Production of any Bevel Gear on 5-Axis Machine
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3. Topological modification
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Introduction – Process of bevel gear design
Introduction – bevel gear production

production with 5-Axis machine

conventional Production

based on 3D models

based on bevel gear machine settings

productivity

flexibility
Introduction – actual situation

There is a need for 5-Axis milled bevel gears because:

- The existing conventional machines “are getting older”

- For small batches the machine equipment and production line is unreasonable expensive

- High flexibility for usage of 5-Axis machines in the production (can be used for other tasks as well)
Introduction – process of 5 Axis milling

- STEP Modell
- CAM
- Production
Demands on the models – cutting methods

Many different cutting methods from conventional cutting:

- \( M \)any different cutting methods from conventional cutting:

<table>
<thead>
<tr>
<th>Cutting Method</th>
<th>Gear Type</th>
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<tbody>
<tr>
<td>Gleason</td>
<td>Single Side, Duplex, Spread blade, …</td>
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<tr>
<td>Klingelnberg</td>
<td>Zyklo-Pallloid, Pallloid, N-Verfahren, Spiroflex, TRI-AC, Kurvex, Arcoid, 5-Schnitt, Completing, Wiener 2-Spur, Wiener 1-Spur, Semi-Completing</td>
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KISSsoft uses the universal method of bevel gear model creation according to ISO 23509. The profile shape is a planar involute, the lengthwise shape is an arc of circle, elongated epicycloid or involute.
Demands on the models – contact pattern

The simulation of the contact has to be identical with the rolled contact patterns of real gears.
Demands on the models – modifications

In the conventional production, each cutting method allows different modifications, which are

- Lengthwise crowning by cutter head tilt, different blade radii, …
- Profile crowning by blade, hollow cone, …
- Modified roll, 1. to n-order
- Helical motion, 1. to n-order
- UMC™ with Ease off optimization per segment
- …

→ The modification types and their combination is almost infinitive
Demands on the models – modifications

The typical modifications are available in KISSsoft as for the conventional cutting methods:

- Angle modification
- Crowning (here combined with angle modification)
- Twist
Demands on the models – meshing behaviour

Highest demands
• Detailed analyses of complete gearbox (shafts, bearings, deformation of housing) under load
• Determination of relative position of gear and pinion (V/E, H/P, J/G, Σ).
→ Contact analysis under load, Transmission Error

Basic demands
• the modifications (crowning) are determined according to literature and / or experience
→ Checking of contact pattern
Application of models

Bevel gear types:
- Straight bevel gears
- Skewed bevel gears
- Spiral bevel gears

Application of models:
- FE analysis
- MK simulation
- Measurement grid data
- Production with 5-Axis milling
Practical application

For production of a Gleason bevel gear pair, the pinion was produced on a conventional cutting machine where as the ring gear was produced on a 5-Axis machine.

Gear set: Gleason-Duplex Generated, ratio 29:36, $m_{nm} = 9.5\text{mm}$, $D_2 = 500\text{mm}$
Topological modification

The topological modification are used as a very general approach to achieve a target topology on the bevel gear models.
Topological modification

How were the topological modification created?
Topological modification

The difference between the measurements grid data is used.
Topological modification

The topological modification is added to the KISSsoft model.
Calculation and results

The measurement grid resolution of 9x5 was used. (Definitions according to ISO/TR 10064-6:2009)

The data are extrapolated to the tooth rim as toe, heel, tip and root form diameter.
Calculation and results

Left flank, start values

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Maximum deviation between KISSsoft model (original model with increased tooth thickness) and grid data of the measured ring gear: 570 μm
**Calculation and results**

Left flank, final values

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Remaining deviation between KISSsoft model (modified model with topological modification) and grid data of the measured ring gear: 5 μm
Calculation and results

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Maximum deviation between KISSsoft model (original model with increased tooth thickness) and grid data of the measured ring gear: 575 μm
Calculation and results

Right flank, final values

Remaining deviation between KISSsoft model (modified model with topological modification) and grid data of the measured ring gear: 5 μm
Measuring and rolling

The ring gear was measured on a coordinate measuring machine and rolled with the pinion.
Measuring and rolling

Drive side

Coast side
Conclusion and outlook

It was shown how to pair successfully a conventionally produced pinion with a 5-Axis milled ring gear.

Therefore, the specific topology of the conventional cutting method were applied to the model for 5-Axis milling.

This approach uses measuring grid data of existing bevel gears. The method is also applicable for general milling corrections or the compensation heat distortion:
Thank you for your attention!