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DEVELOPMENT OF A CEC-PITTING TEST METHOD FOR GEAR LUBRICANTS – MEASURES TO REDUCE SCATTERING AND MICROPITTING GENERATION IN GEAR PITTING TESTS

CATEGORY

Gears

AUTHORS AND INSTITUTIONS

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INTRODUCTION

The lubrication condition in the contact zone of two meshing gears has essential influence on the pitting lifetime of oil-lubricated gears. Mechanical and chemical stresses are mainly influenced by surface texture, lubricant film thickness and chemical-physical interaction between tooth flank surface and lubricant. To determine the performance of gear lubricants regarding the pitting load carrying capacity, standardized test methods are desired. Extensive testing has shown that the generation of micropitting can strongly influence the pitting lifetime. As a result, increased scattering may occur, which impedes a reliable determination of the pitting load capacity of different lubricants and complicates the discrimination between the pitting performance of the investigated lubricants. Measures to reduce scattering and to improve the test reliability have been investigated within the development work for a standardized CEC-Pitting test method, which is expected to be published in the near future.

STATE OF KNOWLEDGE

The FZG-pitting test acc. to FVA 2/IV [4] is widely used to determine the performance of gear lubricants with respect to their pitting load carrying capacity. The FZG standard back-to-back test rig with center distance a = 91.5 mm [1] is operated using specified FZG-C-PT test gears with surface roughness values of 0.15 µm ≤ Ra ≤ 0.40 µm in FVA 2/IV [4]. This test method has proved to be suitable for determining the pitting performance of gear lubricants. However, after a large number of conducted tests, it has been shown that comparatively wide scattering of the test results can occur. Depending on the micropitting performance of the lubricant tested, the pitting lifetime can be strongly influenced by the generation of undesired micropitting, which results in large scattering of the test results.
Further investigations, e.g. in [2, 3], show that the operational and tribological conditions under which micropitting or other undesired surface impairments occur are highly dependent on the specific lubricant film thickness λ and the micropitting performance of the lubricant. Furthermore, the surface roughness of the test gears has a significant influence on the formation of micropitting.

TEST PROCEDURE DEVELOPMENT AND EXPERIMENTAL INVESTIGATIONS

Based on the FZG-pitting test acc. to FVA 2/IV [4], a new CEC-pitting test method is developed. The experience with the previous test procedure shows that an additional conditioning run for smoothing the tooth flanks with resulting lower surface roughness leads to reduced scattering. However, this preconditioning procedure is not standardized in FVA 2/IV [4] so far. Based on this experience, a preconditioning run of the test gears is required in the new developed CEC test method in order to decrease the surface roughness variations appearing after the gear grinding process. This has positive effects in terms of scattering of the pitting running time and in terms of reducing undesired occurrence of micropitting. Table 1 shows the conditions of the mandatory preconditioning run, which aims to reduce the flank surface roughness of the test gears before starting the main test run. The flank roughness is determined after preconditioning on three circumferentially distributed teeth. The resulting mean arithmetic surface roughness Ra has to range in between 0.10 µm ≤ Ra ≤ 0.25 µm with a maximum surface roughness of a single tooth of Ra ≤ 0.27 µm. Test gears that do not meet the required roughness specification after the preconditioning run should be rejected. The preconditioning run is followed by the two staged pitting test. A running-in phase at reduced load serves to further smooth the tooth flanks and to clean the test gear from any lubricant residues from previous tests with other lubricants. The main phase is carried out at a pinion torque of T_1 = 302 Nm (p_c = 1650 N/mm^2), a pinion speed of n_1 = 2250 rpm and a lubricant temperature of ϑ_{Oil} = 90 °C. The test bench is stopped at regular intervals and visually inspected until the failure criterion of 4 % pitting area of the active flank on an individual tooth of the pinion gear or a maximum number of $40 \cdot 10^6$ load cycles is reached.

