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Modern advancements in lubricating grease technology

Piet M. Lugt [a,b,*]

[a] SKF Engineering & Research Centre, Nieuwegein, The Netherlands
[b] University of Twente, Enschede, The Netherlands

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ABSTRACT

Grease is one of the major bearing components and the performance of a grease lubricated bearing is strongly determined by the performance of the grease. This paper describes how grease knowledge is linked to improved rolling bearing performance. First the various performance indicators will be described such as rolling bearing life, sealing performance, bearing friction, bearing noise and grease life. Next, the dominating grease parameters and specifications on these aspects will be given. It will also be shown how re-lubrication will enhance the bearing performance. There is synergy between grease formulation and bearing design. In the last years new generation grease lubricated bearings have been developed where grease technology was used to provide significantly lower friction and longer grease life. This was achieved by developing better greases but also by improving the internal bearing design, which could be done by using modern advancements in understanding the lubrication mechanisms. Finally, an outlook will be given on future developments in lubricating greases for rolling bearings. The various test methods are not described in this paper. For an extensive list the reader is referred to [67] (Lugt et al., 2013).

1. Introduction

The word grease is derived from the Latin crassus which means fat. It has been used at least since the Egyptian and Roman eras and originally consisted of the combination of lime (calcium carbonate) and olive oil to make calcium based greases or of animal fat used in plain bearings for carriages. After the discovery of oil in the USA in 1859 most lubricants were based on mineral oil. The first modern greases were calcium soaps which are not much used anymore. Later aluminum and sodium soaps were developed that could cope with higher temperatures. In the 1930 – 1940s new greases were developed based on calcium, lithium and barium, NLGI [1]. Today the most widely used greases are based on lithium, which was developed in 1940, Earle [26]. Aluminum complex and PTFE greases were developed in the 1950s, lithium complex greases in the 1960s. Polyurea and calcium sulfonate (complex) greases were invented in the 1980s. The latest developments that got into a commercial product (1992) is the polymer grease, Meijer et al. [73]. Obviously also other technologies are explored such as nano-technology, e.g. nanotubes, Hong et al. [44]. Although scientifically interesting, the latter has not shown to be technologically and commercially promising as yet. The historical overview shows that greases are classified according to their thickener type which forms about 10–15% of the grease. The main part of the grease consists of lubricating oil which can be either mineral or synthetic. Almost each grease type can be made in any lubricating oil type. The same applies to additives which can be liquids or solids. It is primarily the thickener which determines the temperature operational window. The 'lubricity' of conventional greases is governed mainly by the base oil and additives. Thickening is the result of the physical interaction between thickener material (such as entanglement) and lubricating oil (such as Van der Waals and capillary forces). The consistency of the grease is a function of the thickener concentration and the manufacturing process. Fig. 1 shows an example of the microstructure of standard lithium grease.

It is the thickener material that gives the grease its consistency, which prevents the grease from leaking out from the bearing. This makes lubrication with grease much easier in use than oil and is the reason that grease is used as a lubricant in about 80–90% of all rolling bearings. The main disadvantage of grease is the limited grease life and the reduced reliability in predicting the performance, which is now given by a combination of bearing life and grease life. The lubrication mechanisms are more complex than those in the case of oil. In general two phases can be distinguished: the churning phase and the bleeding phase [67], as depicted in Fig. 2.

The churning phase starts after the bearing is freshly filled with grease and is characterized by macroscopic grease flow. After some time (typically 24 h) most of the grease has been pushed away into

* Correspondence address: SKF Engineering & Research Centre, P.O. Box 2350, 3430 DT, Nieuwegein, The Netherlands

