PREDICTION OF FATIGUE DAMAGE IN ROUGH SURFACE EHL

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Abstract

The study of elastohydrodynamic lubrication (EHL) with rough surfaces results in a transient problem due to time varying geometry. In conditions where the \( \lambda \) ratio (smooth surface film thickness : composite roughness) is low, significant pressure deviations from the corresponding smooth surface results occur. The relative motion of asperity features on the two surfaces leads to cycling of these pressure deviations as surface features move through the nominal contact area. The paper presents a numerical procedure for prediction of fatigue damage as a result of this load cycling. The way in which the calculated fatigue damage varies with changes in factors such as slide roll ratio, viscosity and the roughness profiles adopted for the analysis are demonstrated in the numerical examples.

Keywords: mixed lubrication, stress, fatigue, micropitting.

1. INTRODUCTION

The study of micro elastohydrodynamic lubrication (micro-EHL) of rough surfaces leads naturally to mixed lubrication where part of the load is carried by pressurised lubricant that separates the surfaces completely, and part of the load is carried by dry or boundary lubricated contact between asperity features. The motion of the roughness relative to the contact point requires that transient effects are considered. A transient analysis is thus necessary to examine the evolution of pressure and film thickness within the EHL contact. In recent years much effort has been made to address this situation and different approaches have been used in numerical analysis.

Fatigue is a common mechanism for failure of the EHL system and is seen as the limiting factor controlling the operational life of rolling element bearings. Another possible example is micropitting which is seen in gears and may well be viewed as rolling contact fatigue on the scale of surface asperities. Although the severity of the EHL contact can be assessed qualitatively by pressure and film thickness within the contact, it is desirable to evaluate the fatigue life quantitatively using a fatigue model. Some recent developments seek to extend the evaluation of pressure variation to include their effect on fatigue life due to roughness and cyclic loading. Ai [1] employed an effective stress concept based on damage accumulation theory and introduced a stress-based fatigue equation with volume integration. Tallian [2] proposed a data fitted life prediction model for rolling contacts under variable operating conditions. Epstein et al. [3] calculated fatigue life in mixed lubrication using fatigue models developed by Ioannides and Harris [4] and Zaretsky [5]. These fatigue models grew out of the Weibull model and were originally developed for rolling element bearings. The current paper presents an alternative model for preliminary fatigue calculations based on numerical analysis of the mixed lubrication problem that uses a novel technique developed by the authors [6, 7]. Numerical simulations are performed and results are presented for several cases of line contacts of rough surfaces.

2. THEORY

2.1 Stress Cycling

Understanding stress cycling is fundamental to fatigue failure analysis. Therefore, an accurate and efficient evaluation of the stresses involved in the EHL contact is necessary in order to implement realistic fatigue prediction. For line contact analysis the solid bodies may be considered to be in plane strain so that the state of stress at any point \((x, z)\) is determined by the three components \(\sigma_x, \sigma_z, \tau_{xz}\). These components can be evaluated at each timestep due to the EHL contact pressure \(p(x, t)\) and surface shear stress loading \(q(x, t)\) by direct integration of the integrals [8]

\[
\begin{align*}
\sigma_x(x, z, t) &= \int p(s, t) k_1(x - s, z) ds + \int q(s, t) k_4(x - s, z) ds \\
\sigma_z(x, z, t) &= \int p(s, t) k_2(x - s, z) ds + \int q(s, t) k_3(x - s, z) ds \\
\tau_{xz}(x, z, t) &= \int p(s, t) k_3(x - s, z) ds + \int q(s, t) k_1(x - s, z) ds
\end{align*}
\]

(1)

where the influence coefficients are defined as