ME – PhD Thesis Defense

Development of Force-controlled Tribometers for Evaluation of Tribo-contacts

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ABSTRACT

This thesis focuses on the development of force-controlled tribometers for evaluating tribo-contacts. Tribometry involves the measurement of friction and wear in sliding or rolling contacts, with or without lubrication. Ideally, such measurements should capture only the true behaviour of the tribo-contacts and remain unaffected by external influences. In reality, however, the results are always influenced by the system dynamics, which is why friction is considered a system-dependent property.

Several factors govern tribological measurements, including testing conditions, system dynamics, and data acquisition resolution (DAQ). Among these, system dynamics such as stiffness, inertia, and damping are critical, as they determine how energy is dissipated within the contact. If this dissipation mechanism is not accurately replicated, the measured tribological quantities will deviate from the actual behaviour.

This challenge becomes especially important in the boundary lubrication (BL) regime, where system inertia and stiffness strongly influence tribological responses such as stick–slip motion. In this regime, tribo-contacts operate in a Force-Controlled (FC) mode, where the applied force drives asperity interactions and produces sliding motion. By contrast, in Displacement-Controlled (DC) testing, displacement is imposed, and the resulting force is measured. The DC mode fails to replicate the actual asperity interaction, leading to results deviated from the actual scenario.

An additional key parameter in tribo-contacts is the Slide-to-Roll Ratio (SRR), which defines the relative contribution of sliding and rolling. SRR is important because it controls the extent of asperity shear and tribofilm formation. By adjusting SRR, we can study critical phenomena such as the effect of tribofilm growth during running-in. In real-world systems such as gears, bearings, and cam–follower mechanisms, SRR directly influences frictional efficiency, wear rates, and component durability. Therefore, integrating SRR into the tribological testing rig is essential for achieving representative results.

Beyond force and SRR, the assessment of noise and vibration (NVH) provides deeper insights into tribological behaviour. Stick–slip instabilities, asperity interactions, and surface adaptations during running-in often manifest as distinct vibration signatures and acoustic emissions. To capture these effects, this research introduces a Force-Controlled Pendulum Tribometer (FCPeT) that allows simultaneous measurement of friction, noise, and vibration under controlled SRR and temperature conditions. This combination provides a more comprehensive and system-representative evaluation of tribological behaviour than conventional displacement-controlled methods.

The second part of this thesis extends the study of tribo-contacts using a lateral force-controlled impact tribometer. This custom-designed setup investigates how varying normal loads influence frictional behaviour during rapid sliding. Such conditions are particularly relevant to automotive crash scenarios, where the friction between the human body and vehicle interior surfaces can shift abruptly—from high to low—within a fraction of a second (typically ~150 ms). These sudden transitions significantly affect energy dissipation at the body–interior interface and can contribute to injury severity. By replicating these dynamic conditions, the developed tribometer provides valuable data for safety analysis and material design in vehicle crashworthiness studies.

ABOUT THE SPEAKER

Vikas Kumar Singh is a PhD student under the supervision of Prof. Satish V. Kailas. His research focuses on the development and validation of tribometers. He holds an M. Tech in Mechanical Engineering from IIT (ISM) Dhanbad and a B. Tech in Mechanical Engineering from Dr. Sudhir Chandra Sur Degree Engineering College, Kolkata.