A finite element approach for a coupled numerical simulation of fluid-structure-electric interaction in MEMS

Prakasha Chigahalli Ramegowda*, **Daisuke Ishihara***, **Tomoya Niho*** and **Tomoyoshi Horie***

* Department of Mechanical Information Science and Technology
Kyushu Institute of Technology
680-4 Kawazu, Iizuka, Fukuoka, Japan
e-mail: * prakasha@solid.mse.kyutech.ac.jp

ABSTRACT

Micro Electro Mechanical System (MEMS) based piezoelectric actuators can be used to actuate the thin and flexible wings of micro air vehicles (MAVs). The actuator produces large deformation at its resonance which is located at the root of the wing, so that the flexible wing can flap and produce enough lift force to support the MAV weight during flight. In the mean time, MAV is surrounded by air and has a significant influence from it on the vibration characteristics of the flapping motion of the wing and hence its response. Therefore, the analysis of fluid-structure-electric interaction must be carefully taken into account during the MAV design process. The analytical solution to the model equations are limited in the scope. From this view point, a novel finite element method for fluid-structure-electric interaction is imperative.

In this paper, at first we study the piezoelectric interaction, which is fundamentally an interaction between electrical and structural fields. Partitioned iterative coupling algorithm is used to study the structure-electric interaction using 3D solid elements and obtain an induced electric forces due to the inverse piezoelectric effect causing the piezoelectric bimorph actuator to bend [1]. Secondly, a novel translation method is implemented to translate the induced nodal electrical forces from 3D solid elements to the equivalent nodal forces and moments acting on MITC4 shell elements for the purpose to take into account the thin structure of the MEMS based piezoelectric actuators. And finally, a projection method for FSI [2] is employed in order to solve the interaction between MITC4 shell structure and fluid field interaction, where the hierarchical decomposition approach [3] is used to couple the structure-electric and fluid-structure interaction analyses. Here structure-fluid interaction is split into the structure-fluid velocity field and pressure field using a kind of algebraic splitting, which avoids larger DOF's of equations in comparison with monolithic coupling.

It follows from the comparison between the numerical and analytical results that our translation method accurately translates the induced nodal electric forces from 3D solids to MITC4 shell elements. The proposed method is applied to a bimorph actuator located at the root of wing plate of a micro air vehicle.

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