Nomenclature		Value / Type
Lubricant	-	ISO VG 32 (e.g. FVA 2)
Lubrication	-	Dip lubrication, 60 °C ± 3 %
Pinion torque	Nm	135
Pinion speed	min^{-1}	150 ± 3 %
Pinion load cycles	-	1125

Table 1: Conditions of preconditioning

In a first round robin with 11 contributing labs, the low reference oil FVA 2A used so far in FVA 2/IV [4] was tested for its suitability as a reference lubricant. The results of the round robin show an impermissible scattering of the resulting pitting life when using FVA 2A as reference fluid as seen in Figure 1. During intensive investigations to determine the cause of the test scatter, metallographic investigations as well as hardness measurements and oil analyses of different oil batches were carried out without a causal correlation with the test scatter being identified. However, it was suspected that the test scattering was caused by very differing degrees of micropitting on the tooth flanks at the end of the test (see Figure 2) since the prolonged running times largely correlate with increased micropitting. The insufficient micropitting carrying capacity of FVA 2A at the test temperature of ϑ_{Oil} = 90 °C disqualifies this lubricant as an adequate reference lubricant.

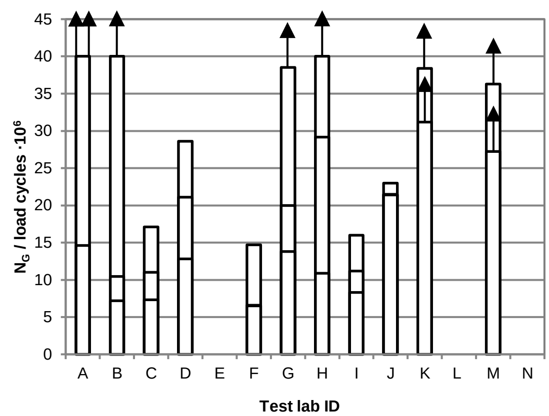
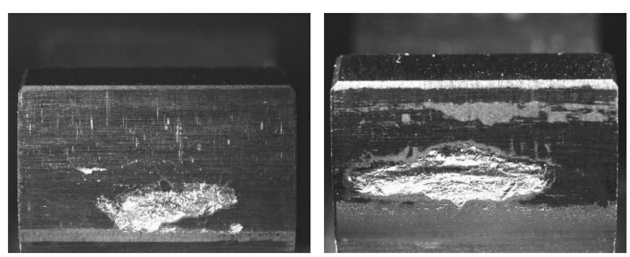


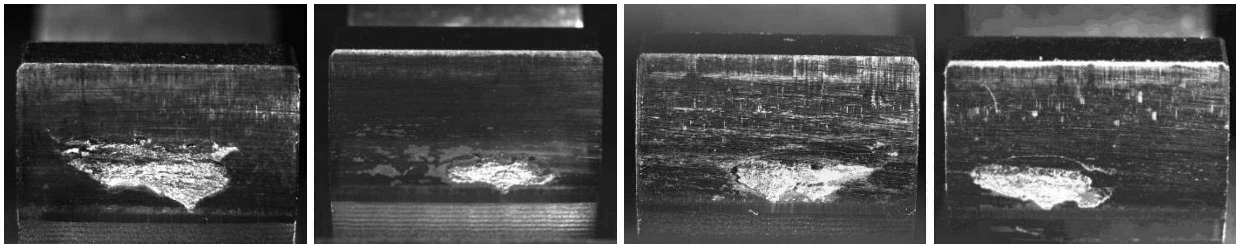
Figure 1: Results of round robin with low reference oil candidate FVA 2A (tests were stopped at max. 40·10^6 LC)

The search for a suitable new low reference fluid resulted in promising results with a SAE 75W fluid using an additive package for use in ATF applications. A second round robin was executed to investigate the suitability of the new reference oil candidate. Figure 3 shows exemplary flank conditions of test runs with the SAE 75W low reference oil candidate fluid in different labs at the end of test. All test runs show comparable flank conditions at the end of test with typical formed pittings and only a very limited amount of micropitting.



very limited micropitting strong micropitting

Figure 2: Differing degrees of micropitting at end of test, FVA 2A



Lab A Lab C Lab D Lab M

Figure 3: Comparable flank conditions after end of test at different labs during the conducted round robin with new low reference oil

