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Gear Lubrication – Gear Protection Also at Low Oil Temperature

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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

To find out if the high-performance gear oils of today are able to reliably protect gears and rolling bearings in gearboxes against damage also at a reduced oil temperature of 40 °C, different high-performance gear oils were examined on a FZG back-to-back gear test rig as well as on a FE8 bearing test rig by modifying the standardized test methods. It has been shown that the advanced additive technologies used in today's high-performance gear oils are capable of inducing the required reactions on the surfaces of gears and bearings also at 40 °C, thus providing reliable damage protection even under these operating conditions.

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Introduction

In practice, industrial gears are often operated with lower oil temperatures than would normally be generated in a fully loaded gearbox. Lower temperatures prevail, for instance, while a gearbox is being taken back into use after prolonged standstill, i.e. during the time it takes for the oil to heat up from ambient temperature to service temperature. Similarly, when a gearbox is being operated below its full load capacity, with reduced speed, or with frequent stop-and-go, the operating temperature of the oil will be lower than it would be under full load. Such applications require gear oils that reliably protect gears and rolling bearings against damage not only at full-load operating temperatures, but also at lower ones. The oil temperature influences the bulk temperature of the gears and bearings as well as the flash contact temperature [3], [10]. Besides the roughness of the mating surfaces, the applied load etc., the flash temperature is strongly influenced by the circumferential speed. Compared to a higher speed, at a lower speed which mostly occurs at the output of a gearbox, the oil temperature, the bulk temperature of gears and bearings, and the flash temperature approximate each other more closely. Naturally, a reduction of the oil temperature leads to a substantial increase of oil viscosity during operation and hence to the formation of a thicker lubricant film in the contact zone. Lubricant film thickness calculations conducted for typical gearbox applications, however, show that even at oil temperatures as low as 40°C the gearbox will still operate under mixed or boundary lubrication conditions depending on the other operating conditions. This means that the formation of a gear oil reaction layer on the component surfaces is vital to protect the friction bodies against damage.

Typical gear failures

Figure 1 shows typical limits of the load-carrying capacity for case hardened gears according to Niemann [11]. In the range of slow and medium circumferential speeds, the micropitting risk is increased, compared to very low circumferential speeds where the risk of slow speed wear prevails.

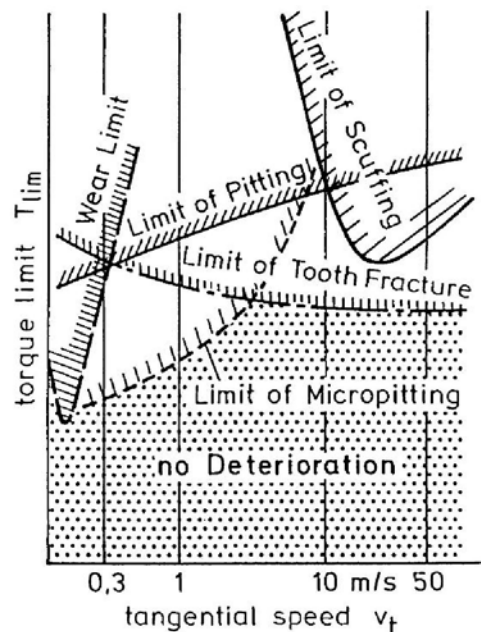


Figure 1. Typical limits of load-carrying capacity for case hardened gears

Micropitting failure of gears

Micropitting is a type of fatigue failure occurring on hardened tooth flanks of highly loaded gears [11]. This failure consists of very small cracks and pores on the surface of tooth flanks. Micropitting looks greyish and causes material loss and a change in the profile form of the tooth flanks, which can lead to pitting and breakdown of the gears. A typical micropitting gear failure of an industrial gear box is shown in Figure 2. In this case, misalignment was the reason for micropitting formation.

The formation of micropitting depends on different influences. Besides material, surface roughness, and geometry of the tooth flanks, it is the lubricant and the operating conditions which have a major influence on micropitting formation. See Table 1.

In modern gearboxes, the gears are often highly loaded and run under conditions of mixed lubrication. In this case, the tooth flanks of the mating gears are not fully separated by the lubricant film and the additives of the lubricant have to protect the tooth flanks against micropitting formation.

