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LUBRICATION OF 2D SOFT ELASTO HYDRODYNAMIC CONTACTS: EXTENSION OF THE AMPLITUDE REDUCTION THEORY

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ABSTRACT
This paper is an extension of the Amplitude Reduction Theory to soft ElastoHydrodynamic contacts. The ART permits a quantitative prediction of the influence of surface roughness on the lubricant film thickness modification as a function of the operating conditions.

INTRODUCTION

Lubrication of soft contacts plays an important role in technology. In these contacts the pressures are low and thus the viscosity η can be taken as constant. The same is true for the density ϱ. Deformation occurs at these low pressures as the elastic modulus of the contacting materials is low. Hence large elastic deformations occur in these contacts, both on a macro scale (contact dimension) and on a micro-scale (roughness dimension). As such the behaviour is identical to the behaviour of highly loaded ElastoHydrodynamically Lubricated (EHL) contacts. To distinguish the two regimes, the latter is coined Piezo-viscous Elastic (PE), whereas the first is named Iso-viscous Elastic (IE). To describe the two regimes and to generate the dimensionless numbers, the two dimensional Moes parameters are introduced. These parameters M and L can be related to the Hamrock Dowson parameters: $M=W/U^{3/4}$, $L=GU^{1/4}$. Using these parameters the PE regime can be defined as $M>10$, $L>2.5$ and the IE regime as $M>10$, $L=0$.

The roughness deformation in the PE regime has been extensively studied in the past, using measured roughness profiles and studying the behaviour of wavy surfaces. The second approach is adopted in this work. The amplitude reduction literature [1-3] shows that a unique master curve is obtained when plotting the relative deformed amplitude A_d/A_i as a function of a dimensionless waviness parameter $\nabla=(\lambda/a)(2M/6L)$, where λ is the wavelength and a is the contact radius. This parameter has been interpreted as the ratio of the waviness wavelength to the inlet boundary layer. It is clear that this approach is of great interest, as it predicts the waviness behaviour analytically. Using Fourier decomposition the behaviour of a “real” rough surface can be analysed as a function of the operating conditions.
It is obvious that a straightforward use of the ∇ parameter in the IE regime is impossible as $\nabla=\infty$ for $L=0$! This implies a complete flattening ($A_d/A_i=0$) for all waviness components. Thus a complete flattening of the roughness is predicted, which implies infinite pressure spikes. This is obviously not a physically realistic prediction!
Hence, an extension of the current Amplitude Reduction Theory is required for the IE regime. In particular a special ∇ parameter has to be devised.

RESULTS

The most straightforward approach to modify the ∇ parameter is to remove the L from the denominator: $\nabla=(\lambda/a)2M$. Pure

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rolling numerical calculations varying M, λ and A_d/A_i show that indeed a single master curve is obtained with this parameter. Rather surprisingly, the range of ∇ is similar to the PE regime: A_d/A_i varies from 0.9 to 0.1, for ∇ between 2 and 20.

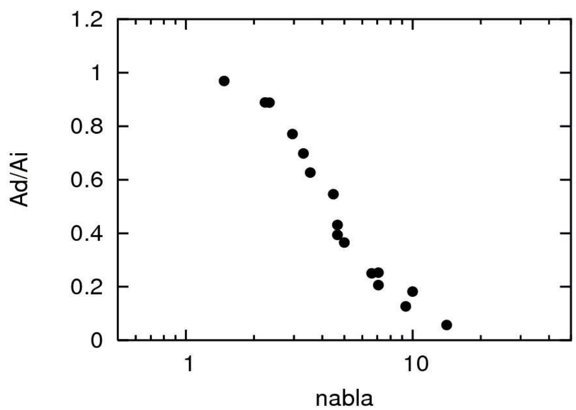

Figure 1, Amplitude reduction for the IE regime as a function of ∇.

The similarities in the range of ∇ parameters between the IE and PE regimes permit a certain optimism as to whether a single parameter can be found describing the amplitude reduction in both the IE and PE regimes.

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