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A Ringed Contact Friction and Boundary Lubrication Test Instrument Design

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Abstract

A simple, inexpensive, easy to use, and very accurate annular contact friction and boundary lubrication tester is described. Data are presented to show excellent reproducibility and extremely low experimental scatter. The system allows the accurate simultaneous measurement of normal load, friction force, ambient fluid temperature, and mean surface contact temperature. Analyses are presented, which are applicable to other testers in addition to the present one, for determining the true mean surface contact temperature from a measured near surface temperature (determined with a thermocouple), and for calculating the viscous drag component of the measured friction (thereby allowing its separation). The tester is particularly well suited for simulating and studying the surface contact phenomena which arise in multiple disc brakes and clutches.

Review Article

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INTRODUCTION

The present system was designed to provide a friction and boundary lubrication tester with an annular nominal area of contact, for use in simulative experiments of contact phenomena arising in mechanical systems such as liquid immersed multiple disc clutches and brakes[1, 2]. The normal load is adjustable over a range of two orders of magnitude and the machine permits significant variation in the sliding speed. The instrumentation can give very accurate determinations of surface temperature, ambient. temperature, friction force, and normal load[3]. Moreover, the system is relatively inexpensive. Annular contact type of testers have been built before, but few of these have the accuracy and repeatability of the present system. Surface temperature is a major experimental variable which must be monitored[4]. As it is physically impossible to measure the actual interfacial temperature, the question always arises of how accurately the measured temperature represents the true mean surface contact temperature. An analysis is included which allows this question to be answered. This analysis is applicable to all annular contact specimen geometries similar to the one to be described, including those of previous experimental configurations for which such an analysis has been lacking[5].

Viscous drag is an additional retarding force whose effect adds to that of surface friction. An analysis is presented which allows this effect to be separately calculated and thereby removed from the total effect[6]. The effect of temperature on the viscous drag force is derived [7]. The analysis allows the user of the present or similar geometric configurations to improve experimental accuracy by allowing the separation of an extraneous effect [8].

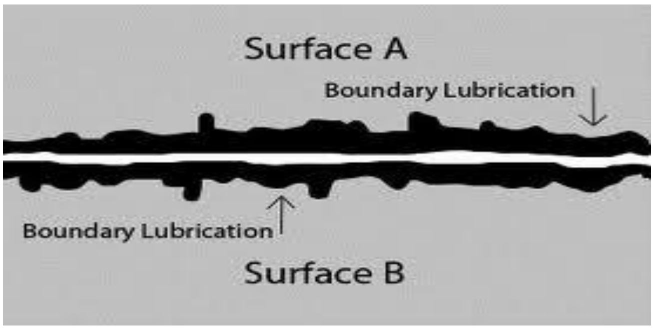

Fig 1. Surfaces of friction

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MATERIALS AND METHODS

A 1.5 hp bench model drill press was used as a rotational power supply and base. The entire system, showing the drill press, is shown in Fig. 1,1 The use of a drill press allows the acquisition of a relatively great deal of machinery at a modest cost; the model chosen sells for only about $525. The press had to be modified to permit a vertical thrust load on its column. The lower right-hand corner of Fig. 2 shows the modification, which consists of a rod going through both the column and its collar. The system could actually deliver up to 3 hp before stalling [9]. The actual friction is shown in Fig. 1, and in sectional view in Fig. 3. A rigid arm extends from the column of the drill press, into which the loading screw turns (this screw is the uppermost object in Fig. 3, shown in the figure without threads). A rigid extension of the arm holds the cantilever system shown in the figure. The mechanical system was designed to support a maximum normal load greater than 1800 kg. The minimum possible load on the system due to the weight of the spring, the double-row bearing, etc., is 16.6 kg. The tank can hold approximately 840 ml of oil[10]. The system has operated successfully with ambient oil temperatures of up to 288°C. The temperature limitations on the system are determined by those imposed by the lip seal materials[11].

