

Synthetic Oils for Worm Gear Lubrication

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Worm gears and combined helical/worm gears are often used as a simple and effective solution for power transmission applications. The load carrying capacity of such gearboxes was increased constantly over the last ten years. Latest calculation methods, new materials, modern manufacturing procedures and, especially, suitable lubricants are the most important parameters for high performance gear drives.

The presented paper shows several synthetic gear oils and their influence on wear and efficiency of highly loaded worm gears. The friction coefficient of the base oil as well as the additives is considered. Taking their extended service life into account, very often synthetic gear oils are the most economic solution.

The results are based on measurements carried out on the Klüber worm gear test rig. This test rig allows to measure input speed, input torque, output torque, bulk and sump temperature of the tested worm gear. It is also possible to ascertain the lubrication regime in the contact of worm and wheel. A detailed description of the test rig is given in the paper.

Finally, the measured results are compared with other investigations (e.g., measurements of friction coefficients) and DIN 3996 (Calculation of load capacity of cylindrical worm gear pairs).

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1 Introduction

Worm gears and combined helical worm gears are often used as a simple and effective solution for power transmission applications. The load carrying capacity of such gear boxes has constantly increased over the last few years. Latest calculation methods, new materials, modern manufacturing procedures and, last but not least, suitable lubricants are the most important parameters for high performance gear drives.

Typically, the development of new gear oils starts with basic investigations modeling the tribological contact. Therefore, test rigs such as the four ball tester and the oscillation-friction and wear tester are helpful. The best way to optimize a gear oil is to test samples in a real gear box, especially in terms of contact pressure and temperature. Several material combinations should be tested. This is the only way to develop a gear oil ensuring:

- low friction and high efficiency
- low operating temperatures to improve oil service life
- low wear and delayed fatigue of materials

A good gear oil allows an increase of the load carrying capacity of a gearbox.

We have designed our own worm gear test rig to improve the development of high performance gear oils. The presented paper reports results obtained from this test rig.

2 Test Rig

2.1 Set Up

Figure 1 shows the worm gear oil test rig. The back-to-back test rig is driven by an electric motor and loaded by a generator. The worm gear is a standard catalog gearbox with no modifications, except for provisions for measurements of several temperatures.

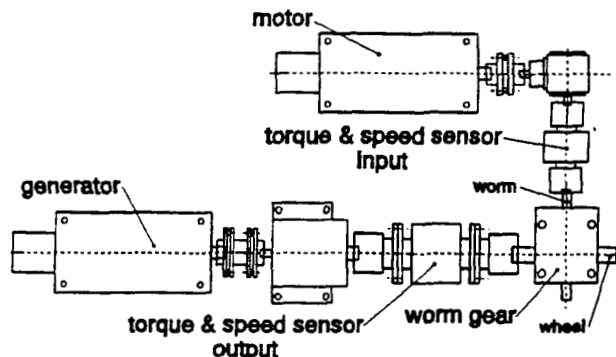


Fig. 1: Test Rig (schematic).

The worm gear is sump lubricated (0.6 liters) with worm under (Figure 2). The housing (gray cast iron) is fan cooled.

The setup of the test rig makes it possible to measure speed and torque of the worm (input side). Calibrated torque measurement shafts are used to determine the torque. These torque measurement shafts were bought ready to operate, an extra calibration is not required. Combined

with the output torque of the wheel, the overall efficiency of the gearbox can be calculated.

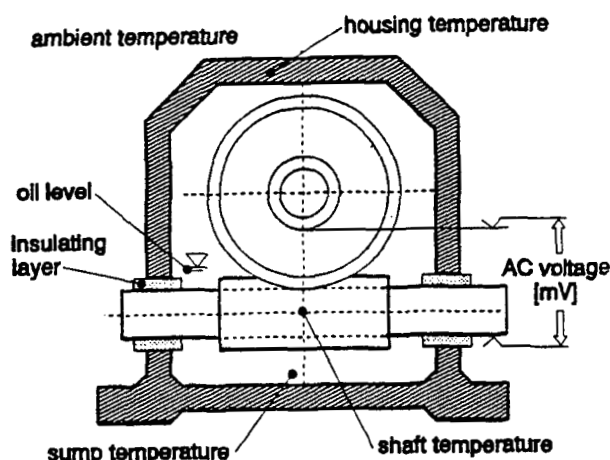


Fig. 2: Determination of Temperatures and Lubrication Regime.

The test rig provides the opportunity to determine the lubricating regime in the mesh (Figure 2). Knowing the lubrication regime makes it easier to check e.g. how an additive package influences the running in behavior of a gear. The worm shaft is electrically insulated against the housing. Therefore, a thin insulating layer is inserted between the outer bearing ring and housing. A low alternating (AC) voltage is applied to the worm and wheel. A short-circuit indicates mixed friction or metal to metal contacts, the full applied voltage indicates a separating lubricant film. This continuous operating method permits determination of changes in lubrication regime during the test run.

The wear of the wheel is determined using the following two methods:

- (1) Weight loss of the wheel after completion of the test run.
- (2) Abrasion of the wheel flank while running. The measurement is based on a continuous measurement of the wheel tooth thickness. Thus, it can be assessed whether the wear is a result of running in or of the actual operating conditions.

The permanent measurement of the wheel tooth thickness is based on the evaluation of the relative angle between worm shaft and wheel. A change of this angle, caused by reduced tooth thickness, indicates wear. The wear rate ($\mu\text{m/h}$) is

determined as the average slope of the measured reduction of tooth thickness.

As mentioned, the measurement of different temperatures is part of the standard test. These are (acc. to Figure 2):

- bulk temperature of worm shaft ϑ_M
- oil sump temperature ϑ_{oil}
- housing temperature $\vartheta_{housing}$
- ambient temperature ϑ_a

The bulk temperature ϑ_M is measured in the center of the worm, relatively close to the mesh.

These parameters are recorded online and evaluated on a PC system. A more detailed description of the test rig and its features is given in [1].

2.2 Gear Set

The tests were performed with a cylindrical worm gear. Table 1 shows data of the gear set. The wheel is made of a continuous cast bronze, the worm is case carburized and ground steel.

	Worm	Wheel
material	16 MnCr 5	GC - CuSn12Ni
no. of teeth	1	39
gear ratio i	39	
center distance a	63 mm (approx. 2.5 inches)	

Table 1: Gear Data

A new gear set is used for every tested oil. While assembling the gearbox the contact pattern is adjusted to the outlet side of the mesh and is approximately 50 % of the flank.

2.3 Test Conditions

The test rig is used for the development and testing of worm gear oils. It is not our aim to test gear sets. Thus, we perform a standard running in procedure with the test oil at low speed and stepwise increase load to achieve comparable starting conditions for every test. Each test starts with a 50 hour run in. At constant speed, the load is increased stepwise up to the maximum torque.