New Dimensions in Bevel Gear Production

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New Dimensions in Bevel Gear Production

1. Introduction

2. Gear Design

3. Gear Production

4. Summary & Outlook
1. Introduction

Thrusters – Then and Now

source: Schottel
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2. Gear Design

Input Data and Design Considerations

Input Data:
- \( u \): gear ratio
- \( \Sigma \): shaft angle
- \( T \): torque
- \( n \): rotational speed
- \( K_A \): application factor
- ...  

Design Considerations:
- definition of gearing system
- input of basic data
- computer aided design by proposals for missing gear parameters
- review and optimization of the actual design based on characteristic values
- load induced stress levels within the teeth

\[
\sigma_F = \frac{F_{mtv}}{b \cdot m_{mn}} \cdot Y_{Fa} \cdot Y_{Sa} \cdot Y_\varepsilon \cdot Y_K \cdot Y_{LS} \cdot K_A \cdot K_v \cdot K_{F\beta} \cdot K_{Fa}
\]
2. Gear Design

Material Strength and Rating

\[ \sigma_F \leq \frac{\sigma_{FP}}{S_F} \]

(to avoid tooth breakage)

\[ \sigma_H \leq \frac{\sigma_{HP}}{S_H} \]

(to avoid pitting)
2. Gear Design

Results of Macro Design

- Basic parameters of the toothing
- Blank dimensions
- EaseOff (crowning data)
- Contact pattern without load
- Transmission error
- Machine settings
- Tooling information
Relative position of pinion and gear is influenced by:

- tolerances in manufacturing and assembly
- deflections under load
- bearing clearances
- thermal expansions
- ...
2. Gear Design

System Boundaries of Software Tools

Gear Calculation Tool

- flexible teeth
- gear bodies of infinite stiffness

Static Analysis Tool

- teeth of infinite stiffness
- flexible gear bodies and surrounding
2. Gear Design

Relative Position of Pinion and Ring Gear

- **H+**
- **V+**
- **Σ+**
- **J+**

**Symbols:**
- **M**
- **D**
- **P**
- **V+**
- **H+**
- **Offset**
- **Pinion**
- **Ring Gear**
- **Shaft Angle**
- **Offset**
- **Σ+**
- **J+**

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Dynamic Positioning Conference - October 11-12, 2011 - Houston, Texas
Dipl.-Ing. Rudolf Houben - Head of Calculation and Design - Bevel Gear Division
2. Gear Design

Closed Loop of Gear Design

Gear Optimization

Static Analysis

\[ F_i = f(\varphi) \]
2. Gear Design

Product Development Processes in Comparison

<table>
<thead>
<tr>
<th>Gear Design</th>
<th>Production</th>
<th>Testing</th>
<th>Optimization</th>
<th>Production</th>
<th>Testing</th>
<th>Operation</th>
</tr>
</thead>
</table>
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3. Gear Production

New Gear Cutting Machine C300

- Double spindle for cutting pinions in one clamping
- Dry processing for soft cutting
- Max. diameter $d_{e2} = 3000$ mm
- Max. mean normal module $m_{mn} = 50$ mm
3. Gear Production

Tooling System

- Modular system
- Cutter heads with radii $r = 350, 450, 550$ and $650$ mm
- No. of starts of all cutter heads $z_0 = 7$
- Universal blades clustered by nominal module $14 \leq m_0 \leq 46$ mm
- Coated carbide inserts for soft cutting
3. Gear Production

**Heat Treatment**

- high surface hardness
- ductile core material
3. Gear Production

- **networking:**
  - no more manual input of summaries and corrective settings

- **appropriate flank form modifications already defined during gear design**
3. Gear Production

- material certificates
- tooling setup reports
- hardness profile
- gear measurement reports
- photos of contact pattern
- ...

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5. Summary

- As a precondition to apply appropriate flank form modifications to a bevel gear set, deflections affecting the relative position of pinion and ring gear need to be known.

- KIMoS and RomaxDesigner in combination represent a powerful software package for analysis and optimization of the bevel gear set and the surrounding components.

- Closed loop production ensures precise gear manufacturing according to the design.

- Heat treatment significantly influences the quality of a bevel gear set.

- Quality record of the overall process chain is most important to guarantee reliable power transmission.
5. Outlook

Simulation of the Overall Drive System

Static Analysis of Drive System

Dynamic Analysis of Drive System

Displacements of the bevel gear set due to the load, as far as known, can be compensated by flank form modifications.
### 5. Outlook

**Load Capacity of Large Bevel Gears**

#### Power transmission and weight of blank for large ring gear diameter

<table>
<thead>
<tr>
<th>Pitch Diameter of Ring Gear [mm]</th>
<th>Power [kW]</th>
<th>Weight of Ring Gear [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1750</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>7000</td>
<td>7925</td>
</tr>
<tr>
<td>2250</td>
<td>10450</td>
<td>10830</td>
</tr>
<tr>
<td>2500</td>
<td>12690</td>
<td>14300</td>
</tr>
<tr>
<td>2750</td>
<td>14790</td>
<td>16187</td>
</tr>
<tr>
<td>3000</td>
<td>17500</td>
<td>20950</td>
</tr>
</tbody>
</table>

**Basic parameters:** $u = 1.72$, $\beta_m = 26^\circ$, $K_A = 2.0$

*Today*:
- Power: 17500 kW
- Weight: 20950 kg

*Yesterday*:
- Power: 15000 kW
- Weight: 16187 kg

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