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Influence of an applied electric field on the torque of rotary lip seals on metal shafts. Part II: Effects of oil type

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Abstract

The experimental results are presented of research on the tribocharging of selected engine oils and on the effect of an auxiliary external DC electric field on the work of rotary machinery. There exists an effect of the type of oil, its temperature, and the electric field on the braking torque of rotating parts such as shafts, crankshafts, etc. sealed with lip seals. The research was especially aimed at the possibility of reduction in the torque under external electric fields for different engine oils. To obtain the auxiliary electric field the DC voltage was applied between the stiffening ring of a fluorocarbon lip seal and the rotating, earthed shaft in the metal shaft–oil film–lip seal system. The measurements of the torque were performed under steady state conditions for given different oil temperatures, angular shaft velocities, and voltages; also three different oils were used. It was found that for the lip seal under test the negative voltage applied produced a beneficial effect on the torque depending on the type of oils.

Keywords: Tribocharging; DC electric field; Engine oil; Lip seal; Braking torque

1. Introduction

Little is known about the charging and specifically tribocharging of oils within the oil film as formed between surfaces of parts moving against each other as it can be observed in real motors, engines, devices, etc. in which rotating parts occur. There are some reports published earlier [1–4] and these dealt with the process of tribocharging in a rotating shaft–oil–lip seal system and its effect on the braking torque of a rotating shaft as well as the trials of reduction in the torque using an external DC electric field established across an oil film.

In general, in rotary machinery, there are some contacting parts which move against each other at high angular velocities, frequently for a long time. Such motion causes rubbing which in turn results in intense friction that absorbs useful engine power and produces useless heat and irreversible energy losses.

Lubricating oil makes a film between surfaces of parts rubbing against each other to reduce direct contact between them. The oil film formed decreases friction, wearing, and generation of excessive heat between the parts. This film also serves as a seal between the moving parts. The additives to oils are so selected to reduce friction between a shaft, an oil film, and a seal [5]. Incidentally, there is a lack of information on the exact composition of engine oils.

During the relative motion of the shaft, lip seal and oil between them the intense tribocharging occurs which results in highly charged oil particles. The electrochemical and electrostatic mechanisms establish a certain complex phenomenon that affects or can affect the efficient work of a whole system as that mentioned above as well as of engines, motors, machines, devices, etc. in which their parts move, rotate and so forth. This phenomenon can be observed, e.g. as the increasing torque of a rotating shaft. If one assumes that tribocharging plays an essential and key

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role in an increase in the torque, then it suggests that an external electric field can compensate for the internal natural ''bad'' electric field established by the net charge of oil particles in the oil film.

The research was partly aimed at looking for the optimum combination of different oils and lip seals, as used in real rotary machinery, for which the auxiliary external DC electric field could cause the torque of rotating shafts, crankshafts, etc. to be reduced. A decrease in the torque would mean the reduction of friction, energy losses, and finally operating expenses.

Only one lip seal used in the experiments and being in contact with all the oils tested revealed a positive, satisfactory, and promising result, namely the torque decreased with the increasing DC voltage. This beneficial effect is shown in Part I of this paper [6].

An external electric field could act as a field that compensates for the natural one of the net charge in the space between the shaft and seal, and this will be shown in some examples for three different oils and one fluorocarbon lip seal.

2. Research facility and procedure

The experiments on the influence of the DC external electric fields on the torque of rotating shafts for different engine oils and one lip seal were performed in the experimental set-up built on the basis of a model engine; the set-up was built for investigating the friction, friction and braking torques, friction losses of rotating parts of machinery, and for testing the lip seals for sealing rotating parts of machines, engines, motors, compressors, and other devices. The whole research facility is shown in Fig. 1 in Part I of this paper [6].

The stiffening ring of the lip seal was an electrode to measure the potential induced by the net charge of oil particles in the oil film between the rotating shaft and lip seal. It was also another electrode to generate a DC electric field, namely the DC voltage U_{DC} was applied between the same stiffening ring and the earthed rotating shaft to establish the external electric field between this ring and the rotating shaft across an oil film, that is across the shaft–oil film and oil film–lip seal interfaces.

The positive voltage was defined as that where the positive potential was applied to the stiffening ring while the negative one to the earthed rotating shaft. The negative voltage was when the stiffening ring had negative polarity.

3. Results of experiments

3.1. Materials tested

The experiments were conducted for one metal shaft of a roughness of 0.32 μm and a diameter of 88 mm. A fluorocarbon lip seal was used whose diameter was 88 mm. The following engine oils were tested: fresh Polish LOTOS 15W40 (oil A), ESSO SAE 30 (oil B), and used LOTOS 10W40 (oil C). Incidentally, the manufacturers of lip seals do not inform about the contents and additives used while producing the seals, and so do engine oil manufacturers.

3.2. Measurements

The measurements of the torque were made under steady state conditions to find its relationship with the voltage applied

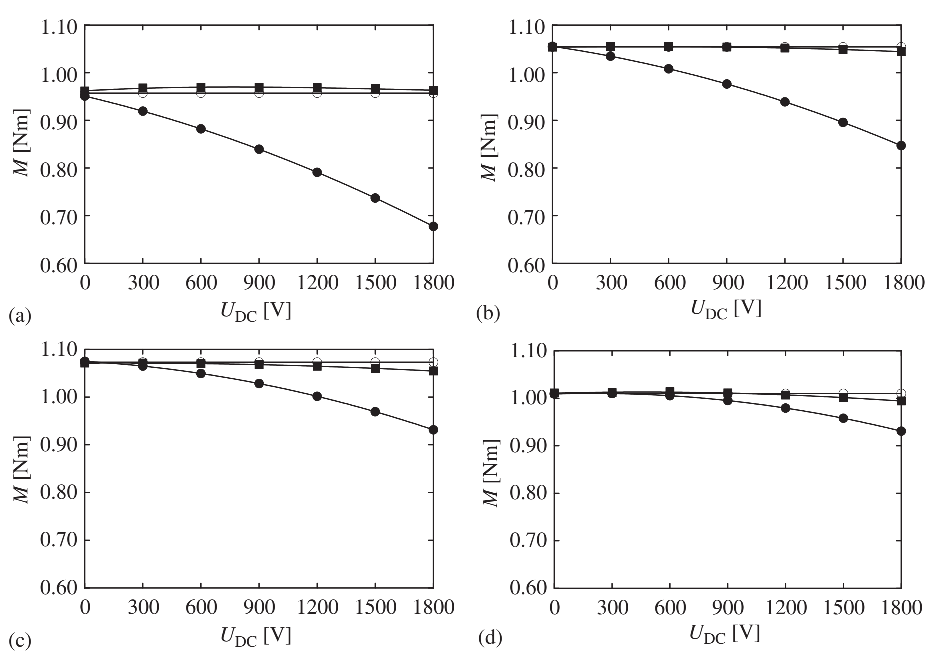

Fig. 1. Torque as a function of the voltage for the 88 mm diameter fluorocarbon lip seal, constant oil temperature ($T = 80\,^{\circ}$C), and angular velocities: (a) 500, (b) 1000, (c) 1500, and (d) 2000 rpm. ● and ■ are the negative and positive voltages, respectively, and ○ means no voltage applied to the system.