ME – PhD Thesis Colloquium

Noise Vibration and Harshness (NVH) and Energy Efficiency Analysis of Lubricant Oils in Boundary Lubrication Using Force-controlled Tribometers

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ABSTRACT

Tribology, the science of friction, wear, and lubrication, plays a critical role in determining the performance and longevity of mechanical systems. Lubricants, composed mainly of base oils and additives, are formulated to improve the tribological properties of interacting surfaces. The base oil contributes to bulk properties like viscosity and thermal stability, while additives enhance specific characteristics. During the formulation stage, tribometer testing becomes essential for verifying whether a lubricant meets its intended performance requirements. Conventional tribometers, such as pin-on-disk and four-ball testers, provide valuable insights into wear, friction, and anti-wear properties yet often fall short of replicating real-world applications. This gap arises because these tribometers fail to accurately account for factors like contact stiffness, mass, and damping at the tribological interface, which are known to alter frictional behaviour significantly. The need for more precise testing methods becomes even more apparent in the boundary lubrication regime. Additionally, the influence of tribometer contact stiffness is particularly significant when measuring noise and vibration resulting from friction, as it directly affects the noise and vibration response characteristics.

In the first phase of the research, boundary lubrication properties were evaluated using a novel Lateral Force-Controlled Parallel Pendulum (LaFCoPP) tribometer. This tribometer eliminates contact stiffness-altering sensors, replicating real tribological conditions more accurately. The study examined the lubrication performance of saturated fatty acids with varying carbon chain lengths, revealing that longer chains provided superior lubricity and reduced fretting. Subsequently, a modified version of the LaFCoPP tribometer, converted into a single pendulum pin-on-disc setup, was employed to explore the effects of temperature on the frictional properties of base oils and a blend with stearic acid (SA). The results demonstrated that pure base oil dissipated more energy as temperature increased, while the SA blend reduced friction due to the formation of a tribofilm. The presence of tribofilm and how it evolves with temperature was confirmed through FTIR and XPS analyses. This highlighted the effectiveness of SA as an organic friction modifier in boundary lubrication. These findings highlight the significance of effective tribological testing techniques in accurately assessing lubricant performance under real contact conditions.

Building on these insights, the research expanded to address the challenge of evaluating lubricant oils' Noise, Vibration, and Harshness (NVH) properties. Effective control of NVH is vital for enhancing comfort in applications like electric vehicles and motors, where traditional noise control devices are ineffective. A novel force-controlled pendulum pin-on-disc NVH tribometer was developed to assess NVH and energy efficiency under boundary lubrication conditions. Conventional motor-driven tribometers often introduce noise that interferes with measurements. The pendulum design of this tribometer, with a hemi-anechoic chamber, significantly reduces background noise. The tribometer's design, free from stiffness-altering sensors, further ensures accurate friction, noise, and vibration measurements. Moreover, a PID-controlled heater allows precise control over lubricant temperature, enhancing evaluation quality. Validation experiments using a base oil and a ZDDP mixture with the same base oil confirmed the tribometer's effectiveness. The ZDDP blend exhibited superior NVH performance, with maximum noise levels reduced by up to 15 dB. Subsequent SEM and TEM analyses verified the formation of ZDDP tribofilms, confirming the tribometer's ability to simulate real-contact conditions accurately. The tribometer possesses the capability to assess the evolution of tribofilms during sliding, which has not been previously reported in the literature. The tribometer was then used to test various base oils and additives combinations, including extreme pressure (EP), anti-wear (AW), and friction modifiers (FM). Results indicated clear distinctions in NVH and energy efficiency across different lubricant formulations. Industrial oils supplied by Indian Oil Corporation Ltd. were also tested, and the tribometer's results closely aligned with those obtained from established testing methods, reinforcing its reliability in practical lubricant development. Additionally, improving upon the current design, a second tribometer was also developed with minor modifications to increase its stiffness and broaden its applications.

ABOUT THE SPEAKER

Adarsh D is a PhD student in the Department of Mechanical Engineering at the Indian Institute of Science, Bangalore. He works under the supervision of Prof. Satish Vasu Kailas and is a recipient of the Prime Minister Fellowship for Doctoral Research (PMFDR). His research investigates the impact of lubricants on friction, noise, and vibration in tribological contacts. His PhD work includes designing unique force-controlled tribometers and developing testing methods to evaluate how friction influences Noise, Vibration, and Harshness (NVH) in the boundary lubrication regime. He holds a Master's degree in Ocean Engineering and Naval Architecture from IIT Kharagpur and a Bachelor's degree in Mechanical Engineering from Govt. Engineering College, Kozhikode