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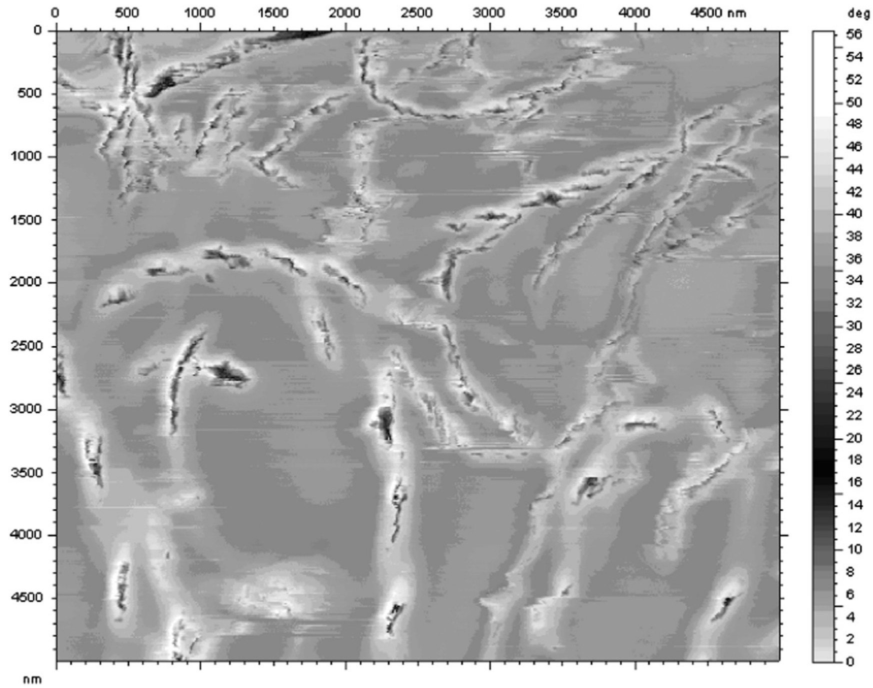

Fig. 1. Atomic force microscope image of unwashed lithium greases, Baart et al. [5]. Reprinted by permission of the Society of Tribiologists and Lubrication Engineers.

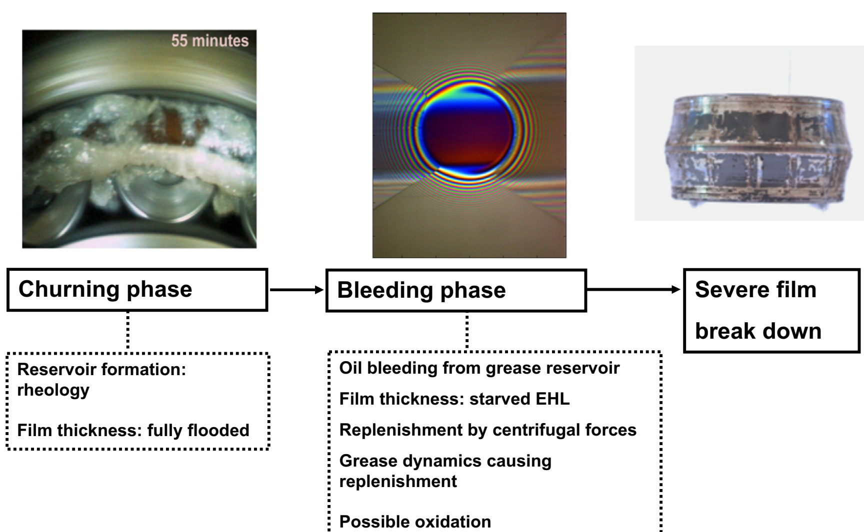

Fig. 2. The phases in the grease lubrication process and the lubrication mechanisms.

the ‘unswept volume’ or has ended up under the cage. During the churning phase there is plenty of lubricant available for lubrication and the contacts are fully flooded. After this, the supply of lubricant to the contacts no longer takes place by grease flow but by a process referred to as 'bleeding' (or sometimes called syneresis), where the grease is releasing oil by a phase separation.

The supply of lubricant to the contacts is primarily by this process although also the thickener may contribute. The lubrication regime is denoted by 'starvation’ and it is a balance of supply and loss mechanisms which will determine the Elasto-Hydrodynamic Lubrication (EHL) film thickness. The performance is then given by the thickness of the EHL film and the ‘lubricity’ of the lubricant. The latter may change in time due to e.g. the formation of oxidation products. The occurrence of starvation has been identified first in the measurements from Wilson [97], later confirmed by Barz [98].

For single contact experimental studies on grease starvation, the reader is referred to the work of Cann, e.g. Hurley and Cann [99] and Chapter 9 in [67]. For a theoretical analysis on starvation (for multiple contacts) the reader is referred to Venner et al. [100] and to Svoboda et al. [102].

At some point in time starvation becomes so severe that metal-to-metal contact will occur leading to heat development ultimately leading to bearing failure (Hoshino [96]). Sometimes, this failure is extended by a number replenishment events caused by softening and/or additional bleeding of the grease by this temperature increase [101].

More information on the history of lubricating grease, the various grease types and lubrication mechanisms can be found in various textbooks [1,7,11,10,67].

In general the selection of thickener and base oil type is done based on the required temperature window and compatibility. EP/AW requirements are based on the expected lubrication regime (full film, mixed, or boundary lubrication), but the slip rates are limited in rolling bearings, primarily on the expected load.