Abstract

The feasibility of using nanoparticles as additives to improve the tribological properties of lubricants used in fluid film bearings is studied both theoretically and experimentally. Presence of TiO$_2$ nanoparticle additives is found to reduce friction force generated in the hydrodynamically developed oil film between the tribo-surfaces. This reduction in friction is expected to reduce power loss in drive systems utilizing journal bearings.

The two-step method of formulating stable TiO$_2$ nanolubricants at low volume fractions is optimized for dispersion stability with regard to type of surfactant, concentration of surfactant, mode of ultrasonication, and the duration of sonication. Dispersion stability of formulated TiO$_2$ based nanolubricants is quantified using UV-vis spectrophotometry and expressed as percentage supernatant particle concentration for the period of static storage. Under optimized conditions, a stability of 75 days with 60% supernatant particle concentration is achieved under static storage. The rheological properties of TiO$_2$ based nanolubricant samples are experimentally studied. Increase in viscosity of base fluid with addition of TiO$_2$ nanoparticles is measured and the results obtained are used to develop a viscosity model to predict viscosities of TiO$_2$ nanolubricants at different volume fractions. Experimental viscosities were found to correlate well with modified Krieger-Dougherty viscosity model.

Conventional theoretical framework of obtaining journal bearing characteristics is modified to account for: i) couple stress effects of TiO$_2$ nanoparticle additives, and ii) influence of TiO$_2$ nanolubricant viscosities as simulated by Krieger-Dougherty viscosity model. The classical Reynolds equation is therefore modified to study the influence of nanoparticle aggregate size and nanoparticle concentration on the static and dynamic characteristics of journal bearings. Theoretical studies reveal a 40% increase in load carrying capacity of journal bearing operating on 0.01 volume fraction TiO$_2$ nanolubricant in comparison to plain oil. A similar increase in friction force was also obtained. Experimental studies are performed on a newly developed journal bearing test rig and results reveal negligible variation in hydrodynamic pressure with nanolubricants, in comparison to plain oil. However, a 20% reduction in friction force is observed for 0.01 volume fraction TiO$_2$ nanolubricants experimentally; which is in contradiction to theoretical results.

The dynamic characteristics and whirl instability of journal bearings operating on TiO$_2$ based nanolubricants were studied using both, linear perturbation analysis and non-linear transient analysis. Results reveal an increase in stability of journal bearings. Threshold stability maps plotted for journal bearings operating on nanolubricants reveal an increase in stable operating region. The presence of nanoparticle additives is found to increase the stiffness and damping coefficients of journal bearings. Therefore, reduced friction and improved stability are the identified advantages in using nanoparticles as lubricant additives employed in journal bearings.