06FTM07

Improvement of Standardized Test Methods for Evaluating the Lubricant Influence on Micropitting and Pitting Resistance of Case Carburized Gears

by: B.-R. Höhn, P. Oster, T. Radev, G. Steinberger, and T. Tobie, Gear Research Institute (FZG)

American Gear Manufacturers Association

TECHNICAL PAPER

Improvement of Standardized Test Methods for Evaluating the Lubricant Influence on Micropitting and Pitting Resistance of Case Carburized Gears

Prof. Dr.-Ing. B.-R. Höhn, Dr.-Ing. P. Oster, Dr.-Ing. T. Radev, Dipl.-Ing. G. Steinberger, Dr.-Ing. T. Tobie, Gear Research Centre (FZG)

Abstract

Micropitting and pitting are typical fatigue failures, which occur on the flanks of highly stressed, case carburized gears. Both failure modes are strongly influenced by the lubricating conditions and lubricant properties. Standardized test methods with defined test conditions are available to evaluate the lubricant performance regarding micropitting and pitting.

The FVA-FZG micropitting test is well established as the standard test method for evaluating the micropitting load capacity of gear lubricants, but requires relatively high costs and is quite time consuming. Therefore an efficient and consistent short test method was developed to classify candidate lubricants in terms of their micropitting load capacity analogous to the FVA-FZG micropitting test and to supplement the existing test. The results of the standardized short test method correlate well with the ones of the FVA-FZG micropitting test.

Regarding pitting the standard FVA-FZG pitting test is a well known and widely used test method that has proved itself to be suitable to discriminate the pitting load capacity of gear lubricants. In order to improve the practice relevance of the test gears and test results, to reduce the influence of undesired phenomena and to increase the reliability of the results an advanced pitting test procedure was developed. This new test procedure is based on the existing pitting test but uses superfinished test gears with adequate flank modifications. The more suitable test gears will improve the reproducibility of the test results and ensure a closer correlation of the results to practical gear applications. The test also offers the possibility to be extended by additional testing at a 2nd load stage and is seen as an improvement of the existing pitting test method.

The paper describes the new developed test procedures and shows basic examples of test results. Furthermore it discusses the correlation and classification to the existing test methods.

American Gear Manufacturers Association
500 Montgomery Street, Suite 350
Alexandria, Virginia, 22314

October, 2006

ISBN: 1-55589-889-0

IMPROVEMENT OF STANDARDIZED TEST METHODS FOR EVALUATING THE LUBRICANT INFLUENCE ON MICROPITTING AND PITTING RESISTANCE OF CASE CARBURIZED GEARS

Professor Dr.-Ing. B.-R. Höhn, Dr.-Ing. P. Oster, Dr.-Ing. T. Radev, Dipl.-Ing. G. Steinberger, and Dr.-Ing. T. Tobie, Gear Research Centre (FZG)

Nomenclature

A	start of line of contact	-
B	lowest point of single tooth contact	-
C	pitch point	-
D	highest point of single tooth contact	-
E	end of line of contact	-
C_a	amount of tip relief	µm
C_b	amount of lengthwise crowning	µm
C_f	amount of root relief	µm
GF	micro-pitted flank area	%
GT	standard micropitting test (FVA 54/7)	-
GFT	micropitting load capacity	-
GFKT	micropitting short test (DGMK 575)	-
KS	load stage (micropitting test)	-
LC_{50}	pitting lifetime, 50% failure probability	-
MS	load (torque) stage (pitting test)	-
N_{Pi}	number of load cycles on pinion	-
N_4	number of load cycles-endurance limit	-
R_a	mean value of tooth flank roughness	µm
SKS	failure load stage (micropitting test)	-
T_1	torque on pinion	Nm
Z_{Lp}	lubricant performance factor (pitting)	-
Z_{Lp50T}	lubricant performance factor from test	-
a	centre distance	mm
f_{fm}	mean profile deviation	µm
p_C	Hertzian contact pressure in C	N/mm^2
$\sigma_{HPdauer, 50\%}$	permissible contact stress (endurance limit for 50% failure probability)	N/mm^2
$\sigma_{HPstat, 50\%}$	permissible contact stress (static limit for 50% failure probability)	N/mm^2
$\sigma_{HP50T, 50\%}$	permissible contact stress based on test result of FZG pitting test for 50 mio. load cycles	N/mm^2
σ'_H	mod. contact stress acc. to [12]	N/mm^2

1 Introduction

Pitting and micropitting are typical fatigue failures of high power transmitting, case carburized gears. Both failure modes are strongly related to lubricant influences as type of base oil, oil viscosity, type of additives and additive content. Since the chemical interaction of base oil and additives with the material of the tooth flank is normally not predictable, adequate test methods to evaluate the lubricant influence on the different gear failure modes are required.