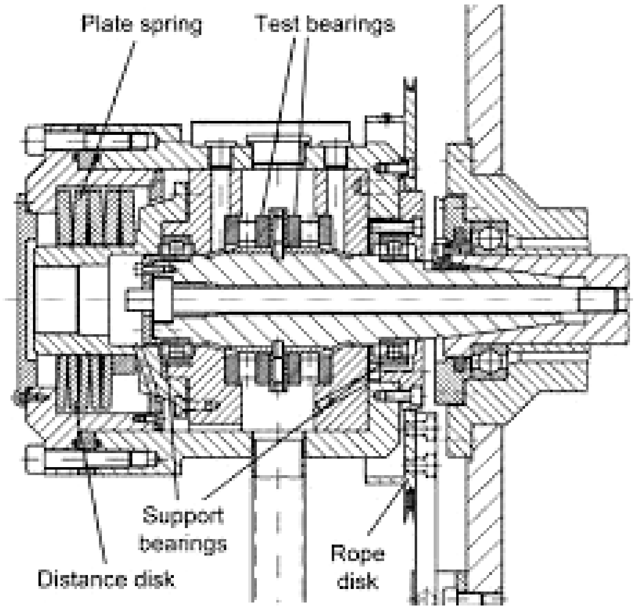

Fig. 2. Sectional side view of friction apparatus

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The system allows significant variation in specimen contact area geometry. A keyway through the backing mated with a keyed driver. The copper-based face. Material was recessed 0.030 to 0.038 cm to leave three annular rings, each 0.127 cm wide, with spaces of 0.127 cm between them. The outside radius of the outer ring was 6.85 cm and the apparent area of contact was 15.87 cm^2. A screw positioned the specimen on the driver.

The normal load was measured using a strain gauge system. The load spring had four 120Ω strain gauges comprising a four-active element bridge, mounted parallel to the principal axes of stress. A light beam galvanometer recording system, recorded the bridge imbalance. Calibration showed that normal load could be determined to within 1%. The friction force was determined with the use of 1200 Ω strain gauges, in a temperature compensating circuit, mounted to the cantilever beam. Their output was recorded in the same manner as the normal load. Calibration showed that friction force could be determined within 2 to 3%.

Two types of iron-constantan thermocouples were used, one to measure ambient oil temperature, and the other surface temperature. The former, had a pipe fitting allowing it to be screwed into the tank with the sensing element protruding 1.27 cm from the wall between the bottom of the table and the floor of the tank. The latter was made by welding two crossed iron and constantan wires, cutting the junction through the middle, then welding the junction to the bottom of the hole provided for it in the stator disc specimens; this placed the thermocouple directly underneath the central annular ring, and a few thousandths of an inch from the sliding surface.

Test Procedures

The system readily lends itself to several quite different test procedures as both normal load and sliding velocity may be significantly varied. The bulk fluid temperature may also be kept at a constant level by the simple addition of a heat exchanger and circulating pump[12]. All tests to date have allowed the bulk fluid temperature to rise throughout the test from an initial room temperature value to a final temperature on the order of 288°C.

RESULTS AND DISCUSSION

Surface contact temperature is one of the most important of all variables in friction and wear. Attempts are usually made to measure it by embedding a thermocouple into one of the surfaces undergoing sliding, as close to the surface as is practicable. (Figure 6 is an illustration of the importance of surface contact temperature.) Unfortunately, this measured temperature can never be the true surface temperature, and the question arises of how accurate a representation it is. Annular contact type testers, including both the present system and previous designs, require an analysis which gives the error induced by taking the measured temperature as the true mean surface contact temperature, and allows the calculation of one from the other.

The measured friction actually consists of the sum of two effects: boundary friction and viscous drag. As the purpose of the tester is the examination of boundary friction, it is necessary to calculate the viscous effect and

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subtract it from the total friction. The short table at the end of this research shows that the correction for viscous drag is inconsequential for a typical mineral oil for temperatures above 100°C.

CONCLUSION

The reason for using a tester, such as the present system, is to accurately simulate complex surface contact phenomena so they can be studied. The actual machinery in which a phenomenon exists, and possibly constitutes an industrial problem, is usually un-amenable to the taking of accurate measurements.

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