 5.1-2. Using „Calculation / Profile Corrections Z15“ (see Figure 5.1-3) a tip relief can be added to the tooth form (here using 90% of the nominal load). The modified tooth form can be accepted using „Take over data“. The messages shown in Figure 5.1-4 will appear, indicating that the reference profile has changed. The tip relief will result in an improved course of the flash temperature, see Figure 5.1-7.

![Flash temperature course for the un-modified tooth form](image)

Figure 5.1-2; Flash temperature course for the un-modified tooth form
Figure 5.1-3 Starting the profile correction module, sizing of a tip relief using 75% of nominal load

Figure 5.1-4; Message after pressing „Accept“

Press “Calculate F5” in the main window again and the new safety factors against scuffing will be shown. Note that they have increased (compare Figure 5.1-1 with Figure 5.1-6.).

Figure 5.1-5, entry of modification

Figure 5.1-6; New safety factors against scuffing for modified tooth form

If the calculation of the flash temperature course is executed again using „Calculation / Flash temperature course“, the graphic below will be generated. Note that the flash temperature at the tip of the tooth has decreased considerably and that the overall temperature is lower:
5.2 Hardening depth

The necessary hardening depth can be estimated using the course of the shear stress level over the depth of the tooth (shear stress due to Hertzian contact stress). Use “Graphics/ Evaluation/ Hardening depth“ to get the stress distribution. The necessary hardness depth is estimated at twice the depth of the shear stress maximum. If the gear is grinded after hardening, the grinding depth has to be added to the recommended value for the hardening depth.

Figure 5.2-1; Shear stress over tooth depth, recommended hardening depth