ME – PhD Thesis Colloquium

Energy Dissipation in Asperity-Scale Contact: Body-Force Modelling of Adhesion and a Phenomenological Model for Plastic Deformation

Mr. Uzair Iqbal, PhD Student, Department of Mechanical Engineering, IISc Bengaluru

August 25, 2026 at 04:00 PM

Venue: ME Conference Room, ME@IISc (Join Online)

ABSTRACT

Contact between solid bodies spans a large range of length scales. When two nominally flat surfaces touch, true contact happens only at a discrete population of asperities. How these elastic contacts deform, dissipate energy, and give rise to macroscopic friction remains incompletely understood, especially when adhesion becomes important. At small scales, adhesion is often treated as a surface force, which becomes less accurate as compliance and deformation increase. This thesis addresses this gap with a self-consistent body-force (SCBF) formulation that preserves the volumetric nature of adhesion and applies to both normal and sliding contact. A phenomenological model is also developed for plastic dissipation during indentation and low-velocity impact.

We first apply the SCBF formulation to normal adhesive contact between an elastic hemispherical asperity and a rigid half-space. Material compliance and asperity size are found to affect the onset of instability and the pull-off force in different ways. A "sandwiching" effect is observed, in which peak stresses approach the material's theoretical cohesive strength, showing that adhesion alone can trigger fracture or plastic yielding. Comparing SCBF with a surface-force (SCSF) formulation shows close agreement for weak adhesion but increasing divergence as adhesion strengthens.

The SCBF formulation is then extended to sliding contact between a deformable asperity and one or more rigid asperities, without plasticity or an imposed friction law. Below a critical adhesion strength, sliding stays smooth. Above it, jump-in and jump-out instabilities appear, leaving the asperity vibrating and storing energy not recovered as useful motion. This depends on elastic modulus, asperity radius, and offset height in distinct ways. The resulting hysteresis defines an effective friction force, drawing a direct link to the atomic-scale stick-slip picture of the Prandtl-Tomlinson model.

Turning to a distinct dissipation channel, the thesis develops a model for the impact of a rigid sphere on an elastoplastic substrate. Elastic and plastic contributions are represented using a Maxwell combination of stiffness elements, yielding closed-form expressions for the residual contact radius and the coefficient of restitution. The elastoplastic impact is unified by a single indentation parameter that collapses the impact response across materials, sizes, and velocities onto a single master curve.

Together, these models give a physically grounded account of two distinct dissipation mechanisms at an asperity-scale contact, and provide a basis for connecting single-asperity mechanics to the macroscopic friction and dissipation of a rough interface.

ABOUT THE SPEAKER

Uzair Iqbal is a PhD student in the Department of Mechanical Engineering at the Indian Institute of Science (IISc), working with Prof. M. S. Bobji. He obtained his B.Tech in Mechanical Engineering from the National Institute of Technology Tiruchirappalli (NITT) in 2019. His research interests include nanotribology, adhesive contact & impact mechanics, and finite element methods. Beyond research, he enjoys playing football.