GTB 500
Measuring of bevel gears with our single flank inspection machine
GEARTEC.CZ, 2017
Main requirements in gear production:

- DIN quality
- Defined backlash
- Low noise / high lifetime
- Influence of assembly precision
- Contact pattern, V/H characteristics
- Where error comes from (pinion / wheel)

All these parameters are measured by single flank inspection machine GTB 500
SINGLE FLANK TESTING PRINCIPLE

- Mounting distance during testing is static
- Left and right flanks are tested separately
- Accurate rotary encoder
- Accuracy up to 1 wsec (5 micro rad)
  \( \sim 1 \mu m \) on radius of 200 mm
- Results in transmission error
- Deviations and tolerances: DIN 3965, AGMA, ISO
MACHINE CAN MEASURE

Standards: DIN 3965, ISO 1328, AGMA 2008

**Single flank deviations**

- $F_i'$ - Tangential composite deviation
- $f_i'$ - Tooth to tooth composite deviation
- $f_l'$ - Longwave component of tangential composite deviation
- $f_k'$ - Shortwave component of tangential composite deviation
- $j$ - Backlash

**Pitch deviations of pinion and gear**

- $F_p$ - Total pitch deviation
- $f_{pt}$ - Adjacent pitch deviation
- $f_u$ - Difference between adjacent pitches
- $F_r$ - Radial run-out

- Contact pattern
- V-H Analysis
- FFT Analysis
- Roundness, eccentricity
OTHER OPTIONS INFLUENCE OF ASSEMBLY

Angular displacement

Correct position

Hypoid offset

Mass displacement

Concentricity
MACHINE VERSIONS

GTB 500 HW - with hypoid offset and setting of angle between axis

GTB 500 H - with hypoid offset, fixed angle between axis 90 rad

GTB 500 W - with hypoid offset 0 – 180 rad, without setting of angle between axis

GTB 500 - Without hypoid offset
Fixed axis angle 90° for bevel gears
Fixed axis angle 0° for spur gears
<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, max.</td>
<td>500 mm</td>
</tr>
<tr>
<td>Diameter of bore for gear</td>
<td>90 mm</td>
</tr>
<tr>
<td>Diameter of bore for pinion</td>
<td>90 mm</td>
</tr>
<tr>
<td>Mounting distance of gear, max.</td>
<td>350 mm</td>
</tr>
<tr>
<td>Mounting distance of pinion, max.</td>
<td>450 mm</td>
</tr>
<tr>
<td>Hypoid offset</td>
<td>± 50 mm</td>
</tr>
<tr>
<td>Angle between axis</td>
<td>0 – 180 rad.</td>
</tr>
<tr>
<td>Revolutions, max.</td>
<td>100 Rev./min.</td>
</tr>
<tr>
<td>Revolutions during measuring, max.</td>
<td>30 Rev./min.</td>
</tr>
<tr>
<td>Brake torque, max.</td>
<td>15 (60) Nm</td>
</tr>
<tr>
<td>Weight of gear, max.</td>
<td>30 kg</td>
</tr>
<tr>
<td>Total weight</td>
<td>1400 kg</td>
</tr>
<tr>
<td>Dimesion</td>
<td>1200x1200x1500 mm</td>
</tr>
<tr>
<td>Accuracy</td>
<td>DIN 3965 / class 1</td>
</tr>
</tbody>
</table>
PRINCIP OF MEASURING WITH DIFFERENT ANGLES

