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DYNAMICS OF LIQUID MEMBRANES. I: NON-ADAPTIVE FINITE DIFFERENCE METHODS

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SUMMARY

A non-adaptive method and a Lagrangian–Eulerian finite difference technique are used to analyse the dynamic response of liquid membranes to imposed pressure variations. The non-adaptive method employs a fixed grid and upwind differences for the convection terms, whereas the Lagrangian–Eulerian technique uses operator splitting and decomposes the mixed convection–diffusion system of equations into a sequence of convection and diffusion operators. The convection operator is solved exactly by means of the method of characteristics, and its results are interpolated onto the fixed (Eulerian) grid used to solve the diffusion operator. It is shown that although the method of characteristics eliminates the numerical diffusion associated with upwinding the convection terms in a fixed Eulerian grid, the Lagrangian–Eulerian method may yield overshoots and undershoots near steep flow gradients or when rapid pressure gradients are imposed, owing to the interpolation of the results of the convection operator onto the fixed grid used to solve the diffusion operator. This interpolation should be monotonic and positivity-preserving and should satisfy conservation of mass and linear momentum. It is also shown that both the non-adaptive and Lagrangian–Eulerian finite difference methods produce almost identical (within 1%) results when liquid membranes are subjected to positive and negative step and ramp changes in the pressure coefficient. However, because of their non-adaptive character, these techniques require an estimate of the (unknown) length of the membrane and do not use all the grid points in the calculations. The liquid membrane dynamic response is also analysed as a function of the Froude number, convergence parameter and nozzle exit angle for positive and negative step and ramp changes in the pressure coefficient.

KEY WORDS Liquid membranes Lagrangian–Eulerian finite difference methods

INTRODUCTION

Vertical annular liquid jets or liquid curtains have applications as protection systems for inertial confinement laser fusion (ICF) reactors and as chemical reactors.[1] Cylindrical chemical reactors can be used for stack emission scrubbing for pollution control, reaction and control of toxic wastes and scrubbing of radioactive and non-radioactive particulates and soluble materials.[1]

Ramos[2] derived the equations governing the dynamics of axisymmetric liquid curtains and axisymmetric liquid membranes from Cauchy's equations and obtained analytical solutions for

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