Oil Test with Cylindrical Worm Gear Drives
- Abstract of test procedure

This report contains 14 pages including 9 figures.

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(Dipl.-Ing. B. Sievers)  
Specialist in charge

(Prof. Dr.-Ing. W. Predki)  
Professor in ordinary
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2 Reference Document

[1] DIN 3996: Tragfähigkeitsberechnung von Zylinder-Schneckengetrieben mit Achsenwinkel $\Sigma = 90^\circ$ (Calculation of load capacity of cylindrical worm gear pairs with shaft angle $\Sigma = 90^\circ$), Sep. 1998
3 Test Bench Data

- Centre Distance \( a = 120 \text{ mm} \)
- Speed Ratio \( i = 10.67 \)

4 Input Speed

- \( n_1 = 60 \text{ min}^{-1} \): right flank of the test wheel set
- \( n_1 = 1500 \text{ min}^{-1} \): left flank of the test wheel set

5 Torques

- for \( n_1 = 60 \text{ min}^{-1} \) the torques are between 0 Nm and 2500 Nm
- for \( n_1 = 1500 \text{ min}^{-1} \) the torques are between 0 Nm and ca. 1600 Nm

6 Oil Viscosities

In principle, the test could be performed with any viscosity. For the given rotational speeds the following viscosities are recommended:

- for \( n_1 = 60 \text{ min}^{-1} \): \( \nu_{40} = 1000 \text{ mm}^2/\text{s} \),
- for \( n_1 = 1500 \text{ min}^{-1} \): \( \nu_{40} = 460 \text{ mm}^2/\text{s} \)

7 Test Procedure

The test starts with run-in procedure, followed by the main test with load steps L0 to L3 and a further increase of the load during step S1 to S9. The test ends if the temperature increase the oil sump temperature exceeds a value of \( \theta_s - \theta_0 = 80 \text{ K} \) or if the torque passes the limit of the test bench \( T_2 = 2500 \text{ Nm} \).
The output shaft torque $T_2$ of the load step L3 corresponds approximately to the output shaft torque of the drive according to DIN 3996.

Further details like runtime, value of torque and rotational speed can be gathered from the following figure 1.

![Figure 1: Test Procedure](image)

8 Measurement Categories

The following data are measured continuously:

- input-torque $T_1$ and output-torque $T_2$,
- input speed $n_1$,
- ambient temperature $\theta_0$,
- increase of oil sump temperature $\theta_S$
- wear $\Delta s_2$ on the wheel
9 Test evaluation

a) Pitting

Pitting damage is not allowable.

b) Oil sump temperature

In figure 2 ($n_1 = 60 \text{ min}^{-1}$) and figure 3 ($n_1 = 1500 \text{ min}^{-1}$) the limits of the increase of oil sump temperature are shown. The test data of the synthetic oils must not cross the limit curve (first shade of grey).

During testing of mineral oil the increase of oil sump temperature must not pass the elevated limit curve (second shade of grey).

c) Efficiency

The requirements according the efficiency are given in figure 4 and figure 5.

White area:
The white area indicates the requirements set by the company Flender.

First shade of grey:
According to DIN 3996 [1] the efficiencies of Polyglycol lubricated worm gear drives are expected to be in this area.

Second shade of grey:
According to DIN 3996 [1] the efficiencies of mineral oil lubricated worm gear drives are expected to be in this area.

Third shade of grey:
Adverse efficiencies for worm gear drives.
The load steps, especially L3 and S1-S9 have to be considered during evaluation. Generally there are no problems to be expected if the load steps L1 and L2 undercut the limiting curve.

d) Wear

The wear is measured continuously. Limit curves are not to be fixed until further tests are performed.

In previous tests the wear levels were identified at the end of the whole test.

In every case the wear level undercut 0,3 mm for rotational speed $n_1 = 60 \text{ min}^{-1}$. For rotational speed $n_1 = 1500 \text{ min}^{-1}$ the abrasion level undercut 0,1 mm.

The wear should not exceed these reference values.

e) Scuffing

Scuffing describes a strong mode of bronze transfer onto the flank of the worm. This type of wear is not allowable.

f) Scoring

The evaluation of scores on the worm flanks is conducted by visual inspection during the test. No scores are allowed until load step L3.

g) Cracks

Cracks at the flank of the worm are not allowable.
Evaluation of measured Oilsumptemperatures, $n_1=60/\text{min}$

- Test passed according to Mineraloil-Class DIN 3996
- Test passed according to Polyglycol-Class DIN 3996

Output Torque $T_2$ [Nm] vs. Increase of oil sump temperature $t_{S-90}$ [K]
Evaluation of measured Oilsumptemperatures, $n_1=1500$/min

Figure 3

- Test passed according to Mineraloil-Class DIN 3996
- Test passed according to Polyglycol-Class DIN 3996
Evaluation of the measured Efficiencies, $n_1=60/\text{min}$

Figure 4

- Test passed according to Mineraloil-Class DIN 3996
- Test passed according to Polyglycol-Class DIN 3996
- Test passed according to Flender-Requirement

Total Efficiency $\eta_{\text{ges}}$ [%]

Loadstage: L0, L1, L2, L3, S1, S2

Output Torque $T_2$ [Nm]
Evaluation of the measured Efficiencies, $n_1=1500$/min

Figure 5

- Test passed according to Mineraloil-Class DIN 3996
- Test passed according to Polyglycol-Class DIN 3996
- Test passed according to Flender-Requirement
Evaluation of measured Oilsumptemperatures, \( n_1 = 60/\text{min} \)

Figure 2a
Evaluation of measured Oilsumptemperatures, \( n_r = 1500/\text{min} \)

**Figure 3a**

- **Axes:**
  - Y-axis: Increase of oil sump temperature \( \theta_S - \theta_0 \) [K]
  - X-axis: Output Torque \( T_2 \) [Nm]

- **Legend:**
  - Test passed according to Mineraloil-Class DIN 3996
  - Test passed according to Polyglycol-Class DIN 3996

- **Loadstage:**
  - L0 to S9
Evaluation of the measured Efficiencies, $n_1=60/\text{min}$

Test passed according to Mineraloil-Class DIN 3996
Test passed according to Polyglycol-Class DIN 3996
Test passed according to Flender-Requirement

Total Efficiency $\eta_{ges}$ [%] vs. Output Torque $T_2$ [Nm]
Evaluation of the measured Efficiencies, $n_t=1500/\text{min}$

Figure 5a

Graph showing the total efficiency $\eta_{ges}$ as a function of the output torque $T_2$ [Nm] for different load stages (L0, L1, L2, ..., S9). The graph includes various tests passed according to different standards:

- Test passed according to Mineraloil-Class DIN 3996
- Test passed according to Polyglycol-Class DIN 3996
- Test passed according to Flender-Requirement

Legend:
-  (Min., VG460)
-  (PG, VG680)
-  (PG, VG460)
-  (PG, VG460)
-  (Vg460)
-  (PG, VG460)
-  (pfl. VG320)