ANALYSIS OF SYNTHETIC MICRO-JETS USING CBS FINITE ELEMENT METHOD ON MOVING DEFORMING GRIDS

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INTRODUCTION

Synthetic Micro-jets

During the past few years, the development in micromachining technology has increased the interest in microelectromechanical systems (MEMS). MEMS are small devices which have characteristic size range from submilimeter to submicrometer and may include sensors, actuators, motors, pumps, turbines, gears, ducts and valves. One of the MEMS technology products is synthetic jet and it is used for various applications including cooling of electronic packages, micro mixing and aerodynamic flow control. A synthetic jet is a zero net mass flow fluidic device and flow is generated at the orifice of a cavity by oscillating membrane opposite to the orifice as seen in Figure 1. Oscillatory motion of the membrane produces the fluctuating jet flow, it interacts with the main flow and transfers linear momentum to the main flow.

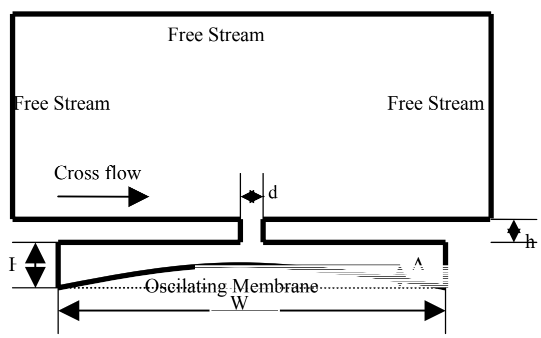

Figure 1.Synthetic jet Configuration

In Figure 1, a sample geometry and flow field is defined. In the figure, d and h are the slot width and height respectively. H and W are the cavity height and length respectively. Maximum oscillation amplitude of the membrane is denoted by A. A sample grid for the computations is shown in Figure 2.

The geometry and of the cavity and oscillation frequency of the membrane are important parameters in determining the efficiency of the jet producing desired flow deflections. The effect of these parameters are investigated in various numerical and experimental studies[1-4].

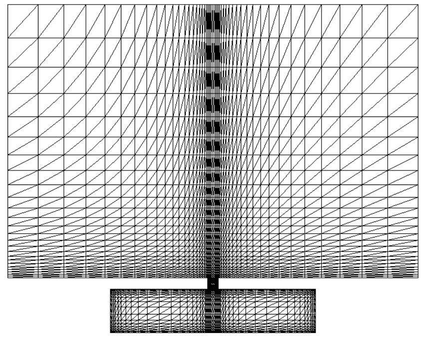

Figure 2.Numerical grid for the synthetic jet configuration

Slip regime

In micro devices, the flow regimes can be characterized by the Knudsen number (Kn, the ratio of gas mean free path λ to a characteristic microfluidic length L) [5]. A full continuum or a full free-molecular analysis may be applicable depending on the Kn range. Typically, the continuum regime is in the range of Kn≤0.001. For the slip regime 0.001≤Kn≤0.1 and the Knudsen number of the transition regime is between 0.1 and 10^2. In the slip regime, the conventional Navier-Stokes solvers can be used for analysis if standard boundary conditions are modified.

Moving-deforming mesh

In the present study, flows in continuum regime are considered and they are modeled using Characteristic-Based-Split (CBS) algorithm as a Navier-Stokes solver[6-8]. To investigate numerically the diaphragm driven flow in and out of the synthetic jet cavity geometries, CBS algorithm can be coupled with space-time-finite element/moving-deforming-grid concept using ALE description[9-10]. It is required for modeling the movement of the piezoelectric-driven diaphragm of the cavity in realistic manner and computing the flow inside the jet cavity accurately[1]. Coordinates of the nodes on the oscillating membrane are changed in time and known at every time step. But the coordinates of the nodes inside the cavity have to be determined by using nodes on the membrane and fixed nodes on the solid walls. It can be done by using a simple interpolation formula[9-10].

Solver Implementation

Standard CBS algorithm, which can be applied to both compressible and incompressible flow problems, is used to analyze the micro synthetic jet by modifying the boundary conditions to account for the slip velocity and the temperature jump condition encountered in MEMS geometries for the Kn number up to 10^{-1}. Details of the Finite-Element formulation and the solution strategies of the CBS algorithm can be found in[6-8]. Pseudo-quadratic velocity/linear pressure elements (pP2P1) are employed in order to reduce the size of the implicit part of the CBS algorithm[6, 11]. pP2P1 elements are constructed by dividing the pressure element, over which the pressure is interpolated linearly or bi-linearly, into sub-elements, over which the velocity also is interpolated linearly or bi-linearly. Combination of these first order velocity interpolations can be considered as pseudo second order velocity interpolation over the original pressure element. Overall, the solution can also be considered to be obtained on two different grids, one for the velocity solution and the other for the pressure solution. pP2P1 element is obtained by inserting mid nodes to the parent pressure element and interconnecting these to give 4 sub-elements over which the velocity is interpolated linearly[11].

CONCLUSION

Flow field generated by a synthetic micro-jet is analysed by implementing a CBS algorithm on a moving deforming grid with boundary conditions modified to accommodate for the slip and temperature jump observed in micro geometries. The results presented will include the flow field inside and outside of the cavity and effects of various parameters.

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