Solutions made by Klingelnberg

Spiral bevel
gear tester
Oerlikon T 60
State of the art
testing technology

The T 60 is a CNC machine used for hard and soft tests of the operating behavior of spiral bevel gears and hypoid bevel gears. The machine has three linear axes used to adjust the gear set locating distances and the axis offset.

As an option, the machine can be equipped with an adjusting shaft for adjusting the shaft angle, so that also bevel gear sets with a shaft angle which deviates from 90° can be checked.

The T 60’s main field of application is the fully automatic run test of bevel gear and hypoid sets via single flank testing and/or structure-borne noise measurement under series manufacturing conditions. The user-friendly software is designed for individual measuring procedure configuration, making it possible to perfectly adapt the test cycle to the respective production requirements.

Optional supplementary tools, such as the speed optimization, are designed to help the machine set-up man with this task. Tolerances for concentricity and mounting position deviations, as well as for parameters of the single flank test and the structure-borne noise test can be defined to monitor and control gear set quality.

In addition, the basic dimension for assembly can be determined via optional front checking device. Beyond that, the T 60 can be used to test the operating behavior at defined mounting positions which deviate from the nominal mounting position of the gear set. This is mainly interesting for the test of gear set sensitivity towards axis displacement, which can - for example - occur in gears due to load-induced housing deformations.

Especially for lapped gear sets, the T 60 continues to offer the possibility of automatic determination of the optimum pinion mounting distance for a high smoothness of running.

Due to the increasing cost pressure in the production, the available periods for testing become shorter and shorter. In order to meet this demand, the T 60 offers the possibility of installing dual programs, which is a combination of a standard cycle with a minimum amount of inspection and an additional extended cycle.

With this option both an inspection level of 100% and a short cycle time can be achieved. In addition to this objective inspection the T 60 can also be used for the subjective inspection of the tooth bearing.

Another important factor for using the T 60 as a test machine for monitoring the production is that the T 60 is a proven measuring device. The machine’s mechanic precision in combination with very exact angular encoders and an efficient measuring computer is the basis for a high reproducibility of the single flank check.
The Oerlikon T 60, the most advanced bevel gear testing machine, has been designed for objective bevel gear testing, whilst also taking into account the requirements regarding ease of operation and productivity, as well as making provision for the future addition of automation modules.

Universal field of use, easy to operate

The fully automatic test cycles coupled with the facility for simple, user-oriented manual operation make the Oerlikon T 60 a truly universal bevel gear testing machine:
- Runout error evaluation for pinion and gear separately
- Contact pattern check – position, form and size
- Measurement of running behaviour in relation to load, speed and mounting distance
- Testing the running properties at different mounting distances while measuring the structure borne noise and/or transmission error

The T 60 is the ideal testing machine for the development of new gears. The determination of the contact pattern position, the displacement characteristics (V/H-check) and the adjustments to contact pattern and tooth thickness are aided by simple machine operation.

The very short testing time enables the immediate availability of test results. Expensive additional equipment is not necessary.

In gear development and prototype production the T 60 is used to optimize the cutting process, in the series production it is used to guarantee the quality level and determine the best mounting distance by analyzing structure borne noise and/or the single flank test results.

Proven CNC-Control

The FANUC FS160i-MB control is globally applied in the automotive industry, and is very well proven. A high degree of operation comfort and reliability connected with outstanding ease of maintenance are features of this control.

Innovative machine concept

- Robust design with great static and dynamic stiffness, 3-point-support
- Maximum accuracy and repeatability
- Input of testing parameters via keyboard, 1/“ floppy disc or network connection to external PC
- Precision ball screw units for X, Y, Z axes with maintenance-free AC servo motors and optical direct and absolute scales
- Pinion and gear spindle units with high axial and radial runout accuracy, high stiffness, long life lubrication and AC motors
- Safety regulations of the automotive industry were taken into consideration for the design and construction (e.g. two hand control)

