Types of Impeller Cavitation

Since cavitation in a pump impeller can take a variety of forms (see, for example, Wood 1963), it is

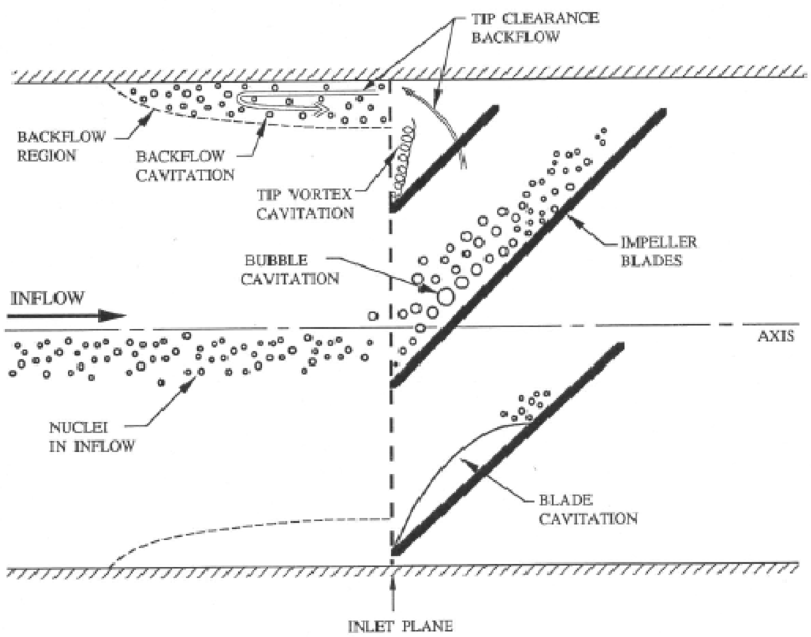

Figure 1: Types of cavitation in pumps.

appropriate at this stage to attempt some description and classification of these types of cavitation. It should be borne in mind that any such classification is necessarily somewhat arbitrary, and that types of cavitation may occur that do not readily fall within the classification system. Figure 1 includes sketches

Figure 2: Tip vortex cavitation on Impeller IV, the scale model of the SSME low pressure LOX turbopump (see figure **??**) at an inlet flow coefficient, ϕ_1, of 0.07 and a cavitation number, σ, of 0.42 (from Braisted 1979).

of some of the forms of cavitation that can be observed in an unshrouded axial flow impeller. As the inlet pressure is decreased, inception almost always occurs in the tip vortex generated by the corner where the leading edge meets the tip. Figure 2 includes a photograph of a typical cavitating tip vortex from tests of Impeller IV (the scale model of the SSME low pressure LOX turbopump shown in section (Mbbi)). Note that the backflow causes the flow in the vicinity of the vortex to have an upstream velocity component. Careful smoothing of the transition from the leading edge to the tip can reduce σ_i, but it will not eliminate the vortex, or vortex cavitation.

Usually the cavitation number has to be lowered quite a bit further before the next development occurs, and often this takes the form of traveling bubble cavitation on the suction surfaces of the blades. Nuclei in the inflow grow as they are convected into the regions of low pressure on the suction surfaces of the blades, and then collapse as they move into regions of higher pressure. For convenience, this will be termed "bubble cavitation." It is illustrated in figure 3 which shows bubble cavitation on a single hydrofoil.

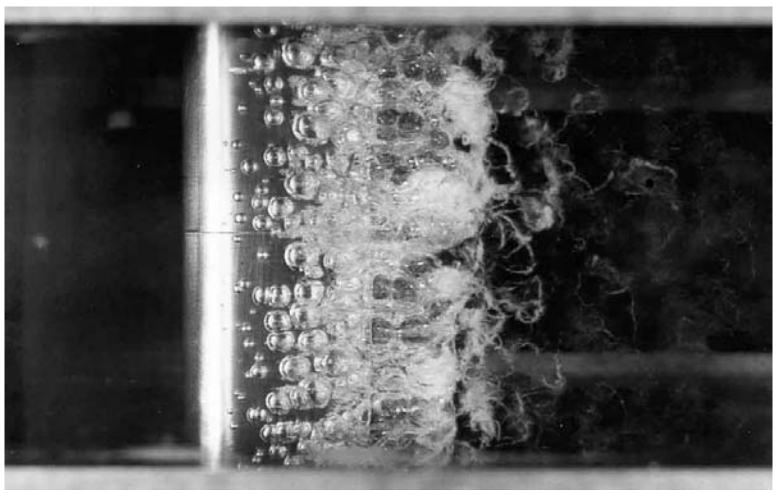

Figure 3: Bubble cavitation on the surface of a NACA 4412 hydrofoil at zero incidence angle, a speed of 13.7 m/s and a cavitation number of 0.3. The flow is from left to right and the leading edge of the foil is just to the left of the white glare patch on the surface (Kermeen 1956).

