UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

FREE-LAGRANGE SIMULATIONS OF SHOCK-BUBBLE INTERACTION IN EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY

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Evidence have shown that significant amounts of violent cavitation activity are present during Extracorporeal Shock Wave Lithotripsy (ESWL). This cavitation has been postulated to play a significant role in kidney stone disintegration during treatment. In this study, a swirl-free Free-Lagrange hydrocode is used to simulate the axisymmetric jetting collapse of initially stable air bubbles in water as a result of interaction with a planar lithotripter shock wave. Various cases were carried out in order to investigate the effect of bubble size, the presence of a rigid boundary at various stand-off distances as well as cases involving arrays of bubbles.

The Free-Lagrange method is highly suitable for the simulation of highly deforming flows. The technique also retains sharply resolved gas/liquid interfaces regardless of the degree of geometric deformation, and reveals details of the dynamics of bubble collapse. This also helps in reducing the degree of numerical diffusion. The numerical code employs second order space and first order time accurate Godunov-type solvers. For validation purposes two different cases were carried out - simulations of the axisymmetric collapse of a bubble by a planar step shock wave of various strengths and two dimensional planar shock/water column interactions.

In addition to the above, two separate numerical acoustic codes have been developed using the Kirchhoff's method and the Ffowcs William-Hawkings formulation. When coupled to the Free-Lagrange code, each can be used to obtain the far-field pressure signatures of cavitation events. Both numerical codes have been validated against analytical results in predicting the far-field pressure signature emitted from an oscillating solid sphere. The relative merits of each method are given along with a few analyses of the far-field pressure signature predicted from the lithotripter shock wave/bubble interaction problems.

The code has been used to simulate the collapse of single cavitation bubbles in free-field and near a planar rigid boundary for various stand-off distance. Simulation of an array of bubbles are also presented. The results clearly capture the phenomena of bubble collapse that are believed to assist kidney stone fragmentation during lithotripsy treatment, i.e. high speed liquid jet impact and blast wave emission. The far-field pressure signature shows the expansion wave originating from the shock-bubble interaction and the high amplitude blast wave.