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Gear Lubrication – Long Term Protection for Wind Turbines

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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 chemical and physical properties of gear oils in use may change more or less depending on its formulation and the operating conditions. For this reason a gear oil was investigated after three years of use in a wind turbine to find out if changes are evident and if the protection of the gears and rolling bearings still meet the requirements as with fresh oil. Beside chemical and physical analyses, the used gear oil was examined on a FZG back-to-back gear test rig and on a FE8 test rig. The test results could show that the used gear oil as well as its ability to protect the gears and rolling bearings has changed very little compared to fresh oil.

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Introduction

An oil condition analysis (OCA) was performed to find out if the chemical and physical properties of the used oil were still within acceptable limits. For this purpose, its viscosity, oxidation, and the water and element contents of the additives and impurities respectively were measured. Ideally, oil condition analyses should be performed at certain intervals to determine a trend with regard to oil ageing. The changes of chemical and physical oil properties can serve to estimate the appropriate moment for an oil change based on empirically established figures. However, the question whether gear oils maintain their ability to protect gears and rolling bearings in a gear unit over a longer period of time remains unanswered.

The gear oils of today are expected to protect gears and rolling bearings against damage such as wear or micropitting even under critical lubrication conditions and during the entire oil change interval. Gear oils are normally tested in standardized mechanic-dynamic test procedures using fresh oil. In contrast to this, a high-performance gear oil was tested after three years of use to find out if chemical or physical changes were evident and if the protection of gears and rolling bearings would still be as high as with fresh oil.

Typical gear failures

Figure 1 shows typical limits of the load-carrying capacity for case hardened gears according to Niemann [12]. 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. Tooth fracture is not influenced by the lubricant.

Micropitting failure of gears

Micropitting is a type of fatigue failure occurring on hardened tooth flanks of highly loaded gears [12]. This failure consists of very small cracks and pores on the surface of tooth flanks. Micropitting looks grayish 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 is shown in Figure 2. In this case, misalignment was the reason for micropitting formation.

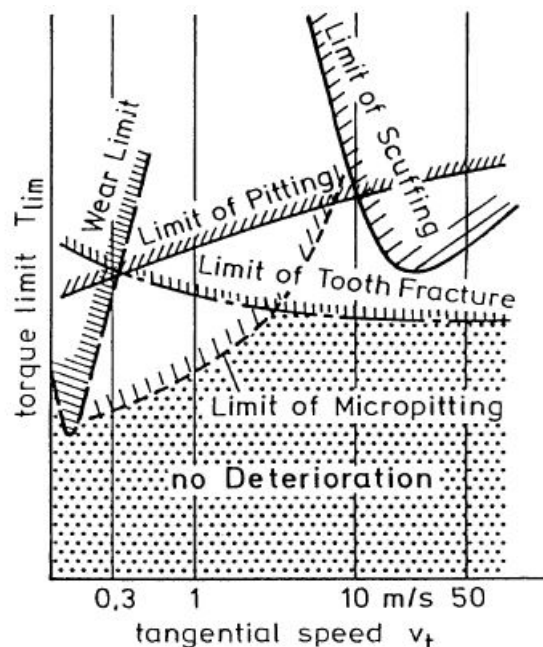


Figure 1. Typical limits of load-carrying capacity for case hardened gears

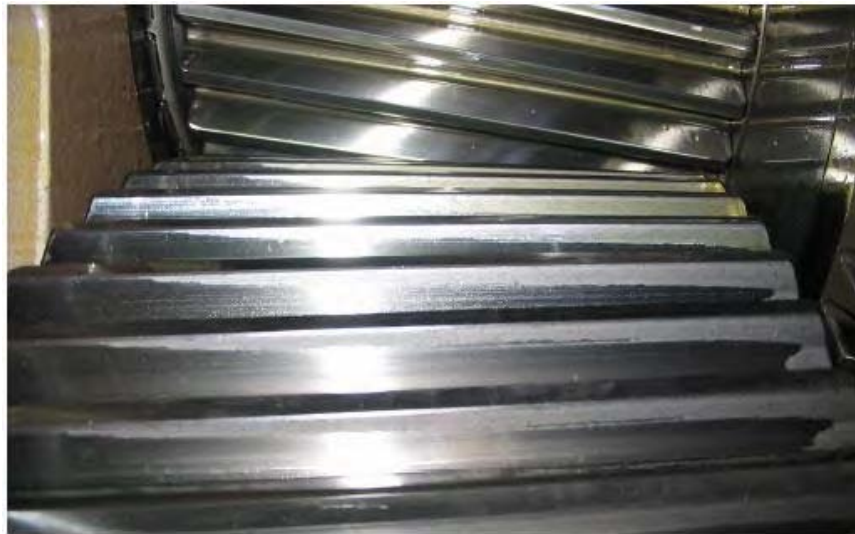


Figure 2. Micropitting gear failure

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.

