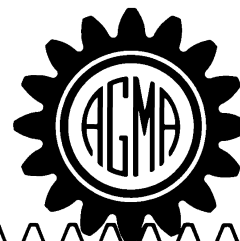


Experience with a Disc Rig Micropitting Test

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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

The experimental work carried out was aimed at developing a test method that was able to consistently produce micropitting damage and could discriminate between a good oil (i.e., one that rarely produces micropitting in service) and a poor oil (i.e., one that does produce micropitting in service). The small-scale 3-Disc test rig that was used for this work employs 3 discs to apply the test load to a 12mm-diameter test roller. This test geometry allows a large number of stress cycles (typically 600,000 to 800,000 cycles/h) to be generated at the contact track on the roller.

The disc rig control system allows test parameters such as entrainment velocity, contact stress and slide/roll ratio at the disc/roller contacts to be accurately and independently controlled. This enables the effect of key parameters to be studied in isolation, which is something that cannot be easily achieved using conventional gear test rigs.

The early work carried out using the disc rig was aimed at producing micropitting damage by operating the rig at contact conditions similar to those used in the FZG micropitting gear test method. These early tests confirmed that the damage produced to the roller track exhibits characteristics that are typical of micropitting damage, and showed that the severity of the micropitting produced was affected by the amount of running-in carried out on the roller prior to applying the full test load.

A test procedure has been developed which provides a good level of repeatability and which allows discrimination between oils which produce micropitting in service and those which do not. In addition, a study of the effect of slide/roll ratio (SRR) has shown that the severity of micropitting damage increases as SRR increased, whereas at 0% SRR no micropitting occurred and, at negative SRRs, microcracking occurred but not micropitting. This is the way that SRR seems to affect micropitting in gears.

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Introduction

Micropitting is a form of surface damage which occurs in gears by means of a contact fatigue mechanism, under a combination of rolling and sliding contact conditions. Micropitting is often a precursor to other, more serious, forms of damage such as macropitting, scuffing and bending fatigue. [1], [2] The miniature three-disc test rig used in this study is able to reproduce the contact conditions that occur in gears. The test rig's compact size and relatively simple test specimen design make it a potentially useful facility for assessing the micropitting properties of gear oils, additives and gear materials.

The test rig, specimens and oils

The microprocessor-controlled miniature three-disc test rig used in this study employs a test configuration consisting of three outer discs arranged around a central test roller (Figure 1). The outer discs are geared together and are driven by an electric motor. The central roller is driven independently by a second motor, and its speed can be

controlled to generate a range of slide/roll conditions at the contact between the roller and the discs. This feature, combined with the accurate load control capability of the rig, allows the contact conditions that occur in meshing gears to be reproduced using relatively simple test component geometries. The central roller, when operated at a typical speed of 4500 rev/min, experiences 810,000 stress cycles per hour, so micropitting can be generated relatively quickly. The exact speed of the test roller will depend on the slide/roll ratio (SRR) being used, as the disc speed is fixed at 1450 rev/min and the roller speed is adjusted to give the required SRR. The test assembly is dip-lubricated from a 150 ml reservoir and a load of up to 400N (which generates a maximum Hertzian contact stress of 2.0GPa with the crowned discs used in this study) can be applied to the central roller. The same type of miniature disc rig has been used by other workers for the study of micropitting (e.g., Benyajati [3]). The test rig is a more compact design than the disc rigs more commonly used hitherto for this type of investigation. [4], [5]

