Stochastic multiscale modeling of stiction failure in MEMS

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Introduction
- Stiction is a common failure in MEMS, in which two micro surfaces permanently adhere together, e.g. the stiction failure of micro cantilever beams.
- The problem is due to the adhesive forces, e.g. the capillary forces.
- The adhesive contact force, and structural behaviors suffer from scatters, due to the roughness of the contacting surfaces.

Method
- Direct Monte Carlo simulation (MCS) multiscale method.
  - Characterize the contact rough surfaces using power spectrum density (PSD) and height distribution.
  - Generate $N_{SC}$ surfaces with size of contact zone.
  - For each generated surface, at each integral point evaluate the corresponding meso-scale apparent contact force. ($v$)
  - Obtain the failure configuration for each generated surface.
  - Requires high computational cost due to step ($v$).

- Proposed method: Stochastic model-based multiscale method
  - Construct a stochastic model of apparent contact force.
  - Each integral point is associated with a generated sample of the random apparent contact forces using the constructed stochastic model.
  - Reduce computational cost.

  - The direct MCS multi-scale method (high computational cost)
    - Generate $N_{SC}$ surfaces of structural scale size
    - Explicitly evaluate $N_{SC} \times N_{TP}$ contact forces ($N_{TP}$ number of integral points)
    - Evaluate $N_{SC}$ structural behaviors (FEM)
    - Identify structural probabilistic behaviors ($v$)

  - The stochastic model-based multi-scale method (reduced computational cost)
    - Generate $m$ surfaces of meso-scale size
    - Explicitly evaluate $m \times N_{TP}$ contact forces
    - Generate $N_{SC} \times N_{TP}$ contact forces
    - Evaluate $N_{SC}$ structural behaviors (FEM)
    - Identify structural probabilistic behaviors - approximations of ($v$)
    - Construct a Stochastic model of random contact forces

Results
- Comparison between direct MCS and stochastic model-based methods
  - The stochastic model-based method can predict the nominate properties of the crack length distribution.

- Comparison between numerical prediction and experimental data [3]
  - The stochastic model-based method can predict the experimental results with high accuracy.

Conclusions
- A novel stochastic multiscale method to predict the probabilistic behaviors of micro structures involving adhesive contacts is developed.
- The model is computationally effective.
- The model is validated by a comparison with experimental data.

References

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