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.

Scuffing failure of gears

Scuffing occurs at failure of the surface protection at excessive temperatures in the tooth contact [11]. With this failure the tooth flanks of pinion and wheel weld locally and are torn apart immediately. The tooth flanks are partially destroyed which could result in breakdown of the gears. A typical scuffing failure on the tooth flanks of a gear is shown in Figure 3.

The scuffing load-carrying capacity depends on different influences. Particularly high sliding, vibrations and non-optimized flank surfaces, e.g. low manufacturing quality or missing running-in, increase the risk of scuffing [3]. Beside this, the lubricant and the operating conditions have a major influence on scuffing.

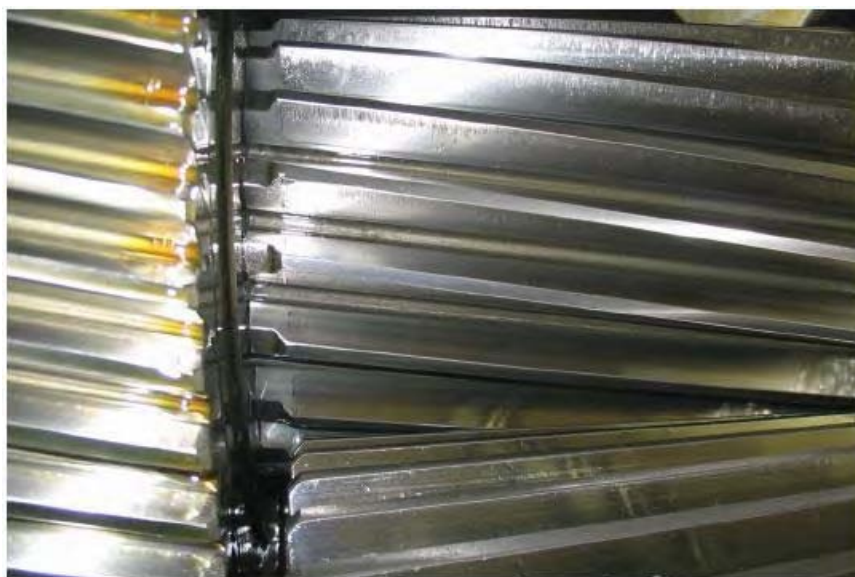


Figure 3. Scuffing gear failure

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 a gear is shown in Figure 4.

Also, the wear behavior depends on different influences. Besides the 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.

Failures of rolling bearings

Gear damage is also often caused by high rolling bearing wear or premature fatigue of rolling bearings [15]. Failures based on material or production mistakes are very seldom. However, type, condition, and quantity of lubricant has a major influence on bearing failures as well as hard or liquid contaminations [14]. Figure 5 shows the typical failures on a rolling bearing.

