THE UNIVERSITY OF MICHIGAN

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Department of Mechanical Engineering

Cavitation and Multiphase Flow Laboratory

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PROGRESS REPORT ON

ASYMMETRIC BUBBLE COLLAPSE STUDIES

by
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BRIEF OUTLINE OF RESEARCH FINDINGS

This project involves experimental and theoretical studies of the collapse of cavitation or sub-cooled boiling bubbles under the influence of various asymmetries such as the presence of an initial asymmetry, a pressure gradient, the proximity of a wall, etc. The work described in references 1 through 6, partially supported by NSF Grant No. GK 730, has been continued and extended. Initial work using a 26,000 frames/second camera demonstrated various important features of the overall collapse phenomenon, thus serving to guide future work.

However, to obtain a better visualization of the highly complex phenomena involved, cameras with higher framing rates and good magnification capabilities were required. Thus a spark camera was designed and assembled with a framing rate of about 10^6/s, but with capability of only 12 photos per run. Highly successful utilization of this camera was attained as reported in references 4 and 5, to obtain informative pictures of both collapsing bubbles and high-speed liquid jets (which are typical of one form of bubble collapse).

For still better photographic resolution of the phenomenon, a Beckman-Whitley high-speed camera was obtained under funding provided by a separate NSF grant and this university. This camera has the capability of 2×10^6 frames/second with 80 frames/run. It has allowed very informative studies of bubble collapse.

Since work elsewhere on asymmetric bubble collapse has concentrated on essentially static systems, we have emphasized flowing systems, which are of course closer to the usual engineering reality, to complement and supplement the earlier work in flowing systems. Hence we have utilized a cavitating two-dimensional venturi system and obtained much useful information from high-speed pictures of the natural cavitation bubbles in this system. However, it was not possible to obtain single bubbles for the more basic study of bubble behavior with this system. Consequently, a spark system capable of producing individual bubbles just upstream of the venturi diffuser entrance has been used. Also, a knife-edge section has been inserted into the diffuser, along the mid-plane and parallel to the flow direction, providing a wall along which the bubbles can be induced to collapse by suitable adjustment of the spark position and energy. Thus the bubble collapse is influenced by a pressure gradient and wall effect. Extremely interesting bubble pictures have been obtained with this set-up, and it has been found possible to obtain an individual crater in soft aluminum resulting from a single bubble collapse, a result which previous experience with flowing cavitation systems allowed little reason to hope. It is believed that this is a very important "first" in the field, which may lead to practical approaches for the design of machines to avoid cavitation damage. No reports have yet been written incorporating these reports, though much effort has been expended in the present report period obtaining and reducing comprehensive data of this type. All this will be reported in a Ph. D. thesis hopefully to be completed within the next report period.[7] If heating wire is substituted for the spark, it may also be possible to study the behavior of sub-cooled boiling bubbles in the same system.

At the same time, a system has been developed for measuring the size-number spectrum of micron-size particles (gaseous and solid) in the cavitation tunnel.[8, 9] With this arrangement it appears possible to roughly distinguish solid from gaseous particles, so that basic information will be obtained on the nature of the "nuclei" from which bubbles (either cavitation or boiling) grow. This information should be of extreme importance to the entire two-phase flow field of research. These results are part of a Ph. D. thesis partly supported under this contract.

The major theoretical effort in this investigation has been the development of computer codes for the numerical solution of the asymmetrical collapse problem, going beyond the range of validity of numerous small perturbation approaches which have been made previously. The Marker and Cell (MAC) technique has been modified for this purpose.[6] After an initial successful use of the modified program for a spherical Rayleigh-type collapse,[3,6] various asymmetrical collapse cases have been investigated, and a number of important results, showing the formation of a jet during collapse, have been obtained. No results on our asymmetrical calculations have yet been reported, although these are part of a third Ph. D. thesis supported under this contract.

A further investigation of spherically-symmetrical collapses has also been made, investigating the effect of thermal film resistence to condensation of vapor during collapse and of large non-condenseable gas contents within bubbles. A program was written and initial results obtained and reported.[12] The work is continuing to investigate the effect of a broad range of parameters in the spherically-symmetrical case. If important effects are found, it should be possible later to incorporate the capability for the study of these effects into the asymmetrical programs.

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