THE UNIVERSITY OF MICHIGAN

College of Engineering

Department of Mechanical Engineering

Cavitation and Multiphase Flow Laboratory

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ASYMMETRIC CAVITATION BUBBLE COLLAPSE NEAR SOLID OBJECTS

by

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For many years following the original analysis of Rayleigh[1] it was tacitly assumed that the mechanical aspects of cavitation damage resulted from the essentially spherical collapse of vapor bubbles, and the subsequent impingement upon adjacent surfaces of shock waves transmitted through the liquid upon neighboring surfaces from the site of such collapses. However, principally within the last decade, experimental and theoretical evidence has accumulated to show that mechanical damage can result only from bubble collapse very near the damage surface, and that under such circumstances the asymmetries caused by the presence of such a surface prevent a substantially spherical collapse, and in fact alter the collapse phenomenon very drastically. More specifically, the actual collapse results in the formation of high-velocity liquid "microjets" which tend to be oriented toward the surface, and which may contribute importantly to the damage. This general idea was first proposed by Kornfeld and Suvorov[2] in 1944, but much more detailed observations on actual bubble collapse near rigid surfaces has been obtained by many investigators within the past decade[3, 4, 5, 6, 7, e.g.] which has strongly supported their hypothesis. Most of these investigations have been concerned with the bubbles in static systems[3, 4, 5, 6, e.g.] whereas our own laboratory[7, e.g.] has concentrated upon observations in a flowing system, such as cavitating venturis, which more closely approximate engineering applications.

Over the same period analytical studies have confirmed the photographic observations, one of the earliest being that by Rattray[8], the validity of which was limited to small perturbations of the spherical shape. However, recent comprehensive numerical studies[9, 10], one of which[10] has recently been completed in our own laboratory, have confirmed the formation of microjets, with velocities adequate to cause damage, during the collapse of bubbles close to rigid surfaces. The propinquity of a rigid surface tends to orient the jet toward the surface[9, 10, e.g.], while recent work by Gibson[11] has shown that a highly-flexible (or free) surface will orient the jet away from the surface. Our own analysis[10] has shown that similar jet formation will occur for bubbles collapsing in a pressure gradient and for two bubbles collapsing in an infinite fluid within close range of each other.

A recent photographic study of spark-generated bubbles collapsing in a venturi adjacent to a flat plate in this laboratory[12, 13] showed microjet formation which then impinged upon the adjacent flat plate. With suitable adjustment of the controlling parameters, the jet velocity was sufficient to create an identifiable single crater from a single bubble collapse upon soft aluminum. Several bubble collapses were required to form a visible crater in a harder aluminum alloy. This situation can be compared to the effects of natural cavitation where only very large numbers of bubbles ($\gtrsim 10^4$) observed to collapse in the vicinity of the plate are required to form a single crater[14, e.g.]. It is thus apparent that damaging cavitation bubble collapse in nature is a highly selective mechanism requiring precisely the "right" combination of parameters. However, it occurs with sufficient frequency to be a major engineering problem because the number of bubbles in a typical flow situation is so very large.

A short* motion picture of numerous spark-generated bubble collapses in our test venturi[15] will be shown with the presentation. These sequences were taken with a framing camera capable of 2 million frames/second, and show the collapse sequence in considerable detail. Fig. 1 is a typical sequence.

A second very short** motion picture[16] will also be shown which has been constructed from the computer results of our bubble collapse analyses[10]. These sequences closely confirm the actual bubble collapse sequences of the first motion picture.

* ~10 minutes

* ~4 minutes

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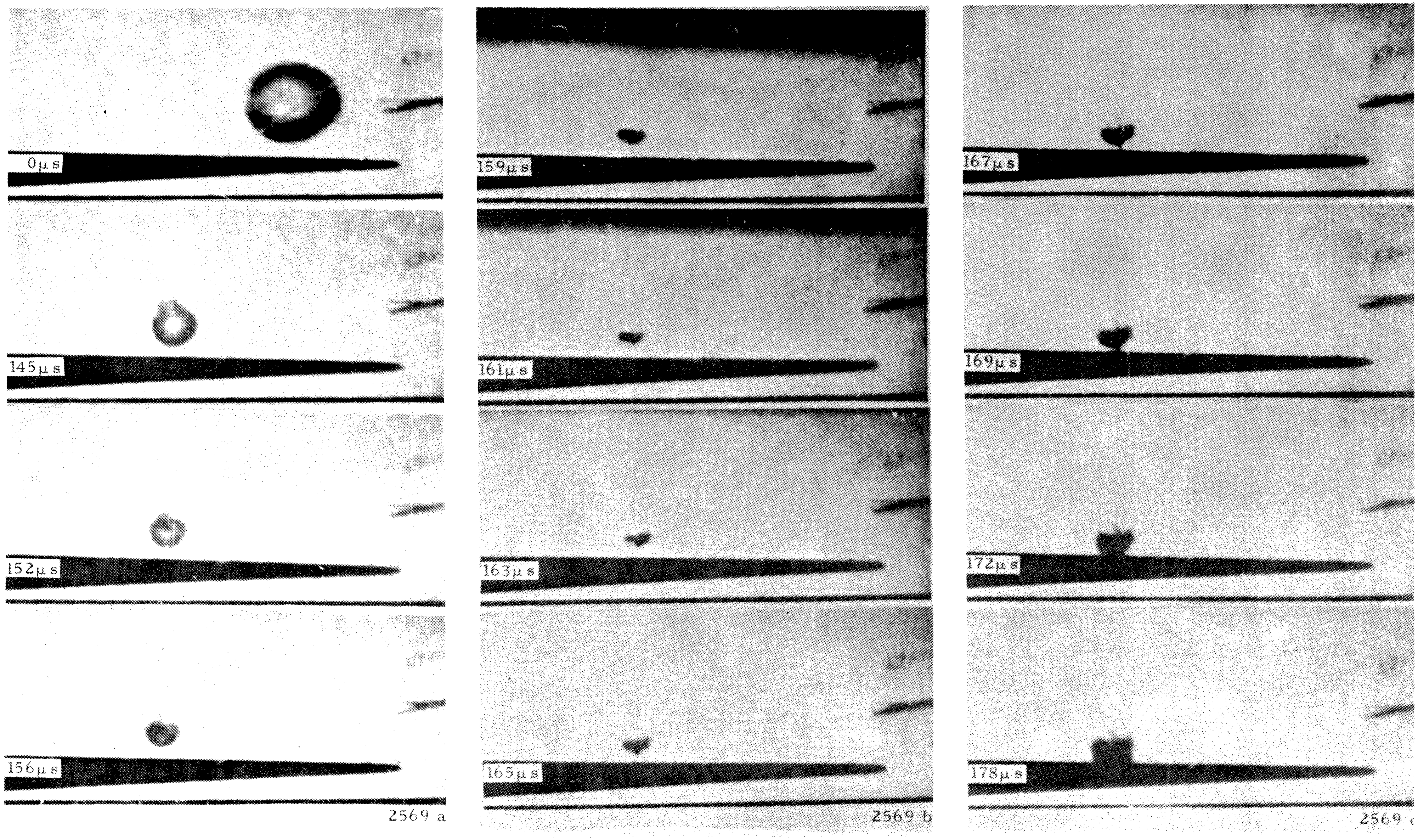
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