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Tribocharging in a rotating shaft–oil–seal system and the effect of an external electric field

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Abstract

The results are shown of tests on the effect of an auxiliary external DC electric field on the braking torque of a rotating shaft. Experiments were carried out on a simplified model of an engine in whose interior a metal shaft rotated with given angular velocities. The shaft was lubricated with different oils producing an oil film between the shaft's surface and a lip seal. The influence of different oil temperatures on the braking torque was also examined. The results are presented here for fresh Polish oil LOTOS 15W40 and a lip seal diameter of 88 mm. An increase in the negative DC voltage applied between the shaft and stiffening ring of the lip seal caused a reduction in braking torque.

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

1. Introduction

Lip seals are widely used in machines, engines, and devices in which there exist rotating parts such as shafts, crankshafts, etc. During their rotation, friction occurs between the shaft and lip seal, which results in irreversible energy losses and higher operating expenses. Research on new methods of lip seal construction is still

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carried out in an effort to obtain new and better solutions that result in lower energy losses [1].

As expected, tribocharging occurs during the intense rubbing of the surface of a lip seal against the surface of a rotating shaft. A thin oil film resides between both surfaces, and the oil is also charged intensely. Previous research [2] has shown that the potential of an isolated seal seating, induced by the net charge of all charged particles and other charged parts of an interface, depend on both the oil temperature and the shaft's angular velocity. Based on a rough analysis of the process(es) that can occur between a shaft and a lip seal and in both interfaces, e.g. the shaft–oil and oil–lip seal interfaces, one may conclude that an electric field is established between the rotating, earthed shaft and any charged layers of oil particles. Consequently, the surface of a lip seal could play a role in increasing the braking torque of a rotating shaft. The observations made during our preliminary experiments also proved that in the majority of different combinations of oils and lip seals tested tribocharging could exert an influence on the braking torque. If so, the question is whether or not an external, e.g., DC electric field could compensate for the "bad" effect of a natural electric field within the charged system consisting of the rotating shaft–oil film–lip seal and at the same time act to reduce the braking torque.

The literature contains a few, if any, papers that deal with the influence of tribocharging between lip seals, oils, and shafts on the shaft's braking torque. Many papers discuss the tribocharging of transformer oils [3–6] and different engine oils [7,8] but the only papers on the subject of rotating shafts are, to the best of our knowledge, those of the authors [2,9,10].

2. Description of experiments

2.1. Experimental set-up

The experiments presented here were conducted on a set-up that is a part of a larger facility for investigating the friction, friction losses, friction force, friction torque, braking torque, etc. of rotating parts (shafts, crankshafts, etc.) of different engines, machines, compressors, gears, etc. and for testing the lip seals used for sealing these parts. The experiments were carried out on a simplified model of an engine.

A diagram of the experimental installation is shown in Fig. 1. The experimental facility is made up of the following parts: the oil chamber housing (1); a seal seating—a metal ring (2) to which DC voltage is applied; the lip seal under test (3); an insulator (4) that separates the ring from the housing; the oil tested (5); an air bearing (6) decreases its own braking torque; the sensor of a torquemeter (7); an electric motor (8); a steel shaft (9); a microprocessor-based system for controlling the angular velocity n and for measuring the braking torque M of the shaft and temperature T of oil (10); a standard capacitor C_s (11) of the high degree of accuracy and thermal stability; a vibrating-capacitor electrometer to measure the ring potential U_e (12); a DC power supply U_{DC} (13), and an oil heater (14). A