A thermal resistances-based approach for thermal-elastohydrodynamic calculations in point contacts

Eduardo de la Guerra Ochoa¹, Javier Echavarri Otero¹, Enrique Chacon Tanarro¹ and Benito del Rio Lopez²

Abstract

This article presents a thermal resistances-based approach for solving the thermal-elastohydrodynamic lubrication problem in point contact, taking the lubricant rheology into account. The friction coefficient in the contact is estimated, along with the distribution of both film thickness and temperature. A commercial tribometer is used in order to measure the friction coefficient at a ball-on-disc point contact lubricated with a polyalphaolefin base. These data and other experimental results available in the bibliography are compared to those obtained by using the proposed methodology, and thermal effects are analysed. The new approach shows good accuracy for predicting the friction coefficient and requires less computational cost than full thermal-elastohydrodynamic simulations.

Keywords

Thermal-elastohydrodynamic, lubrication, thermal resistance, friction, point contact

Introduction

In recent years, a large amount of research has been devoted to improving the energy efficiency of mechanical components operating under elastohydrodynamic lubrication (EHL). This improvement depends on the capability to predict the behaviour of the contacts under EHL conditions. A decisive influence on this issue is the distribution of temperatures in the lubricant, which determines its viscous properties.^{1,2}

It is known that the severe operating conditions of these contacts involve a generation of heat by friction, which gives rise to non-isothermal behaviour. The increase in temperature directly affects the film thickness and the friction coefficient.

Of the initial research into tribological contacts with thermal effects, it is worth mentioning Blok³ and Jaeger.⁴ They modelled the contact as a uniform frictional heat source moving over the surface and studied the rise in temperature for different geometries in the absence of any lubricant.

One of the first numerical solutions to the thermal-elastohydrodynamic (TEHL) problem was developed by Cheng and Sternlicht,⁵ who studied the pressure, temperature and film thickness for a line contact between two rollers lubricated with a Newtonian fluid. Similarly, the numerical solution for the case of point contacts was approached by Zhu and Wen.⁶

Sui and Sadeghi⁷ solved the TEHL problem for non-Newtonian lubricants. Their solution was based on the Reynolds equation modified by the Eyring rheological model⁸ to incorporate the shear-thinning effect of the fluid. More recently,⁹⁻¹² solving the TEHL problem was approached by applying multi-level techniques based on the studies carried out by Lubrecht.¹³

Thermal network-based analysis is a very useful tool in numerous engineering problems.¹⁴ Olver and Spikes¹⁵ developed a one-dimensional thermal network for TEHL point contact. Later on, Morales-Espejel and Wemekamp,¹⁶ Echavarri et al.,¹⁷ Paouris et al.¹⁸ and Shirzadegan et al.¹⁹ used this approach to account for thermal effects in analytical models and calculate an average value of the temperature of the lubricant within the

¹Grupo de Investigación en Ingeniería de Maquinas, Universidad Politécnica de Madrid, Spain

²Física Aplicada e Ingeniería de los Materiales, Universidad Politécnica de Madrid, Spain

Corresponding author:

Javier Echavarri Otero, Grupo de Investigación en Ingeniería de Maquinas, Universidad Politécnica de Madrid, Jose Gutierrez Abascal, 2, Madrid, 28006, Spain.

Email: je.chavarri@etsii.upm.es