Wear failure of gears

Wear is an abrasive material removal occurring on the tooth flanks of gears. This failure proceeds continuously and causes material loss and a change in the profile form of the tooth flanks, which can lead to breakdown of the gears. Typical wear on the tooth flanks of an industrial gear is shown in Figure 3.

Also the wear behavior depends on different influences. Besides surface hardness, material, and geometry of the tooth flanks, it is again the lubricant and the operating conditions which have a major influence on wear behavior. See Table 2.

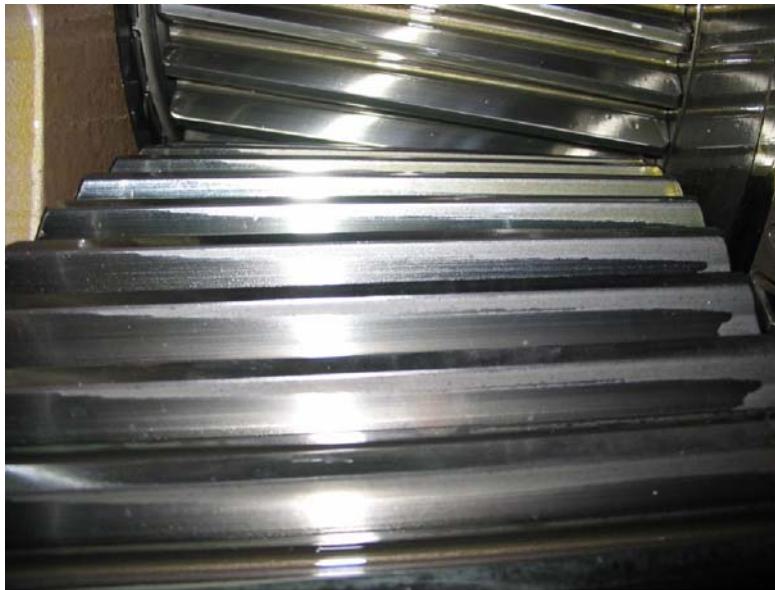


Figure 2. Micropitting gear failure of an industrial gear box

Table 1. Influences on the micropitting load-carrying capacity

Lubricant	Chemistry of the base oil Viscosity of the base oil Type and amount of additives
Tooth flank surface	Roughness Surface texture Surface hardness
Operating conditions	Normal and frictional load Circumferential speed Temperature



Figure 3. Wear on an industrial gear

Table 2. Influences on the wear behavior

Lubricant	Chemistry of the base oil Viscosity of the base oil Type and amount of additives
Tooth flank surface	Surface hardness Profile modification (tip relief) Material
Operating conditions	Normal and frictional load Circumferential speed Temperature

Failures of rolling bearings

Gear damage is also often caused by high rolling bearing wear or premature fatigue of rolling bearings [14]. Failures based on material or production mistakes are very seldom. But type, condition, and quantity of lubricant has a main influence on bearing failures as well as hard or liquid contamination [13]. Figure 4 shows the typical failures on a rolling bearing.

The additives contained in gear oils may have a decisive effect on rolling bearing damage.

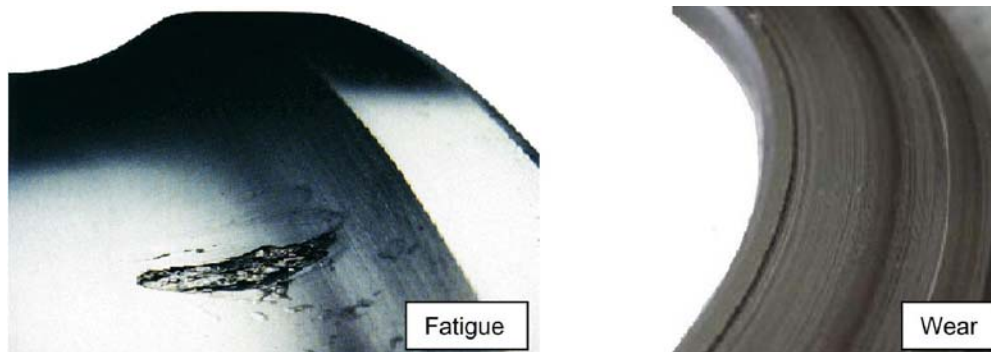


Figure 4. Typical rolling bearing failures