The Oerlikon T 60 with its future oriented conception can be delivered in various configurations to match the individual needs of the customer:
- Single flank testing
- Structure borne noise analysis measured at gear or pinion spindle
- “Best-Fit” – Determination of the best possible mounting position through an incremental variation of the pinion cone distance
- “Continuous measurement” – Best-Fit through a continuously varied mounting distance
- “Speed Scan” – Continuous measurement over a pre-selectable speed range, as a tool to find the optimal test parameters/conditions
- Automatic recording of measurement results
- Automatic application of marking compound to tooth flanks
- Additional interfaces for automation modules such as gantry loaders, marking equipment etc.
Four quadrant operation

Reduced testing times and an optimum contact pattern through testing in the 4 quadrant operation, for simulation of the running condition in the vehicle.

1. cw / drive
2. cw / coast
3. ccw / coast
4. ccw / drive

rotational direction

torque direction
**Evaluation**

Single flank test and vibration analysis on the same machine

The fully integrated Gear-Analyzer (GA) equipped with evaluation electronics enables a single flank test and structure borne noise analysis on the same machine and under vehicle like test condition.

The current results are shown constantly on the screen. Additionally, a freely configurable test report print-out is possible (fig. 1).

Measurement results can be saved continuously. The saved data-sets enable the user to process additional evaluations at any time.

The software module GEARSTAT (Option) enables to filter the accumulated amount of data with freely selectable criteria (date, time, serial #, etc.). The extracted data is the basis for a further statistical evaluation, which can be individually processed.

The Windows based software offers the user an easy to use, flexible and most effective tool for the measurement, analysis and graphical display of the test results. To minimize evaluation times the software is programmed in C and Assembler.

The clear and easily understandable graphical user interface allows the user to process, analyze and display measurement results in different ways.

---

**Table:**

<table>
<thead>
<tr>
<th>Machine Branch</th>
<th>TED 202</th>
<th>501</th>
<th>Section</th>
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<th>No. of teeth</th>
<th>No. of teeth gear</th>
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<td></td>
<td>Backlash</td>
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<td>Deviat.L for bestpos</td>
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</table>

Deviation H [mm] | 0.016 | 0.016 | 0.037 | 0.033 | 0.029 | 0.006 | 0.009 | 0.010 | 0.010 |

Deviation J [mm] | 0.050 | 0.046 | 0.041 | 0.037 | 0.033 | 0.029 | 0.005 | 0.005 | 0.018 | 0.012 |

**Single Flank Test - Drive**

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<tr>
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<th>1</th>
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**Pinion Orders, Peak [μm]**

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**Gear Orders, Peak [μm]**

<table>
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**Single Flank Test - Coast**

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**Pinion Orders, Peak [μm]**

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**Gear Orders, Peak [μm]**

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<td>15.66</td>
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<td>51.03</td>
<td>51.00</td>
<td>52.55</td>
<td>48.79</td>
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</tbody>
</table>
The assessment criteria used as a base for the quality control of spiral bevel and hypoid gears are principally based on the function and thus dominant requirements; low noise level and kinematic precision.

Compared with the test of the individual deviations the function-oriented single flank test can provide valuable information for both the improvement of the gear design as well as for process optimization. Furthermore, the correlation of this testing procedure with the to be expected noise behavior of the transmission in the vehicle is high.

- The significance of the evaluated characteristics of gearsets which need to show very high transmission precision is very distinct. The short wave component (fig. 2) is an important criteria for the gear noise estimation.

- The measured transmission error (fig. 3) is separated in their components with a fast Fourier transformation (FFT). This evaluation provides the order spectra, which are decisive for determining the running behaviour of the transmission in the vehicle.

- The order spectra provides information on noise influencing components, where tolerances may be individually set to enable good / reject decision (fig. 4).
Significant method for assessing the dynamic behavior of the gear set in the vehicle

On the Oerlikon T 60 a structure borne noise analysis under testing conditions that are close to reality can be performed.

The T 60 enables a replacement of the conventional testing method (subjective evaluation of vibration emission) by the objective measurement method using structure borne noise analysis. As a result of this dynamic measurement, the irregularities of the tooth mesh are evaluated. Therefore an accelerometer on the gear spindle housing is used.