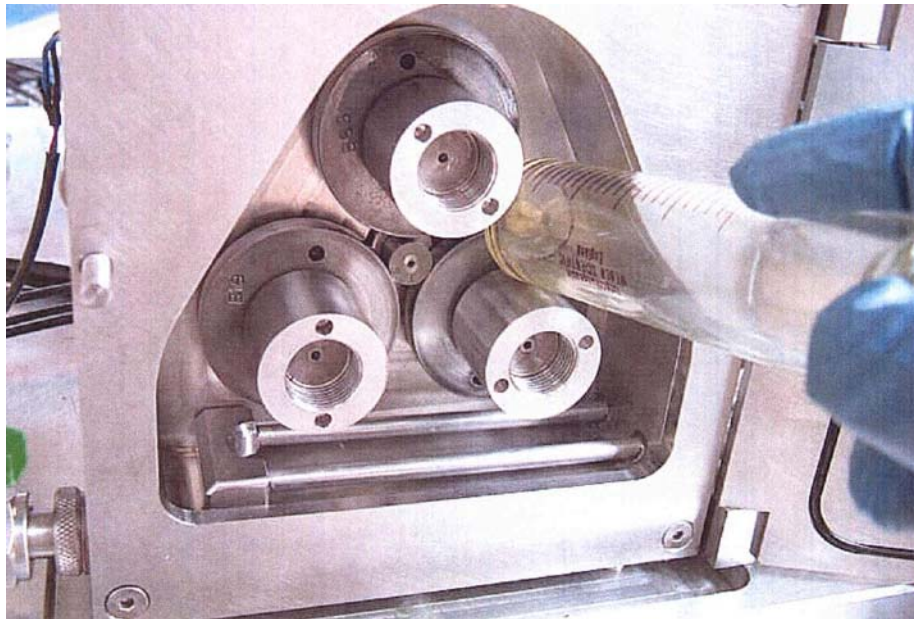


Figure 1. The disc rig test chamber

The crowned discs were 54 mm in diameter, manufactured from a commercial gear steel (16MnCr5) and case carburised. The outer diameters of the discs were finish ground to a target axial surface roughness (Ra) of 0.25 to 0.35 µm. The crown radius was selected to enable a Hertzian contact stress of up to 2.0 GPa to be generated. The central test rollers were 12 mm in diameter and 12 mm long, were made from the same material as the discs, and were ground circumferentially to a surface roughness of 0.40 to 0.50 µm Ra. The rollers were heat treated to a hardness of 660 Hv to 700 Hv, and the discs to 730Hv to 770Hv.

Two reference oils were selected for this study:

Oil A: This low reference oil is an ISO VG 68 EP additive oil, specifically designed for steam turbines and reduction gearboxes operating at around 50°C. Service experience has shown that this oil has a low to medium micropitting resistance and, in gear-based micropitting tests, it typically produces profile losses of about three times that of Oil B. The oil uses a conventional sulphur and phosphorous additive package formulated to be most effective at around 50°C.

Oil B: This high reference oil is a commercially-available ISO VG 68 gear oil which service experience has shown has a high micropitting resistance. The additive package used in this oil is more complex (it includes boundary lubrication additives and friction modifiers) than that in Oil A, as it was developed for use in a variety of gear applications over a wide range of operating conditions.

Objectives of the early work

In order to become a useful test facility, the disc rig micropitting test method needed to achieve the following:

- Establish micropitting as the dominant degradation mechanism in the test roller
- Achieve an acceptable level of repeatability
- Achieve adequate discrimination between the two reference oils

The initial series of tests

The purpose of the initial tests was to investigate the operation of the disc rig under test conditions similar to those occurring in gears when carrying out the

FVA micropitting test method 54/I-IV [6] at test condition GT-C/8.3/90. This FVA test uses FZG C-GF type gears, which were specifically developed to generate micropitting. The selected disc rig test conditions were as follows:

Entrainment velocity:	3.15 m/s
Slide/Roll Ratio (SRR):	20%
Hertzian contact stress:	1.7 GPa
Oil temperature:	90°C.

A wide range of SRRs are generated along the C-GF type gear flanks during meshing, and micropitting is known to be influenced greatly by the slide/roll conditions. Consequently, this initial series of disc rig tests was carried out at a relatively low SRR of 20%. NB: The entrainment velocity and SRR are calculated as follows:

$$\text{Entrainment velocity} = \frac{1}{2} (U_D + U_R)$$

$$\text{SRR} = \frac{(U_D - U_R)}{\frac{1}{2}(U_D + U_R)} \times 100\%$$

Where U_D is the peripheral velocity of the discs and U_R is the peripheral velocity of the roller. NB: the above equation for SRR gives a value of 200% for conditions of pure sliding, a positive value if the roller velocity is lower than that of the discs and a negative value if the roller velocity is higher than that of the discs.

For the crowned discs used in this study, which generate elliptically-shaped contacts, these test conditions generate contacts between the discs and the roller that are typically 1200 µm x 300 µm in size. The oil film thicknesses generated are typically 230 nm at 90°C and 450 nm at 60°C for the reference oils. These represent Lambda values (the ratio of oil film thickness to surface roughness) of about 0.77 and 1.5 respectively.

Although some micropitting damage was produced during the initial series of tests, the discrimination between the two reference oils was inadequate and the repeatability was poor. A detailed study of specimen consistency and rig operation was carried out to identify the cause of the poor repeatability. The results of this indicated that the probable cause was a large variation in the roughness (Ra) of the test discs. The target Ra range was 0.25 to 0.35 µm but many of the discs were much rougher (up to about 0.60 µm). In addition, surface profilometry showed that the Ra of the roller track became much smooth-