0° < W ≤ 45°

45° ≤ W ≤ 90°

W = 90°

90° ≤ W < 180°
BEVEL GEARS WITH DIFFERENT AXIS ANGLES
<table>
<thead>
<tr>
<th>Pinion</th>
<th>Ritzel24</th>
<th>Ring gear</th>
<th>Rad36</th>
<th>Measured points</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth</td>
<td>$z_1$</td>
<td>24</td>
<td>Number of teeth</td>
<td>$z_2$</td>
<td>36</td>
</tr>
<tr>
<td>Normal module</td>
<td>$m_n$</td>
<td>3,500</td>
<td>Spiral angle</td>
<td>$\beta_m$</td>
<td>$35.0000^\circ$</td>
</tr>
<tr>
<td>Pressure angle</td>
<td>$\alpha_n$</td>
<td>20.0000$^\circ$</td>
<td>Hypoid offset</td>
<td>$a$</td>
<td>0,000 mm</td>
</tr>
<tr>
<td>Spiral angle</td>
<td>$\beta_m$</td>
<td>$35.0000^\circ$</td>
<td>Drawing distance</td>
<td>$e_1$</td>
<td>170,000 mm</td>
</tr>
<tr>
<td>Load torque</td>
<td>$---------$</td>
<td>Nm</td>
<td>Drawing distance</td>
<td>$e_2$</td>
<td>88,000 mm</td>
</tr>
<tr>
<td>Measuring speed</td>
<td>10 rpm</td>
<td>Shaft angle</td>
<td>$\Sigma$</td>
<td>$90.0000^\circ$</td>
<td>Note</td>
</tr>
</tbody>
</table>
LEFT AND RIGHT FLANK

Mounting distance

Rolling deviation

Angular position

Left flank

Right flank
### EVALUATION

#### Allowed values according to DIN 3965

<table>
<thead>
<tr>
<th>Standard</th>
<th>F-factor 25%</th>
<th>Allowed</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total composite deviation</td>
<td>$F_i^+$ [µm]</td>
<td>94,0</td>
<td>6</td>
</tr>
<tr>
<td>Single flank composite dev.</td>
<td>$f_i^-$ [µm]</td>
<td>38,0</td>
<td>6</td>
</tr>
<tr>
<td>Mean value</td>
<td>$t_{i,m}$ [µm]</td>
<td></td>
<td>22,3</td>
</tr>
<tr>
<td>Max value</td>
<td>$t_{i,max}$ [µm]</td>
<td></td>
<td>27,0</td>
</tr>
<tr>
<td>Long wave component</td>
<td>$t_i$ [µm]</td>
<td>94,0</td>
<td>6</td>
</tr>
<tr>
<td>Short wave component</td>
<td>$t_k$ [µm]</td>
<td>47,0</td>
<td>6</td>
</tr>
<tr>
<td>Tooth backlash - normal</td>
<td>$j_n$ [mm]</td>
<td>0,200 \pm 0,300</td>
<td>0,221</td>
</tr>
</tbody>
</table>

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Measuring software is user-friendly requiring no special PC knowledge. It can communicate in many languages and runs under Microsoft Windows operation system.

All measured results are saved to the databank. Time needed for preparing of measurements is shortened to minimum.
Evaluation of measured data is available according to DIN, ISO, AGMA standards or free values.

Gears with CP or DP profiles can also be measured and evaluated.

Graphical evaluation of „good“ or „bad“ may be printed on measuring reports.
MANUAL MODE

- Actual position and angle depicted
- Contact pattern measuring
- Measuring of backlash in a concrete position

X = -195,139 mm
Y = 0,741 mm
Z = --------- mm
S1 = 0.0000°
S2 = 0.0000°
W = 90.0065°
Ra = --------- mm
Rb = --------- mm
n1 = 0,0rpm
n2 = 0,0rpm
EXAMPLE 1: RUN-OUT AND BUMP

- Diagram of single flank, gear ratio 19/38
- Big run-out of pinion
- Tooth No. 8 has bump on the left flank
EXAMPLE 2: BACKLASH

- Chart of backlash for one revolution of gear
- Backlash is changed by pinion run-out
- It is available to measure backlash in a concrete position in manual mode
EXAMPLE 3: CONTACT PATTERN

- Stored in database with measuring results
- Ration of contact pattern surface to total tooth surface in %
EXAMPLE 4: V-H CYCLE

- Digital image of contact pattern, shown in more positions on pinion and gear
- Automatic cycle
EXAMPLE 5: SINGLE FLANK ERRORS

