

New Test Methods for the Evaluation of Wear, Scuffing and Pitting Capacity of Gear Lubricants

by: B.-R. Höhn, P. Oster, K. Michaelis, Gear Research
Centre (FZG), Germany

American Gear Manufacturers Association



TECHNICAL PAPER

New Test Methods for the Evaluation of Wear, Scuffing and Pitting Capacity of Gear Lubricants

B.-R. Höhn, P. Oster, K. Michaelis, Gear Research Centre (FZG), Germany

[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

For maximum energy savings low viscosity lubricants are frequently used. Increasing transmitted power leads to higher temperatures and thus thinner lubricating films. These tendencies increase the failure probability in gear contacts with respect to wear, scuffing, micropitting and pitting performance.

New test methods on modified FZG gear test rigs were developed to evaluate the load carrying capability of gear lubricants.

For the low speed regime a wear test using C-type gears at low pitch line velocity of 0.05 m/s, and two different temperatures of 90 and 120 °C to consider different additive response at high loading of load stage 12 (C/0.05/90:120/12) was developed and applied to many different lubricants.

New scuffing procedures for gear lubricants of scuffing performance between API GL 3 and GL 5 were developed. The step test A10/16.6R/90 uses A-type gears of 10 mm pinion face width at 16.6 m/s pitch line velocity with a driven pinion. A discrimination of all gear oils up to the level of API GL 4 is possible. A shock test S-A10/16.6R/90 with direct loading in the expected load stage discriminates between GL 4 and GL 5 lubricants.

Different standard pitting tests are available for different lubricant viscosity grades using C-type gears at 8.3 m/s pitch line velocity and 90 °C in load stages 9 (PT C/9/90) or 10 (PT C/10/90). For automotive applications load spectrum testing is possible at low (PT C/LLS/90) and high (PT C/HLS/90) loads. For applications with long oil drain intervals a combined pitting and oil ageing test was developed (PITS C i85 TS) using C-type gears at variable load, speed and temperature conditions. At high temperature conditions between 120 and 150 °C the oil ageing properties together with their influence on pitting characteristics is evaluated in correlation to a reference oil.

The test methods are described. Test results with different market products are discussed.

Copyright © 1998

American Gear Manufacturers Association
1500 King Street, Suite 201
Alexandria, Virginia, 22314

October, 1998

ISBN: 1-55589-726-6

NEW TEST METHODS FOR THE EVALUATION OF WEAR, SCUFFING, AND PITTING CAPACITY OF GEAR LUBRICANTS

B.-R. Höhn, P. Oster, K. Michaelis
Gear Research Centre (FZG), Germany

1 Introduction

The lubricant as a design element can play an important role in the slow speed wear, scuffing, micro-pitting and pitting behavior of gears in power trains. With the demand of extended oil drain intervals, predominantly in automotive applications, not only the performance of the new oil but also that of used oils with thermal and oxidative degradation has to be observed. Base oil type, viscosity and additive system influence the different failure modes. Comprehensive knowledge of the lubricant performance under comparable test conditions is the key factor for lubricant optimization for transmissions in practice.

A number of test methods was developed using the FZG back-to-back gear test rig where over 500 machines are available world-wide. These methods are the Chevron wear test A/0.57/120/10 for tractor hydraulic fluids [1], the scuffing test A/8.3/90 [2, 3], the micropitting test GF C/8.3/90 [4] for industrial gear oils, and the pitting test PT C/9:10/90 [5] for automotive gear oils (see **Table 1**). Continuous oil development, cost reduction and new market demands made it necessary to develop new test methods for gear oils. These new methods on the FZG gear test rig are presented and discussed.

2 General Considerations on Test Strategies

The best test configuration for full comparability is the actual gearbox under typical operating conditions. For industrial gear applications this is always too

expensive and for automotive gear applications this is mostly too time consuming.

The second best are test procedures using defined test gears with high reproducibility in geometry, heat treatment and surface finish being exposed to exaggerated operating conditions in order to reduce test time. Parameters which are modified versus operating conditions have to be chosen very carefully for best simulation.

Test Gears

High reproducibility of test gears can only be achieved when one manufacturer produces such gears on the basis of a commercial interest. Exotic test gears where only 200 pairs are ordered every three years, can hardly be produced to the required high quality standard. Therefore, it is highly recommended to write a new test procedure around already existing test gears, as e.g. FZG standard test gear types A and C (see **Table 2**). The production figures of FZG standard test gears type A are in the range of some 2000 per year and type C in the range of some 500 per year. The manufacturer of these gears has dedicated three grinding machines only for the finishing of A type gears. Together with the control in the CEC project group ST 007, dealing with the scuffing test, a continuously high accuracy and reproducibility of the test gears can be guaranteed.

Test gear geometry can be chosen for best simulation of the desired failure mode. A large module is in any case necessary to avoid tooth breakage. For wear investigations according to Plewe [6] the sliding

Table 1: Standard Test Methods on the FZG Gear Test Rig

Parameter	Scuffing test	Wear test	Micropitting test	Pitting test
Gear type	A	A	GF-C	PT-C
Pitch line velocity	8.3 m/s	0.57 m/s	8.3 m/s	8.3 m/s
Lubrication	Dip	Dip	Spray	Dip
Oil Temperature	90 °C uncontrolled	121 °C controlled	90 °C controlled	90 °C controlled
Driving gear	Pinion	Pinion	Pinion	Pinion
Failure criterion	Load stage to total scuffed face width > 20 mm	Wear rate in mg/kWh	Load stage to micropitting depth > 7.5 μm	Running time to pitted area on one tooth > 4%
Test procedure	15 min per LS	20 h in LS 10	16 h per LS	< 300 h in LS 9
Standards	DIN 51 354 IP 334 ASTM D-5182 CEC L-07-A-96	ASTM 4998	FVA	FVA

Table 2: Main Test Gear Data

Dimension		Symbol	Unit	A10	PT-C	GF-C
Centre distance		a	mm	91.5		
Number of teeth	pinion gear	z_1 z_2	- -	16 24		
Module		m	mm	4.5		
Pressure angle		α	°	20		
Operating pressure angle		α_w	°	22.5		
Helix angle		β	°	0		
Face width	pinion gear	b_1 b_2	mm mm	10 20	20 20	
Profile shift factor	pinion gear	x_1 x_2	- -	0.8532 -0.5000	0.1817 0.1715	
Operating pitch diameter	pinion gear	d_{w1} d_{w2}	mm mm	73.2 109.8		
Tip diameter	pinion gear	d_{a1} d_{a2}	mm mm	88.8 112.5	82.5 118.4	
Material		-	-	20MnCr5	16MnCr5	
Heat treatment		-	-	case carburized		
Surface roughness	pinion gear	R_{a1} R_{a2}	μm μm	0.35 0.30	0.30 0.30	0.50 0.50
Roughness tolerance		ΔR_a	μm	± 0.1		