- During the structure borne noise measurement the analogue signal of the accelerometer is recorded related to the pinion and the gear revolution.
- The fast Fourier transformation (FFT) of the analogue signal is providing the order spectra (fig. 5) as an important information for the noise properties of a gear set.

During the automatic testing procedure the software compares the measured values with the tolerances established by the user. Any exceeding of the limit values is indicated to the operator.

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**Fig. 5: Order spectra of structure borne noise analysis**

**Measurements**
- Measurement Family: 000001441
- TEST: 321081 00060302
- Result: **Good**
- **Vibration Analysis**

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**Order Spectrum of Vibration (Avg. Rev. of Gear)**

- Drive
- Coast

**Vibration Analysis**

**Tolerances**

**Spec. Amplitudes**

**Over Limits**
Evaluation strategies for determining the optimal mounting distance

- **First position in tolerance**
The predetermined positions are approached and measured successively until the FIRST position with all characteristics within tolerances is found.

- **Best position**
All of the up to 12 selectable mounting distances (positions) are being measured during automatic test cycle. The measurement results (structure borne noise or single flank test) are analyzed and the best position is determined using an algorithm, which takes a user-defined importance of individual characteristics into consideration. The results of the BEST Position must be within tolerance.

- **Best position, all positions within tolerance**
Best position of all measurement positions. With this evaluation strategy all positions must be within tolerance.

**Fig. 6: Protocol with evaluated best pinion cone distance “BestPos”**

<table>
<thead>
<tr>
<th>Machine</th>
<th>TGD 292'501</th>
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</thead>
<tbody>
<tr>
<td>Brand</td>
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<tr>
<td>Section</td>
<td>V2</td>
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<table>
<thead>
<tr>
<th>Description</th>
<th>REP-JORK</th>
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<tbody>
<tr>
<td>Serial number</td>
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<td>Sequence No.</td>
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<table>
<thead>
<tr>
<th>BEST POS.</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos.1 [mm]</td>
<td>-0.010, -0.005, 0.000, 0.020, 0.040</td>
</tr>
<tr>
<td>Pos.2 [mm]</td>
<td>0.017, 0.008, 0.000, -0.008, -0.017</td>
</tr>
</tbody>
</table>

**Single Flank Test - Drive**

1 2 3 4 5

Mesh Orders, Peak [rad]
1 15.33 8.91 4.02 6.42 8.02
2 7.25 7.59 7.21 6.70 6.53
3 0.53 0.59 0.40 0.39 0.57

Pinion Orders, Peak [rad]
1 160.63 151.57 187.15 387.52 186.02
2 19.91 19.36 8.04 4.03 17.30
3 2.37 0.40 6.62 9.82 11.76

Gear Orders, Peak [rad]
1 207.00 279.62 276.14 269.12 281.60
2 11.36 41.60 42.41 24.19 26.17

**Single Flank Test - Coast**

1 2 3 4 5

Mesh Orders, Peak [rad]
1 20.18 20.48 31.66 33.69 38.01
2 14.43 15.68 15.41 21.84 31.82
3 0.28 0.70 0.83 0.82 0.60

Pinion Orders, Peak [rad]
1 113.32 132.12 120.68 328.50 140.73
2 8.90 9.36 7.17 7.47 7.45
3 4.72 6.90 12.48 6.00 2.17

**Single Flank Test - Specials**

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<th>Optim</th>
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<tr>
<td>Speed of pinion</td>
<td>149.2 rpm</td>
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<tr>
<td>Pinion B/D error</td>
<td>0.018 mm</td>
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<td>Gear B/D error</td>
<td>0.021 mm</td>
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<td>Deviat.4</td>
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<td>Deviat.5</td>
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Unlike the method widely established in the industry, where defined positions (drive and coast) are measured and evaluated individually, the continuous measurement permits to record characteristics of single flank transmission error or structure borne noise continuously over a pre-selectable range of pinion cone distance. This shortens the cycle time to determine the best mounting distance, resulting in a high productivity of the process.

