Traveling Bubble Cavitation

Since the early work by Plesset (1948) had demonstrated some approximate validity for models of cavitation events that use the equation we now refer to as the Rayleigh-Plesset equation, Parkin (1952) was motivated to attempt a more detailed model for the growth of traveling cavitation bubbles in the flow around a body. It was assumed that the bubbles began as micron-sized nuclei in the liquid of the oncoming stream and that the bubble moved with the liquid velocity along a streamline close to the solid surface. Cavitation inception was deemed to occur when the bubbles reached an observable size of the order of 1 mm. Parkin believed the lack of agreement between this theory and the experimental observations was due to the neglect of the boundary layer. Subsequent experiments by Kermeen, McGraw, and Parkin (1955) revealed that cavitation could result either from free stream nuclei as earlier assumed or from nuclei originating from imperfections in the headform surface, which would detach when they reached a critical size. Later, Arakeri and Acosta (1973) observed that, if separation occurs close to the low-pressure region, then free stream nuclei could not only be supplied to the cavitating zone by the oncoming stream but could also be supplied by the recirculating flow downstream of separation. Under such circumstances some of these recirculating nuclei could be remnants from a cavitation event itself, and hence there exists the possibility of hysteretic effects. Though the supply of nuclei either from the surface or from downstream may occasionally be important, the majority of the experimental observations indicate that the primary supply is from nuclei present in the incident free stream. Other viscous boundary layer effects on cavitation inception and on traveling bubble cavitation are reviewed by Holl (1969) and Arakeri (1979).

Rayleigh-Plesset models of traveling bubble cavitation that attempted to incorporate the effects of the boundary layer include the work of Oshima (1961) and Van der Walle (1962). Holl and Kornhauser (1970) added the thermal effects on bubble growth and explored the influence of initial conditions such as the size and location of the nucleus. Like Parkin's (1952) original model these improved versions continued to assume that the nucleus or bubble moves along a streamline with the fluid velocity. However, Johnson and Hsieh (1966) showed that since the streamlines that encounter the low-pressure region are close to the surface and, therefore, close to the stagnation streamline, nuclei will experience large fluid accelerations and pressure gradients as they pass close to the front stagnation point. The effect is to force the nuclei to move outwards away from the stagnation streamline. Moreover, the larger nuclei, which are those most likely to cavitate, will be displaced more than the smaller nuclei. Johnson and Hsieh termed this the "screening" effect, and more recent studies have confirmed its importance in cavitation inception. But this screening effect is only one of the effects that the accelerations and pressure gradients in the flow can have on the nucleus and on the growing and collapsing cavitation bubble. In the next section we turn to a description of these interactions.