Figure 4 shows the result of the round robin with the new low reference fluid SAE 75W. Similar to the previous round robin, the tests were carried out in different labs in compliance with the test specifications. The test scattering could be significantly reduced. The average number of load cycles to pitting failure is approximately $11.5 \cdot 10^6$ load cycles, which is within the expectations. All test runs carried out with the new low reference fluid show no or only slight degrees of micropitting comparable to those shown in Figure 3. Further investigations with a corresponding high reference fluid for long running times also show satisfactory results with acceptable test scattering, so that a reliable discrimination can be made between the two reference fluids.

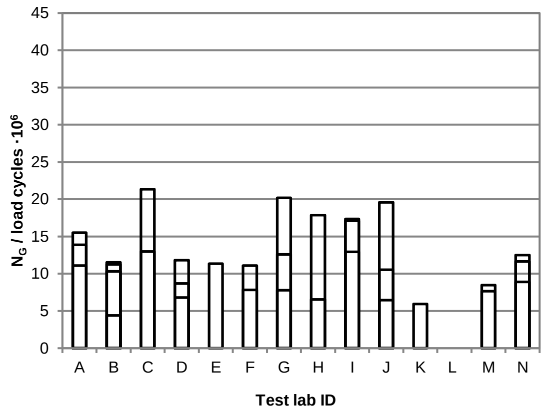


Figure 4: Results of test runs with new low reference oil

CONCLUSION

The pitting test acc. to FVA 2/IV [4] has been used for many years to determine the pitting load carrying capacity of gear lubricants as it is an appropriate method to discriminate between the pitting performance of different lubricants. However, extensive investigations have shown that the formation of micropitting prevents the reliable investigation of the applicability of lubricants. Therefore, a new modified method of testing gear lubricants with respect to their pitting performance has been developed within a CEC working group. One of the main objectives of the modified test method was to reduce test scatter, which was achieved, due to the reduction of surface roughness and the introduction of a mandatory preconditioning run. Furthermore, reduced scatter values are observed in the low reference runs after a new low reference oil has been defined and investigated. The FVA 2A low reference oil used so far led to increased test scattering due to its low micropitting carrying capacity, which is prevented by the use of the new reference oil. In the newly developed test method, the proven principles of the FVA 2/IV [4] pitting test were adopted, modified and optimized at points where potential for improvement existed, so that the user now benefits from a qualified test procedure for determining the pitting load capacity of different gear lubricants. The proposed new CEC-Pitting test method is currently under approval and expected to be published in the near future.

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REFERENCES

[1] DIN ISO 14635-1:2006-05: Zahnräder – FZG-Prüfverfahren – Teil 1: FZG-Prüfverfahren A/8,3/90 zur Bestimmung der relativen Fresstragfähigkeit von Schmierölen. Beuth Verlag, Berlin (2006).

[2] König, J.; Felbermaier, M.; Tobie, T.; Stahl, K.: Tribologische Einflussfaktoren auf die Entstehung von Graufleckigkeit an einsatzgehärteten Zahnrädern. Tribologie und Schmierungstechnik. Jg. 64 (2017).

[3] König, J.; Felbermaier, M.; Tobie, T.; Stahl, K.: Influence of low circumferential speeds on the lubrication conditions and the damage characteristics of case-hardened gears. 73rd Society of Tribologists & Lubrication Engineers Annual Meeting & Exhibition 2018. Minneapolis, Minnesota, USA, 20-24 May 2018, Red Hook, NY (2018).

[4] Schedl, U.; Oster, P.; Tobie, T.; Höhn, B.-R.: Pittingtest – Einfluss des Schmierstoffes auf die Grübchenlebensdauer einsatzgehärteter Zahnräder im Einstufen- und im Lastkollektivversuch., FVA-Informationsblatt 2/IV, Forschungsvereinigung Antriebstechnik e.V. (FVA), Frankfurt am Main (2010).

KEYWORDS

Gear Lubricants, Spur Gears