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The Grease Worker and its Applicability to Study Mechanical Aging and Rheology of Lubricating Greases for Rolling Bearings

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The lubricating grease is usually the element that limits the lifetime of the complete bearing. Mechanical degradation is caused by the change of the micro-structure of the thickener-oil system due to shear or over-rolling. This degradation can be performed and quantified using a grease worker, where the mechanical energy and pressure losses are calculated using the measured force that is required to push the plate with holes through the grease in the cylinder. Considering a power-law fluid pipe flow through the holes, the change in rheological properties can be estimated in-situ.

Keywords: grease lubrication, rheology, rolling element bearings, grease degradation, microstructure

1. Introduction

The lifetime of a bearing is usually limited by the lifetime of the lubrication grease, which is subjected to mechanical degradation due to shear or over-rolling. In order to study the change microstructure or bleed properties efficiently, a sample of grease can be mechanically degraded in a grease worker up to a certain rheological state. In earlier work the rheological parameter 'yield stress' is measured in a rheometer after mechanical degradation, which is time-consuming. The goal of this study is to establish a relationship between the mechanical energy input of the grease and the in-situ measured rheological properties as described by the power-law model.

2. Methods

The mechanical energy input and the pressure losses inside the 'pipes' of the plate are derived from the force measured using a load cell at the bottom of the grease worker. Using all relevant dimensions, the pressure difference and flow rate can be calculated. Depending on the hole size (standard or small) the resulting wall shear rates are in the range of 200 s^{-1} to 10000 s^{-1}.

2.1. Equations

The specific mechanical energy input into the grease where the piston motion is sinusoidal

$$E(t) = \frac{\pi f \hat{s}}{2V_{gw}} \int_0^t F(t')\, sin(2\pi f t')dt' \qquad (1)$$

with f and $\hat{s}$ the frequency and amplitude of the piston motion, V_{gw} the volume of the cylinder, t the time and F the force. The viscosity of the shear-thinning grease is described by the power-law model

$$\eta = K\dot{\gamma}^{n-1} \qquad (2)$$

with K and n are the flow consistency and flow behavior index. The flow rate of a power-law fluid through a circular pipe is given by

$$Q = \frac{\pi R^3}{3+1/n}\left(\frac{R\Delta P}{2KL}\right)^{1/n} \qquad (3)$$

with R and L the radius and length of the pipe, and ΔP the pressure loss between the ends of the pipe.

2.2. Results

For a Li/M grease, the estimated viscosity is compared with amplitude sweep plate-plate geometry rheometer measurements. So far the results are promising, absolute agreement is fairly good and relative changes appear to be well predicted.

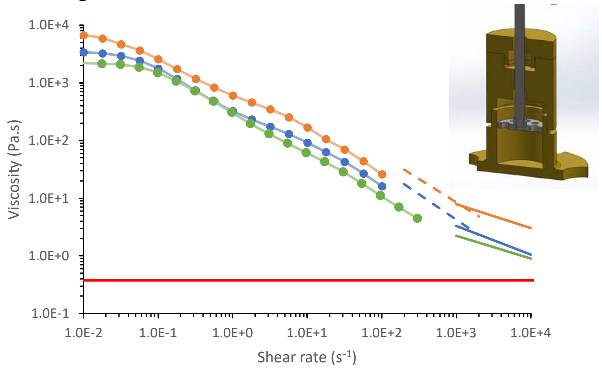

Figure 1: Viscosity as a function of shear rate and amount of degradation, rheometer measurement (circles), grease worker standard holes (dashed line) and small holes (solid line) and base oil viscosity (red line). Inset: grease worker

3. Discussion

The grease worker can be used as a device to measure mechanical energy input and rheological properties in-situ in order to prepare degraded samples for further study on aspects like microstructure or bleed properties.

4. References

[1] Zhou, Yuxin, Rob Bosman, and Piet M. Lugt. "A Master Curve for the Shear Degradation of Lubricating Greases with a Fibrous Structure." Tribology Transactions 62, no. 1 (January 2, 2019): 78–87.