- Right flank with a little pitch error
- Both gears without radial run-out

Pitch error on the right flank
EXAMPLE 6: ROUNDENESS

Single flank composite measurement, bevel gears

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teeth, ( z_1 )</td>
<td>14</td>
</tr>
<tr>
<td>Number of teeth, ( z_2 )</td>
<td>57</td>
</tr>
<tr>
<td>Normal module, ( m_n )</td>
<td>9.687</td>
</tr>
<tr>
<td>Pressure angle, ( \psi_n )</td>
<td>20.000°</td>
</tr>
<tr>
<td>Spiral angle, ( \psi_{pm} )</td>
<td>30.000°</td>
</tr>
<tr>
<td>Mounting distance, ( y_2 )</td>
<td>196.727 mm</td>
</tr>
<tr>
<td>Measuring speed</td>
<td>500 mm/min</td>
</tr>
<tr>
<td>Shaft angle ( \Sigma )</td>
<td>0.0000°</td>
</tr>
</tbody>
</table>

Graphs showing deviations for left and right flanks with measured values and allowed limits.

Table: Standard: DIN 3965

<table>
<thead>
<tr>
<th>Component</th>
<th>Allow.</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total composite deviation</td>
<td>( F_t ) [µm]</td>
<td>94.0 [B]</td>
</tr>
<tr>
<td>Single flank composite dev.</td>
<td>( F_1 ) [µm]</td>
<td>56.0 [B]</td>
</tr>
<tr>
<td>Mean value</td>
<td>( F_m ) [µm]</td>
<td>55.8 [B]</td>
</tr>
<tr>
<td>Max value</td>
<td>( F_{max} ) [µm]</td>
<td>56.3 [B]</td>
</tr>
<tr>
<td>Long wave component</td>
<td>( F_1 ) [µm]</td>
<td>94.0 [B]</td>
</tr>
<tr>
<td>Short wave component</td>
<td>( F_2 ) [µm]</td>
<td>47.0 [B]</td>
</tr>
<tr>
<td>Tooth backlash - normal</td>
<td>( \Delta_B ) [mm]</td>
<td>0.390 - 0.390</td>
</tr>
</tbody>
</table>

Graphs showing the distribution of roundness and eccentricity with measured and allowed values.
EXAMPLE 7: BUMP DETECTION

Single flank deviations – pinion with approximately 20 μm eccentricity

Left flank of pinion with bumps (marked in red color)

Left flank of wheel with a bump (marked in green color)

Right flank of wheel with a bump (marked in blue color)
RUN-OUT AND ROUNDENESS

- Run-out of pinion and gear
- Elimination of error from single flank test

Measuring of control rings
Calculated acceleration spectrum of signal
QUESTION: Which gear causes big deviation on single flank result?

ANSWER: Use decomposition of single flank test.
ASSEMBLY OF BASIC MACHINE
ASSEMBLY OF SPINDLES
ASSEMBLY OF PINION AND GEAR SPINDLES
PINION – CLAMPING FIXTURES based on customer's specification
PINION – DETAIL OF CLAMPING FIXTURE AND ITS TEST
GEAR – CLAMPING FIXTURES based on customer's specification
GEAR – DETAIL OF CLAMPING FIXTURE AND ITS TEST
TESTING OF MACHINE GEOMETRY
CHECKING OF ACCURACY OF ROTATION TABLE
CALIBRATION ARBOR
WIRING BOX
CONTROL PANEL

- Potentiometer for smooth rotation
- Manual motion to designed position
- TOTAL STOP
- Buttons for main functions of measuring application
CONTROLLING COMPUTER

- It is based on high performance industrial computer by Advantech
- Measuring cards by Heidenhain
- Controlling I/O cards by Advantech for communication with proper hardware
ADVANTAGE OF SINGLE FLANK INSPECTION

- Standards DIN, AGMA, ISO, BS ...
- Helps improve gear quality
- Optimization of gear parameters
- Quick measuring and results
THANK YOU

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