**Fig. 7:** 3D-waterfall-diagram of pinion order spectrum (drive/coast)

**Fig. 8:** 3D-waterfall-diagram of pinion order spectrum (drive)

**Fig. 9:** First mesh harmonic over pinion mounting distance

**Fig. 10:** Second mesh harmonic over pinion mounting distance
The measurement (single flank test or structure borne noise analysis) during a speed scan gives the user an excellent tool to find the optimal testing speed.

Similar to the continuous measurement, here the speed is increased continuously during the measurement. This way any characteristics can be drawn over a selectable speed range.

![3D-waterfall-diagram over selected speed range](image)

Fig. 12: 3D-waterfall-diagram over selected speed range
## Technical data

### Working range

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
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<td>Gear diameter, max.</td>
<td>500 mm</td>
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<tr>
<td>Pinion headstock Z (J)</td>
<td>200 mm</td>
</tr>
<tr>
<td>Gear headstock Y (H)</td>
<td>200 mm</td>
</tr>
<tr>
<td>Hypoid shift X (V)</td>
<td>± 70 mm</td>
</tr>
<tr>
<td>Shaft angle</td>
<td>90°</td>
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<tr>
<td>Distance gear axis / pinion spindle flange</td>
<td>150 - 350 mm</td>
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<tr>
<td>Distance pinion axis / gear spindle flange</td>
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### Pinion headstock (4-quadrant operation)

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<tbody>
<tr>
<td>Speed range, continuous</td>
<td>0 up to 5000 min⁻¹</td>
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<tr>
<td>Torque (50% operating rate)</td>
<td>57 Nm at 0 - 1240 U/min⁻¹</td>
</tr>
<tr>
<td></td>
<td>57 - 21 Nm at 1240 - 5000 U/min⁻¹</td>
</tr>
<tr>
<td>Power 100% operating rate</td>
<td>5.5 kW</td>
</tr>
<tr>
<td>Inner taper / length</td>
<td>99,218 (3²⁹/₃²&quot;) / 80 mm</td>
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<tr>
<td>Drawing force, max.</td>
<td>20000 N</td>
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### Gear headstock (4-quadrant operation)

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<td>Torque (50% operating rate)</td>
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<td></td>
<td>95 - 24 Nm at 750 - 3000 U/min⁻¹</td>
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<td>Power 100% operating rate</td>
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<tr>
<td>Inner taper / length</td>
<td>99,218 (3²⁹/₃²&quot;) / 80 mm</td>
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### Electrical data

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### General data

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</tr>
<tr>
<td>Weight (machine incl. electrical cabinet) approx.</td>
<td>6400 kg</td>
</tr>
</tbody>
</table>

Subject to alterations in design, dimensions and attachments, and to export permits where required.
Floor space requirements and installation dimensions

All dimensions in mm
Spiral bevel gear lapping machine
Oerlikon L 60

The L 60 is a CNC lapping machine designed for spiral- and hypoid bevel gears. The machine has three linear axes used to adjust the gear set assembly dimensions and the axis offset.

As a special feature, the machine can be equipped with an adjusting shaft used to adjust the shaft angle, so that also bevel gear sets with a shaft angle which deviates by 90° can be lapped.

The L 60’s main range of application is the automotive industry. On a worldwide average, more than 80% of all manufactured spiral bevel gear and hypoid gear trains are lapped. So lapping still has its place in the bevel wheel gear manufacturing despite the „dirty“ process and the high degree of professional knowledge required of the lapping machine set-up man.

The L 60 supports the work of the set-up man and the operator with several standard and optional miscellaneous functions. The compact design takes the rising costs of production space into account. The working area, which opens wide to the front enables easy access for retooling and manual loading. The latter is additionally facilitated by the optional foot switch for clamping and releasing the workpieces. The machine can also be equipped with an automatic loading system.

An automatic ratio detection ensures that the correct lapping program is always started, even during random delivery of different gear set ratios.

A network card, which belongs to the standard scope of the machine, can on one hand be used to enable a connection with other Klingelnberg machines and a KIMoS data base as stand-alone solution, and can on the other hand be used to enable a connection with an existing company network.
Further information on our products is available from

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