With further reduction in the cavitation number, the bubbles may combine to form large attached cavities or vapor-filled wakes on the suction surfaces of the blades. In a more general context, this is known as "attached cavitation". In the context of pumps, it is often called "blade cavitation". Figure 4 presents an example of blade cavitation in a centrifugal pump.

When blade cavities (or bubble or vortex cavities) extend to the point on the suction surface opposite the leading edge of the next blade, the increase in pressure in the blade passage tends to collapse the cavity. Consequently, the surface opposite the leading edge of the next blade is a location where cavitation damage is often encountered.

Blade cavitation that collapses on the suction surface of the blade is also referred to as "partial cavitation", in order to distinguish it from the circumstances that occur at very low cavitation numbers, when the cavity may extend into the discharge flow downstream of the trailing edge of the blade. These long cavities, which are clearly more likely to occur in lower solidity machines, are termed "supercavities". Figure 5 illustrates the difference between partial cavitation and supercavitation. Some pumps have even been designed to operate under supercavitating conditions (Pearsall 1963). The potential advantage is that bubble collapse will then occur downstream of the blades, and cavitation damage might thus be minimized.

Finally, it is valuable to create the catch-all term "backflow cavitation" to refer to the cavitating bubbles and vortices that occur in the annular region of backflow upstream of the inlet plane when the pump is required to operate in a loaded condition below the design flow rate. The increased pressure rise across the pump under these circumstances may cause the tip clearance flow to penetrate upstream and generate

Figure 4: Blade cavitation on the suction surface of a blade in a centrifugal pump. The relative flow is from left to right and the cavity begins at the leading edge of the blade which is toward the left of the photograph. From Sloteman, Cooper, and Graf (1991), courtesy of Ingersoll-Dresser Pump Company.

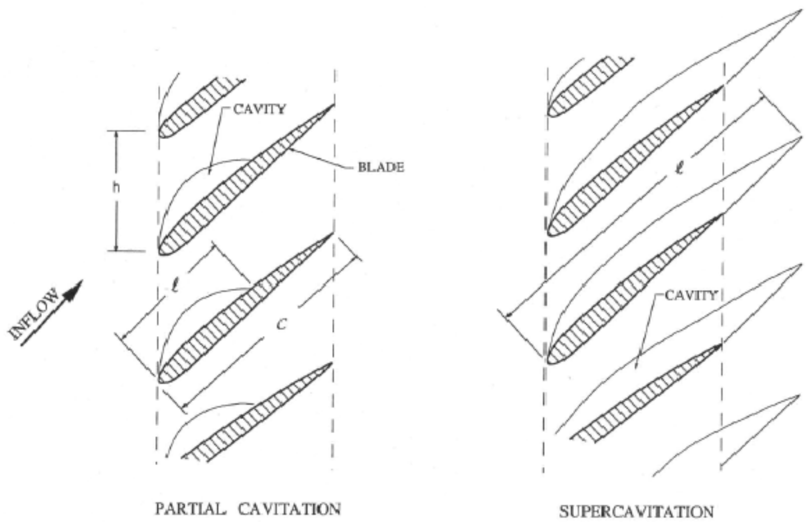

Figure 5: Partially cavitating cascade (left) and supercavitating cascade (right).

a backflow that can extend many diameters upstream of the inlet plane. When the pump also cavitates, bubbles and vortices are swept up in this backflow and, to the observer, can often represent the most visible form of cavitation. Figure 6 includes a photograph illustrating the typical appearance of backflow cavitation upstream of the inlet plane of an inducer.

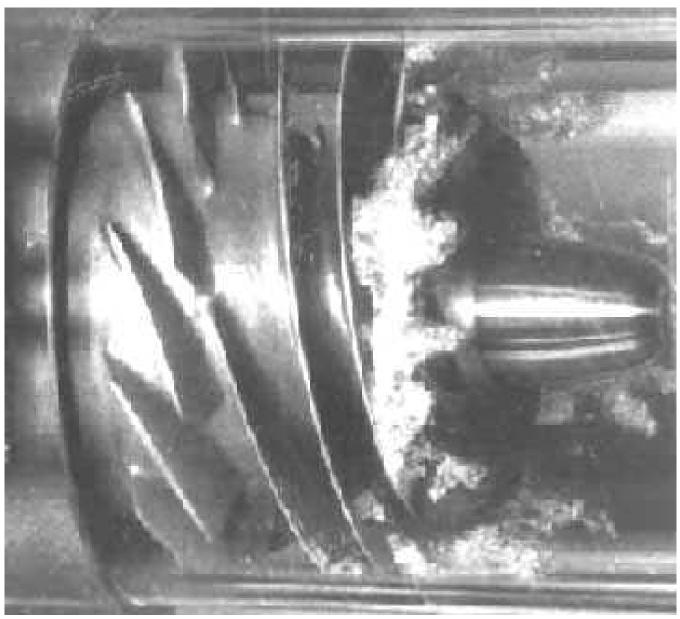

Figure 6: As figure 2, but here showing typical backflow cavitation.