Frictional effects on the dynamic responses of gear systems and the diagnostics of tooth breakages

Assist. Prof. Dr. Khaldoon K. Brathea

College of Engineering / University of Anbar

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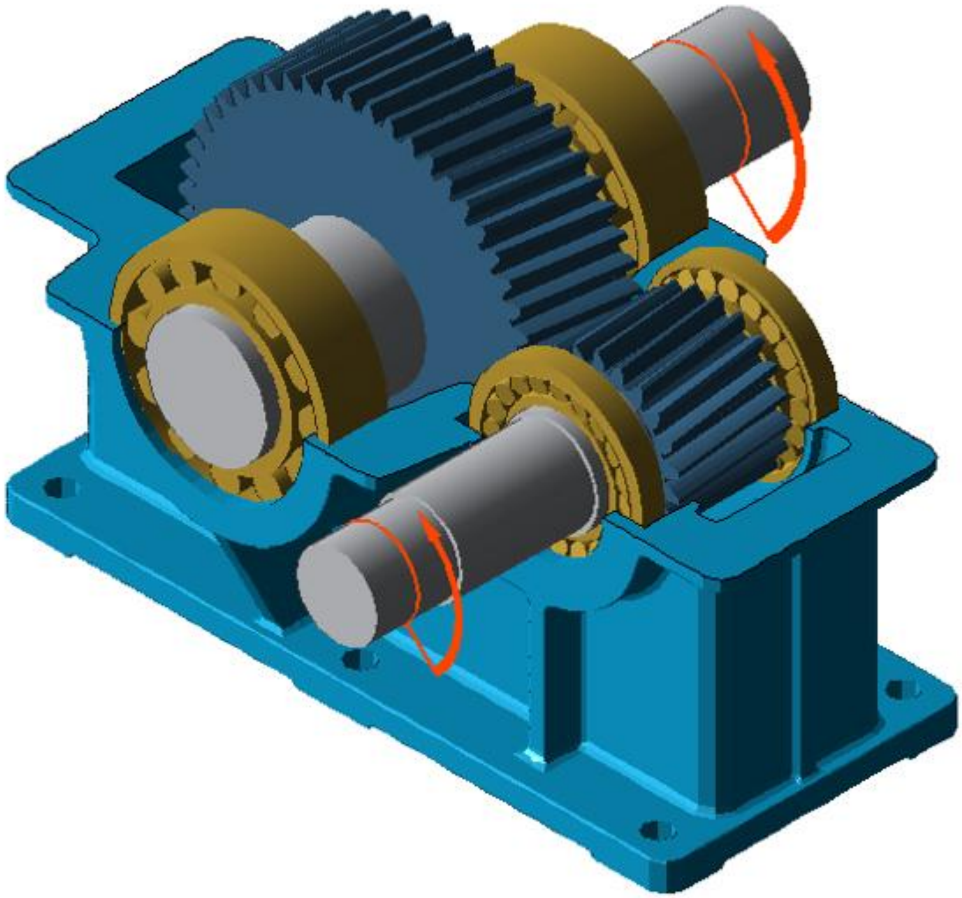
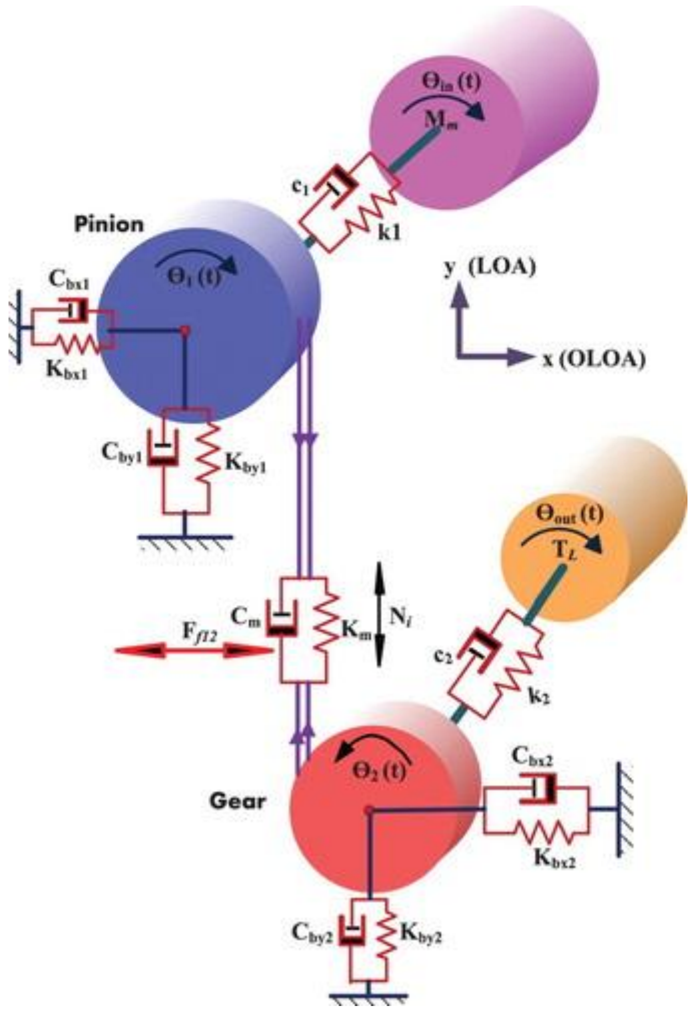
To develop accurate diagnostic techniques, this study examines the dynamic responses of spur gear transmission system with including frictional effects on a tooth mesh process. An 8-degree-of-freedom model is developed to include the effects of supporting bearings, a driving motor and a loading system. Moreover, it takes into account not only the time-varying stiffness, but also the time-varying forces and moments due to the frictional effect. The latter causes additional vibration responses in the direction of the off-line-of-action (OLOA). To show the quantitative effect of the friction, vibration responses are simulated under different friction coefficients. It shows that an increase in friction coefficient value causes a nearly linear increase in the vibration features of diagnostics. However, features from torsional responses and the principal responses in the line-of-action show fewer changes in the vibration level, whereas the most significant increasing is in the OLOA direction. Furthermore, the spectral peaks at the rotational and sideband frequencies are influenced significantly by small breakage defects, especially when the friction effect is taken into account. In addition, the second and third harmonics of the mesh frequency are more influenced than the first harmonic component for all motions, which can be effective features for both indicating lubrication deterioration and improving conventional diagnostic features.



The dynamic model coupling with tooth friction produces consistent vibration responses to the change in friction due to lubrication degradation. The linear response is used to calibrate the model parameters, by including resonance frequencies and damping ratios to be convenient with an industrial gearbox. The model shows that there is an increase up to 2.18% in power consumption due to friction coefficient change, which leads to additional resistive frictional torque. However, the maximum increase of vibration responses in the spectral peaks can be more than 100%. These show that it is much easier to use vibration responses to monitor the power consumption directly. Both rotational responses and translational responses of vibration can be effective indicators for lubrication conditions, but the translational one is more sensitive even though the rotational responses are generally more nonlinear.



The spectral peaks of vibration response at the characteristic rotational and sideband frequencies are considered to diagnose different TB severities in the light of the impulsive sources from frictional excitations. The results show more influential increase in spectral peaks at these features when the friction effect is included. In addition, these features are also significantly increased with different TB severities when friction is considered in the model. Therefore, frictional effects should be taken into account of vibration analysis if it is to be an accurate method for the detection and diagnosis.

KEYWORDS:

Diagnostics, tooth breakage, friction coefficient, vibration response