Using Bouc-Wen model to capture asperity level friction within a meso-scale FEM contact model– WTC 2022, Lyon

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The use of heuristic friction models to capture “rough” contact, or asperity scale contact is developed using the Bouc-Wen model within an elasto-plastic friction framework. This method also allows for the computation of energy dissipation, which can be compared with tribology experiments. Energy dissipated is a metric, along with friction force, wear volume, used to benchmark levels of wear and surface fatigue in tribology experiments. The presented method allows for comparison between computation and experimental outputs.

Keywords: tribology, Bouc-Wen, elasto-plastic friction, energy dissipation

1. Introduction

One of the challenges in tribology is not having a consistent set of computational or numerical set of tools to simulate real tribology experiments. FEM simulations using Coulomb’s law are typically used to simulate tribology experiments, however, this formulation does not adequately capture the dissipative characteristics of real experiments. Computational tribology uses contact mechanics, computational mechanics and constitutive friction models to simulate different types of friction experiments. In the present work, the use of a heuristic friction model, Bouc-Wen[1] is used to simulate fretting fatigue by using the elasto-plastic friction(EPF) method[2]. This framework also captures the energy dissipated for each fretting cycle, allowing for a consistent benchmark to compare with fretting experiments [3].

2. Methods

An elastic half-space is considered with a rigid indenter applied to the surface with reciprocating tangential motion. The plane-strain elasticity problem with contact and friction is iteratively solved using the penalty method within a Newton-Raphson algorithm. The EPF method utilizes the same principles in plasticity by specifying a yield surface that is governed by a bounding function f_s, that defines the elastic or “stuck” regime and the plastic or “slip” regime. Additionally, a flow rule and an evolution equation must be defined. The resulting constraint equations are governed by the Kuhn-Tucker conditions.

2.1. Equations: The elasto-plastic friction slip criterion derived from Coulomb’s friction law (1). Energy dissipated via tangential slip (2).

$$f_s(\boldsymbol{t}_T) = \|\boldsymbol{t}_T\| - \mu \boldsymbol{t}_N \leq 0 \quad (1)$$
$$D^s = \boldsymbol{t}_T \cdot \dot{\boldsymbol{g}}_t^s \leq 0 \quad (2)$$

2.2. Boundary conditions
For the elastic domain, all edges are free except the bottom boundary, which is fixed in the x and y directions.

2.3. Numerical Scheme
The Newton-Raphson algorithm is used to iteratively solve the contact problem.

2.4. Results
The energy dissipated by three different friction models is computed using this method.

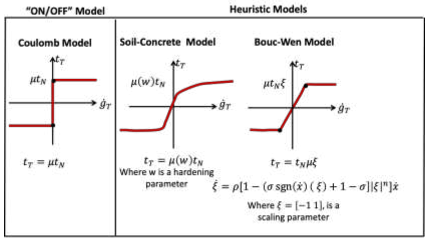

Figure 1: Three different friction models studied

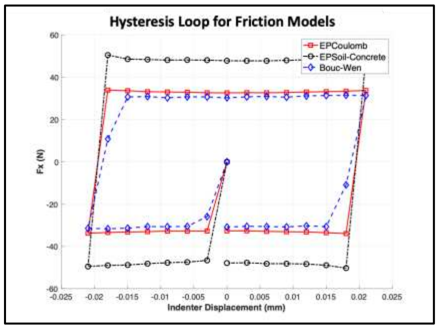

Figure 2: Hysteresis Loops generated from study

3. Discussion

The use of a “rough” friction model that allows asperity scale response to be captured within the contact patch presents a new development in tribology modeling. The Bouc-Wen and other heuristic models that model rough contact can be well utilized in matching tribology experiments, potentially eliminating the need for long-term, expensive tribology experiments.

4. References

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