Transient effects and associated time scales in thermal elasto-hydrodynamic line contacts

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1. Abstract

During their life cycle, complex tribological systems such as gears and cam-followers are subjected to extremely severe operating constraints. Those invariably involve substantial shear rates, pressures and temperatures within the lubricant, in addition to dynamic applied conditions of load, speeds and conjunction geometry [1]. In recent years, the use of transient TEHD models is progressively becoming a standard for the simulation of gears and cam-follower systems. New advances focus on topics such as roughness, starvation, boundary lubrication, etc. Surprisingly, a clear understanding of the onset and magnitude of the transient effects in TEHD configurations is still lacking. The present study aims at addressing this point by providing a comprehensive numerical analysis of the transient phenomena occurring within the conjunction, their respective influence (depending on the operating conditions and material parameters), and their associated time scales.

As a prerequisite, the system of equations, boundary conditions and numerical scheme used in the model are described. In addition, developments to solve transient fully-flooded TEHD problems are detailed, on the basis of a previous work [2] dedicated to the study of steady state cases.

Then, the phenomena at the origin of transient effects in a TEHD contact are reviewed along with their characteristic time. In this context, a particular focus is placed on the thermal problem. The complexity in finding a relevant thermal characteristic time is illustrated by the influence of the slide-to-roll ratio (SRR) on the contact performance (film thickness and friction) [3]. The dependency of the dominant heat transfer mode on the SRR is showed. A distinction between low sliding, pure sliding and high sliding conditions is made. Each configuration is thoroughly analyzed, leading to the formulation of new thermal characteristic times.

Finally, in order to determine the onset of transient effects, time-dependent TEHD computations are performed. A reference configuration consisting of two contacting cylinders subjected to a sinusoidal load variation (of amplitude A_w and period t_w) is used. Transient evolutions of the central film thickness and friction coefficient are compared to quasi-steady solutions for the three different SRR cases and varying t_w. For this purpose, characteristic variables of a periodic TEHD problem, namely the mean value (hc_m) and amplitude (Ahc) of the central film thickness and the mean value of the friction coefficient (Cf_m), are extracted from each computation. Those are, in turn, used to create a set of normalized variables (Δhc_m, ΔAhc and ΔCf_m) allowing to calculate deviations induced by the transient effects. Results, as the example plotted on Fig.1, show that the onset of transient effects of the different configurations can be matched if related to their dominant physical characteristic time t_φ. A parametric study on the operating conditions (load, entrainment velocity, amplitude of fluctuation) and material properties further validates this conclusion.

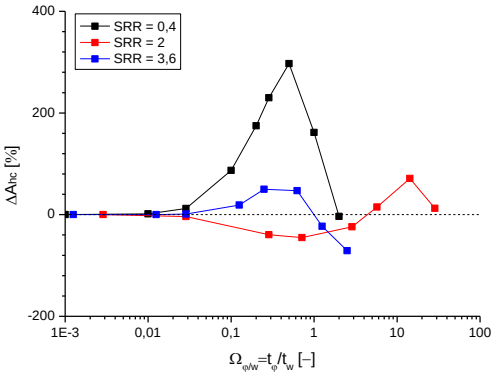

Fig. 1: Influence of the transient effects on the variation of the normalized average friction coefficient ΔAhc as a function of the load fluctuation frequency $1/t_w$. In abscissa, the latter is normalized by the dominant physical time t_φ identified for each SRR.

2. References

[1] D. Dowson, P. Ehret, Past, present and future studies in elastohydrodynamics, Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology 213 (5) (1999) 317-333.

[2] W. Habchi, D. Eyheramendy, P. Vergne, G.E. Morales-Espejel, "A Full-System Approach of the Elastohydrodynamic Line/Point Contact Problem", ASME Journal of Tribology 130 (2) (2008) 021501-021510.

[3] V. Bruyere, N. Fillot, G. Morales-Espejel, P. Vergne, Computational fluid dynamics and full elasticity model for sliding line thermal elasto-hydrodynamiccontacts, Tribology International 46 (1) (2012) 3-13.