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Fluid Flow and Heat Transfer Analysis of a Piezoelectrically Actuated Beam within a Cavity with a Flexible Wall

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ABSTRACT

A fundamental problem in the realm of fluid-structure interaction (FIS) is the analysis of flexible membranes experiencing vibration due to the fluid motion. The presence of such membranes is prevalent in quite a bit of industrial applications such as dividing two different fluids. Another FSI problem which has got much more attention in recent years is simulating Piezoelectrically actuated beams immersed in air for heat removal purposes. Combination of these two FSI problems will lead to a novel configuration which provides insight about fluid flow as well as heat transfer in such problems. This work aims at simulating the induced fluid flow and heat transfer of a piezoelectrically actuated beam immersed in air within a square cavity with a flexible wall in order to determine Nusselt number on the cavity wall heated with a constant temperature. Therefore, a two-dimensional laminar model is deployed to mimic the beam motion with relatively small vibration amplitudes as well as the flexible wall deformations. Moreover, it is assumed that one end of the fan is fixed and the other end of it oscillates sinusoidally. The commercially available finite element software, COMSOL Multiphysics, has been used to discrete the conservation of mass, momentum, and energy equations in Arbitrary Lagrangian-Eulerian formulation. Two sets of studies have been considered for this study: a lid-driven square cavity with a flexible bottom boundary and a piezoelectric fan vibrating at its resonance frequency. It has been found that there is an agreement between this work and existing numerical and experimental data. For the Piezofan validation, the average error for the current model in comparison with experimental data is less than 7.6 percent, which could be considered as an acceptable error level regarding the simplifications. Results show that two counter rotating vortexes will be formed due to the pressure gradient in the blade tip. Moreover, despite the confinement effect of surrounding walls, the generation and propagation of the vortexes are evident. Also, it has been shown that the increase in vibration amplitude enhances the heat transfer within the square cavity. Hence, adding the flexible boundary wall enhanced heat transfer within the vibration envelope further and it was found that the enhancement is small if the gap between the fan tip and the wall is large.