Improved Model of Near-Contact Damping

Motivation & Background

Improved gas damping modeling is needed for prediction of dynamics of microsystems with large-amplitude displacements. In particular, the near-contact damping is expected to have a significant effect on the impact velocity between contacting surfaces. The majority of existing squeeze-film damping models have been derived for conditions dissimilar to those at contact. For example, in the proximity of contact the gap between the moving surfaces is extremely small compared to the beam thickness.

Objectives

- Formulate improved near-contact aerodynamic damping model applicable for conditions encountered in contacting MEMS.
- Enable coupled fluid-structure interaction simulations for contacting MEMS cantilevers.
- Validate modeling by comparison with experimental measurements of MEMS accelerometer response.

Theory and Modeling Approach

Boltzmann-ESBGK Equation:

\[
\begin{align*}
\frac{\partial f(x,y,u,v)}{\partial x} + v & \frac{\partial f(x,y,u,v)}{\partial y} = \frac{f_0(x,y,u,v,n,T,u_s,u)}{\tau} - f(x,y,u,v) \\
\end{align*}
\]

where \( f_0 \) - equilibrium distribution function, \( u \) - velocities in the (x,y) directions, \( v=1/t \) - collision frequency, \( f \) - velocity distribution function, and \( \tau \) - collision frequency.

Damping coefficient:

\[
C_f = \frac{D}{V_{num}} = \frac{1}{A \, g^a + B \, g^b}
\]

where \( A = 0.7333 \), \( B = 0.0337 \).

Simulations and Validation

- A new model of microscale aerodynamic damping for near-contact regime has been formulated based on Boltzmann-ESBGK simulations of rarefied gas flow around moving microbeams.
- The coupled fluid-structure dynamics simulations with the new model predict accurately the contact closing time for MEMS accelerometer under high-G external acceleration and reproduce the experimentally observed repeated contact events.
- The observed difference between the measured and predicted opening times for the MEMS accelerometer is attributed to adhesion after contact.

Conclusions

- A new model of microscale aerodynamic damping for near-contact regime has been formulated based on Boltzmann-ESBGK simulations of rarefied gas flow around moving microbeams.
- The coupled fluid-structure dynamics simulations with the new model predict accurately the contact closing time for MEMS accelerometer under high-G external acceleration and reproduce the experimentally observed repeated contact events.
- The observed difference between the measured and predicted opening times for the MEMS accelerometer is attributed to adhesion after contact.

References