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

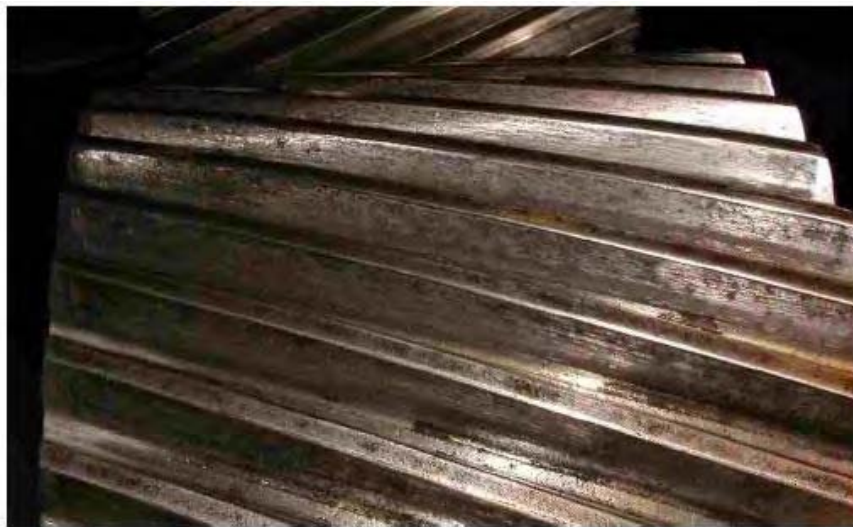


Figure 4. Wear gear failure



Figure 5. Typical rolling bearing failures

Test equipment

Investigation of micropitting load-carrying capacity and wear behavior of gears

The test runs conducted to determine the micropitting load-carrying capacity and the wear behavior of gear oils on gears were performed on a FZG back-to-back gear test rig [7]. The setup schematic of the FZG back-to-back gear test rig is shown in Figure 6.

The FZG back-to-back gear test rig utilizes a recirculating power loop principle, also known as a four-square configuration, in order to provide a fixed torque (load) to a pair of test gears. The test gearbox and drive gearbox are connected with two torsion shafts. One shaft is divided into two parts and contains a load coupling used to apply the torque (load) through the use of weights hung on the loading arm. Heating and cooling elements are used to control the oil temperature as required by the operating test conditions.

In order to investigate the micropitting load-carrying capacity, test gears type C-GF of the standard micropitting test according to FVA 54/7 [10] are used. The slow speed wear behavior is investigated by using test gears type C-PT according to DGMK 377-01 [2]. The geometric data and manufacturing details of the test gears type C-GF and type C-PT are given in FVA 54/7 and FVA 2/IV.

Investigation of the wear behavior of rolling bearings

The test runs conducted to determine the wear behavior of gear oils on rolling bearings were performed on an FE8 bearing test rig [5] required for lubricating oils CLP according to DIN 51517-3 [4]. The schematic setup of the FE8 bearing test rig is shown in Figure 7.

The wear behavior of rolling bearings according to DIN 51819-3 [5] is investigated with test bearings type D (81212 according to DIN 722).

Investigation of the foam behavior of gear oils

The foam behavior of gear oils is determined on the foam test apparatus according to ISO 12152 [6] developed by Flender. The test apparatus comprises a sealed gear unit housing to receive the gear oil sample to be tested. A pair of test gears are mounted on two vertically arranged shafts in order to mix 1.0 liter of the gear oil with air and generate foam. The test rig is shown in Figure 8 [9].

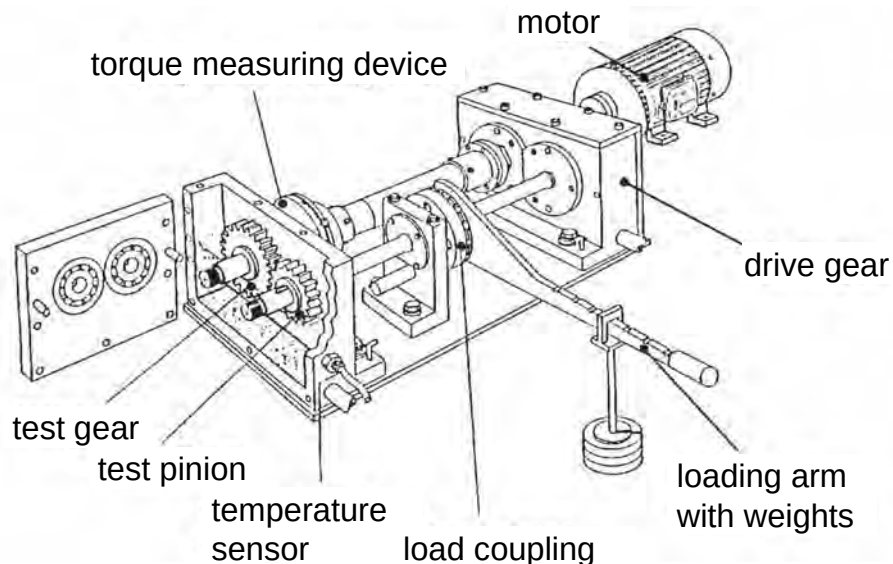


Figure 6. FZG back-to-back gear test rig