Non-Newtonian rheological and thermal effects on the noise and vibration of a spur gearset

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Electrification of powertrains has unmasked new sources of noise, vibration and harshness (NVH) in electric and hybrid electric vehicles (EV and HEV) such as gearbox whine. For vibroacoustic predictions, simple analytical models are proposed due to their time efficiency and cost effectiveness. These analytical models, however, neglect the squeeze film effect and hence, are deemed to be inappropriate for transient conditions. The aim of this study is to develop a semi-transient tribological model for EHL contact of a gearset. The proposed model is used to analyse the gear tribodynamics and effect of squeeze film on more accurate prediction of gear NVH. The model is verified using experimental results from the literature.

Keywords: Gear dynamics, NVH, EHL, squeeze film, thermal effects

1. Introduction

The global concerns regarding emissions has driven the automotive industry toward electrification. In the absence of internal combustion (IC) engine noise, other sources of NVH are unmasked in the drivetrain. Gearbox is one of the main contributors to NVH in these drivetrains, mainly appearing as gear whine noise. This research aims to study the noise and vibration characteristics of a simple spur gear system by creating a dynamics model and incorporating a tribological model that includes film squeeze effects in gear tribodynamics. This improved analytical model is then utilised in predicting the acoustic performance of a spur gear system. The thermal effects on the acoustic characteristics is investigated through a series of parametric studies including the effect of contact temperature.

2. Methods

Gear whine is mainly affected by the dynamics and tribological effects in gear meshing. These physical concepts are related through dynamic transmission error (DTE). A dynamic model of the system is established considering the nonlinearities in the gear teeth stiffness and structural damping. A model from the open literature is adapted for this study [1]. This model uses a basic relationship between damping coefficient and the minimum film thickness subject to EHL conditions in the gear teeth. This study adapts this approach and improves upon the tribological model to account for the effect of squeeze film. A semi-transient model including film squeeze effect is adapted using the model developed by Mostofi and Gohar [2]. In this model, the lubricant film thickness is calculated as:

$$h_0^* = 1.67 G^{*0.421} U^{*0.541} W^{*0.059} e^{-96.775 w_s^*} \quad (1)$$

where, w_s^* includes the squeeze film effect.

2.1. Results

DTE is evaluated at various meshing frequencies between 0 and 4000 Hz. The root mean square (RMS) of DTE is used to predict the amplitudes of vibrations during gear meshing. Experimental results from the literature are used to verify the developed model. Figure 1 shows the preliminary results from the modified model. The effects of lubricant properties such as shear thinning, and thermal conditions are also studied.

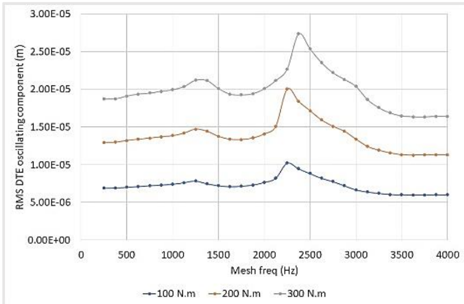

Figure 1: Preliminary results for the predicted DTE including film squeeze effect

3. Discussion

An improved model is proposed to include the film squeeze effects on the DTE and gear dynamic response. the film squeeze effect, considered through use of an analytical model, shows reasonable accuracy whilst it is time efficient and cost effective. The parametric study predicts the effects of temperature and lubricant properties including shear thinning on DTE. The acoustic characteristics of the improved model is also modelled

4. References

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