Some important aspects for such test methods are:

- test method as simple as possible
- high reliability of test results
- good correlation to gears in practice
- time-saving and cost-effective

In continuous work covering several research projects standardized test methods were developed to determine the actual lubricant performance regarding the different gear failure modes. These standard FZG test methods are based on the use of the FZG back-to-back gear test rig and are performed under defined test conditions using specified test gears.

FVA-FZG micropitting test and FVA-FZG pitting test are well known and widely used standard test methods for evaluating the micropitting respectively pitting resistance of lubricants in gear drives. Nevertheless there was a demand from the gear and lubricant industry for further supplement and improvement of these existing test methods.

2 Micropitting Test

Micropitting on gears is a surface fatigue damage that is strongly influenced by the conditions of the tribological system consisting of the tooth flank surface and the lubricant. Micropitting is most frequently observed on gear flanks with a high surface hardness and normally starts in flank areas with high negative specific sliding. The damage pattern of micropitting is characterized by a large number of microscopic cracks. Small pits originating from these cracks can result in a removal of surface material and create local flank wear (**Fig. 1**).

Consequently progressing micropitting can cause increasing changes of the involute profile in form of profile deviations. In this case the dynamical additional forces and the gear noise can increase and the occurrence of pitting may be influenced.

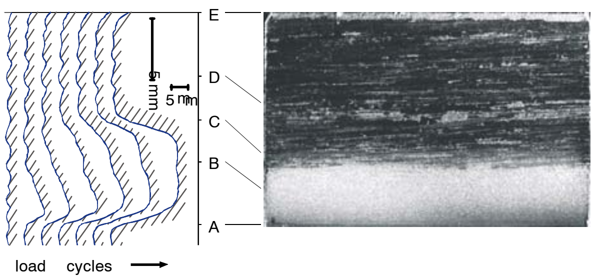

Figure 1. Changes of the involute profile of a gear tooth caused by progressing profile deviations due to micropitting and correlation to the tooth flank

The FVA-FZG micropitting test acc. to [3] is well established as a standard test method for evaluating the micropitting load capacity of gear lubricants. The test provides a quantitative evaluation of the influence of lubricant (especially additives) on the occurrence of micropitting, differentiates oils according to their micropitting load capacity and enables the choice of a lubricant with a sufficient micropitting resistance. The results of the test can be introduced into a micropitting capacity rating method for gears [6, 10, 11].

The FZG micropitting test consists of a load stage test with incremental increasing of the contact stress followed by an endurance test. In the load stage test the ability of the tribological system to resist micropitting is determined in form of a failure load stage. The endurance test provides additional information on the damage progression after higher numbers of load cycles. This test method provides precise results, but requires relatively high costs and is quite time-consuming. An efficient and consistent short test method to evaluate the lubricant influence on micropitting has been missing so far. Therefore the available FVA-FZG micropitting test was supplemented by a standardized <u>short</u> test method, that is able to classify candidate lubricants analogous to the existing test method.

FZG Micropitting Test GT acc. to FVA 54/7

Fig. 2 shows schematically the test procedure of FZG micropitting test acc. to FVA-information sheet 54/7 [3] (for test conditions see also **Fig. 4**).

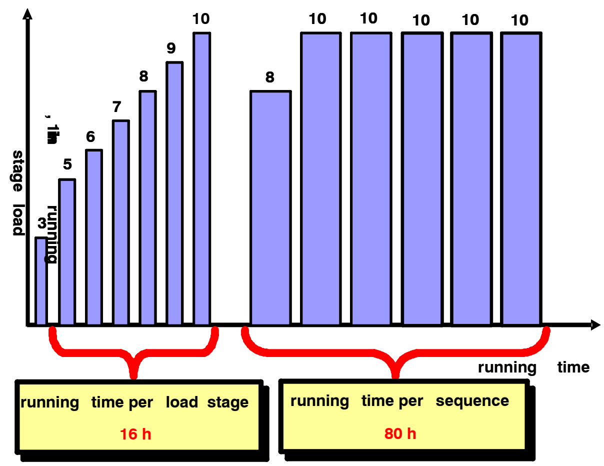

Figure 2. Test procedure of FZG micropitting test acc. to FVA 54/7

After running in (1 h at load stage 3) the load is stepwise increased from load stage 5 through load stage 10 (p_C = 795 N/mm^2 - 1547 N/mm^2). Running time is 16 h per load stage. After each load stage the test gears are dismounted and the development of the damage is documented by measuring the profile deviation and evaluating the micro-pitted area and the material losses. If the mean profile deviation exceeds the limiting value of 7.5 μm (corresponding to a change of gear accuracy from DIN # 5 to DIN 6) the failure load stage is reached.

In case of failure load stage ≥ 8 the load stage test is followed by an endurance test with the same gear pair for 80 h in load stage 8 and maximum 5 times 80 h in load stage 10. After each test sequence the gears are inspected and the profile deviation is measured again. The endurance test is terminated if the profile error exceeds 20 μm (corresponding to