Micro-Lorentz-Force-Driven Linear Motor Simulation with Air Effect Using an OverSet Finite Element Method

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In Micro-Electronic-Machinery design, as the device shrinks in size, the surrounding ambient air environment becomes increasing more important due to the pronounced air viscosity and momentum effect. Traditionally, the air effect is considered using the fluid-solid-interaction algorithm, either through a direct-coupled method or other indirect-coupled techniques. Usually, an Arbitrary Lagrangian-Eulerian method[1] is applied since the finite element meshes could be subjected to large translational or rotational motions. In most cases when the translational motion is extremely large, a remesh or a spatial remap of the discrete variables could be necessary. These methods require complex mesh smoothing or time-space transformation of the variables, and in many cases, they can not handle general situations.

To overcome these problems, an OverSet method[2] has been proposed and implemented in AMPS finite element analysis software. The method allows solid finite elements to move through the background fluid flow finite element region. The OverSet method kinematically constrains the dynamic momentum equations on the fluid-solid interface to the incompressible Navier-Stokes airflow equations. Other multi-physics fields such as the thermal, electrical, or magnetic field variables can also be solved simultaneously using the same constraint.

The transient dynamic behavior of a micro-Lorentz-force-driven linear motor is analyzed using the OverSet method. The transient dielectric electro-potential distribution along with the coupled continuum stress field is solved using the OverSet method. The motion of the analysis is compared with the experimental data, and consistent results are presented with discussions. Several numerical sensitivity studies are also performed and discussed. Possible design applications are also presented to demonstrate the general applicability of the method with further refinement.

References

[1] Hsien-Jan Chang, H. Theodore Lin, "A Mixed Lagrangian Eulerian Finite Element Method with ALE Formulation for Large Deformation Fluid-Structure Interaction Simulation," WCCM VI in conjunction with APCOM'04, Beijing, China, September 2004.

[2] H. Theodore Lin, "An OverSet Method for Fluid-Solid Interaction Analysis Based on Least-Squares Fluid Formulations," USNCCM VIII, Austin, Texas, July, 2005.