EHD CONTACTS IN LOW-AMPLITUDE OSCILATORY MOTION

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ABSTRACT
In some practical applications such as spline couplings or constant velocity joints, the machine components are subjected to a low amplitude lateral motion, very often oscillatory, so that conditions for a full elasto hydrodynamic film to form are not completely realized. The questions that arise are what mechanism of lubricating takes place in such contacts and what is the influence of working parameters and lubricant properties on such mechanism? In the present study, a EHD contact formed between a flat and a ball is subjected to oscillatory-motion of amplitude ranging between one half to one contact diameter. High speed ultra-thin film interferometry is used to monitor the gap between the two solid surfaces. The influence of parameters such as load, frequency and amplitude of motion are investigated.

INTRODUCTION
Transient phenomena, in which parameters such as load, speed or geometry vary rapidly are common to elasto hydrodynamic lubrication (EHD). Cams and gears are typical examples of machine elements working in transient conditions, but constant velocity joints and bearings also experience non-steady conditions during operation. For all these cases it is important to know or predict the effect that these transient conditions have on contact pressure and lubricant film thickness, as these ultimately dictate the life of the machine elements. For relative low rates of variation of the operating parameters it is usually assumed that a steady-state approach gives a sufficiently accurate prediction, but for high rates of variation it is more difficult to predict film thickness since other phenomena such as film squeeze, the time of transit of the lubricant through the contact and even acceleration can play a role in film generation. Researchers in the area of elasto hydrodynamic lubrication have always been aware of the potential importance of transient effects, but only relatively recently, have advances in numerical methods and the development of accurate and fast experimental techniques made possible the systematic study of these phenomena. Early numerical approaches to transient EHD phenomena tackled mainly the effect of load, but expanded later to cover other aspect such as macro- and micro- geometry changes, and velocity [1-3]. From an experimental point of view the task is demanding as it requires a system capable of recording data at sufficient high frequency to capture behavior within the timescale of the rate of variation of the operating parameter of interest. Relatively recently the authors have coupled optical interferometry with a high speed acquisition camera to allow the study of lubricating film behavior during rapid variation of entrainment speed. These studies have investigated sudden halting of motion [4], rapid start from rest [5], reversal of entrainment [6], and alternating start-stop [7]. It has been found that, during rapid acceleration and deceleration, the film behavior is dominated by two different mechanisms: fluid entrainment and film squeeze.

The present study focuses on film thickness during longitudinal and lateral oscillations induced on a rolling contact. This case has been previously studied numerically for a line contact [8].

EXPERIMENTAL METHOD
Since it was developed in the early 1960s optical interferometry has proved a powerful technique for measuring the thickness of the film formed in EHD contacts. Developments to this technique have enabled film thicknesses measurements to be made down to two nanometers [9, 10] and also the study of the mixed regime and the behavior of surface features in thin film conditions [11]. In essence the technique consists on a steel ball rolling/sliding against a transparent flat disc, usually made of glass or sapphire as shown in Fig. 1. The transparent disc is double-coated with a very thin semi-reflective chromium layer and a silica layer of thickness between 100 and 500 nanometers. In steady state conditions a CCD camera is used to grab the images which are then analyzed by the computer to extract film thickness values. To study transient events, a high-speed camera, black and white or color is employed to store the interferometric images, which are subsequently download them to the PC computer for frame-by-frame analysis.

In the current work the speed of the disc was kept steady at 0.1 m/s in all tests, while the ball was subjected to the oscillatory motion. In longitudinal oscillation tests the ball speed was varied in a sinusoidal fashion about an average
surface speed of 0.2m/s. During lateral oscillation tests the longitudinal velocity of the ball was fixed at 0.2m/s but the ball and its support were driven in an oscillatory motion transverse to the main entrainment direction by a device specially designed for this work. The amplitude of these oscillations was relatively low, between half and one diameter of the contact.

The lubricant used was a base mineral oil (HV160) with properties listed in Table 1, while the load and temperature were set at constant values of 20N and 40°C respectively.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Viscosity [Pa s]</th>
<th>Pressure/viscosity coefficient [Gpa⁻¹]</th>
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<tr>
<td>40°C</td>
<td>0.022</td>
<td>19.8</td>
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RESULTS

The experiments show that during longitudinal variation of speed, the film thickness over the contact area is dominated by the formation of a fluid entrapment during rapid deceleration. The depth and shape of this entrapment depends on the rate of speed variation. Figure 2 shows a cross section of the film along the center line for the moment when the entrainment speed is minimum. An interferometric image of the contact is also shown.

CONCLUSIONS

A film thickness study on the behavior of elastohydrodynamic contacts subjected to longitudinal and lateral oscillation has been conducted. Spacer layer optical interferometry was employed to obtain 3-D maps of the film during transient conditions. It has been shown that film thickness variation depends strongly on the frequency of the oscillatory motion super-imposed on the rolling motion.

REFERENCES