THE INTERACTION OF A CAVITATION BUBBLE WITH A RIGID BOUNDARY

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Abstract. This paper presents the results of incompressible flow computations for the collapse of cavitation bubbles close to a rigid boundary, for stand-off distances in the range 0.8–1.4Rm, where Rm is the maximum bubble radius. After jet impact on the far side of the bubble, the bubble assumes a toroidal shape with a high velocity outflow along the rigid boundary. This outflow is met by an inflow from the collapsing bubble thence throwing up a vigorous splash into, or around, the bubble. This splash, when coupled with the larger internal gas pressures, may generate higher pressures on the boundary than the original jet impact, although, instead of being on the axis of symmetry, the peak pressures occur on a ring around the axis.

1. Introduction

Data available on the growth and collapse of cavitation bubbles (typically mm sized bubbles) near a rigid boundary is used for comparison and validation of our boundary integral codes [1–6, 8]. The significant feature of this study is that jet impact does not yield the highest pressures on the boundary, but rather a phenomenon we call the 'splash' when the outward flow along the rigid boundary, after jet impact, meets the inrushing liquid due to the bubble compression. The peak pressures associated with the splash occur near minimum volume and thence high internal gas pressures, thus...
leading to a stagnation pressure on a ring on the boundary which can be an order of magnitude higher than the pressure attributed to jet impact.

There are a number of limitations to our computational study, the most serious being the restriction to incompressible flow, thus limiting our analysis to stand-off parameters between about 0.8 and 1.4$R_m$ (the precise values depending on experimental conditions). Outside this range shock pressures would be more important than those developed using incompressible theory.

This paper represents a summary of our current thinking on the modelling of cavitation bubbles near boundaries using integral equation methods, bearing in mind the restrictions mentioned above. We proceed by introducing the dimensionless physical parameters in the next section, followed by a discussion based on a selection of figures that show the principal phenomena.

2. Dimensionless parameters

In this study we suppose the flow is dominated entirely by inertial effects, thus neglecting any role for viscosity. Likewise, surface tension effects do not play an important part in such a violent process, with the possible exception of providing an instability mechanism for spray and droplet formation. Even in the sonoluminescence studies of cavitation bubbles, surface tension only plays a minor role.

We specify two dimensionless parameters as follows. The stand-off,

$$\gamma = \frac{h}{R_m},$$

where $h$ is the distance of bubble initiation from the boundary and $R_m$ is the maximum bubble radius. The second parameter is the strength parameter

$$\alpha = \frac{p_0}{\Delta p},$$

which essentially determines the contribution to the internal bubble pressure due to noncondensable gaseous contents (where $\Delta p$, which scales the initial pressure, is the difference between the hydrostatic pressure at the location of bubble inception and the vapour pressure). The ‘gas’ inside is specified by an adiabatic polytropic exponent $\kappa$.

The computations follow a number of Lagrangian marker particles on the surface of the bubble in either the axisymmetric or fully 3D codes. For the axisymmetric code we use 31–64 particles on the surface and for the 3D code, 362. The particles give us a clear picture of the bubble shape and, furthermore, allow the calculation of the pressure field anywhere in the fluid or on the rigid boundary.