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Dynamic Simulation of IC Engine Bearings for Fault Detection and Wear Prediction

Authors : M. D. Haneef, R. B. Randall, Z. Peng

Abstract : Journal bearings used in IC engines are prone to premature failures and are likely to fail earlier than the rated life due to highly impulsive and unstable operating conditions and frequent starts/stops. Vibration signature extraction and wear debris analysis techniques are prevalent in the industry for condition monitoring of rotary machinery. However, both techniques involve a great deal of technical expertise, time and cost. Limited literature is available on the application of these techniques for fault detection in reciprocating machinery, due to the complex nature of impact forces that confounds the extraction of fault signals for vibration based analysis and wear prediction. This work is an extension of a previous study, in which an engine simulation model was developed using a MATLAB/SIMULINK program, whereby the engine parameters used in the simulation were obtained experimentally from a Toyota 3SFE 2.0 litre petrol engines. Simulated hydrodynamic bearing forces were used to estimate vibrations signals and envelope analysis was carried out to analyze the effect of speed, load and clearance on the vibration response. Three different loads 50/80/110 N-m, three different speeds 1500/2000/3000 rpm, and three different clearances, i.e., normal, 2 times and 4 times the normal clearance were simulated to examine the effect of wear on bearing forces. The magnitude of the squared envelope of the generated vibration signals though not affected by load, but was observed to rise significantly with increasing speed and clearance indicating the likelihood of augmented wear. In the present study, the simulation model was extended further to investigate the bearing wear behavior, resulting as a consequence of different operating conditions, to complement the vibration analysis. In the current simulation, the dynamics of the engine was established first, based on which the hydrodynamic journal bearing forces were evaluated by numerical solution of the Reynold's equation. Also, the essential outputs of interest in this study, critical to determine wear rates are the tangential velocity and oil film thickness between the journal and bearing sleeve, which if not maintained appropriately, have a detrimental effect on the bearing performance. Archard's wear prediction model was used in the simulation to calculate the wear rate of bearings with specific location information as all determinative parameters were obtained with reference to crank rotation. Oil film thickness obtained from the model was used as a criterion to determine if the lubrication is sufficient to prevent contact between the journal and bearing thus causing accelerated wear. A limiting value of 1 μm was used as the minimum oil film thickness needed to prevent contact. The increased wear rate with growing severity of operating conditions is analogous and comparable to the rise in amplitude of the squared envelope of the referenced vibration signals. Thus on one hand, the developed model demonstrated its capability to explain wear behavior and on the other hand it also helps to establish a correlation between wear based and vibration based analysis. Therefore, the model provides a cost-effective and quick approach to predict the impending wear in IC engine bearings under various operating conditions.

Keywords : condition monitoring, IC engine, journal bearings, vibration analysis, wear prediction
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