Cavitation Damage

Perhaps the most ubiquitous problem caused by cavitation is the material damage that cavitation bubbles

Figure 1: Photograph of localized cavitation damage on the blade of a mixed flow pump impeller made from an aluminium-based alloy.

Figure 2: Cavitation damage on the blades at the discharge from a Francis turbine.

can cause when they collapse in the vicinity of a solid surface. Consequently, this aspect of cavitation has been intensively studied for many years (see, for example, ASTM 1967, Knapp, Daily, and Hammitt 1970, Thiruvengadam 1967, 1974). The problem is complex because it involves the details of a complicated unsteady flow combined with the reaction of the particular material of which the solid surface is made.

As we have seen in the previous section, cavitation bubble collapse is a violent process that generates highly localized, large amplitude disturbances and shocks in the fluid at the point of collapse. When this collapse occurs close to a solid surface, these intense disturbances generate highly localized and transient surface stresses. Repetition of this loading due a multitude of bubble collapses can cause local surface fatigue failure, and the detachment of pieces of material. This is the generally accepted explanation for cavitation damage. It is consistent with the appearance of cavitation damage in most circumstances. Unlike the erosion due to solid particles in the flow, for which the surface appears to be smoothly worn with scratches due to larger particles, cavitation damage has the crystalline and jagged appearance of

Figure 3: Cavitation damage to the concrete wall of the 15.2 m diameter Arizona spillway at the Hoover Dam. The hole is 35 m long, 9 m wide and 13.7 m deep. Reproduced from Warnock (1945).

fatigue failure. To illustrate this, a photograph of localized cavitation damage on the blade of a mixed flow pump, fabricated from an aluminium-based alloy, is included as figure 1. More extensive damage is illustrated in figure 2 which shows the blades at discharge from a Francis turbine; here the cavitation damage has penetrated the blades. Cavitation damage can also occur in much larger scale flows. As an example, figure 3 shows cavitation damage suffered by a spillway at the Hoover dam (Warnock 1945, Falvey 1990).

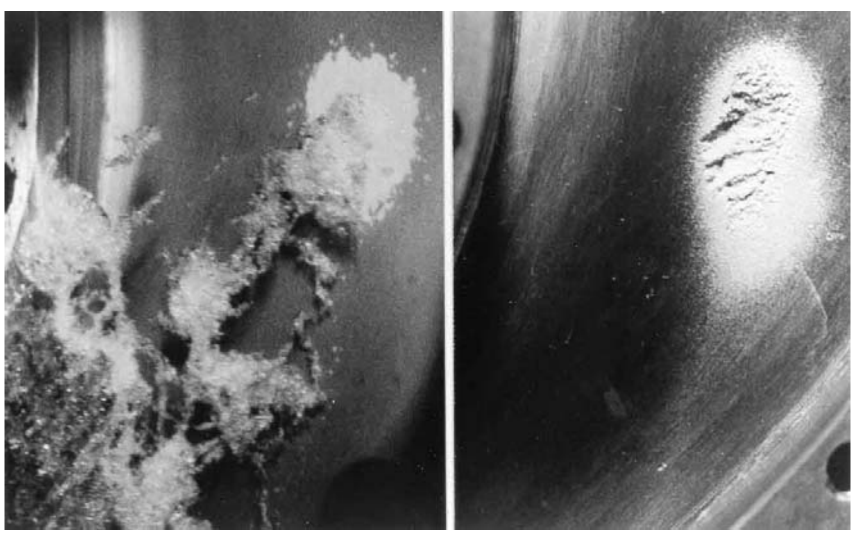

Figure 4: Axial views from the inlet of the cavitation and cavitation damage on the hub or base plate of a centrifugal pump impeller. The two photographs are of the same area, the left one showing the typical cavitation pattern during flow and the right one the typical cavitation damage. Parts of the blades can be seen in the upper left and lower right corners; relative to these blades the flow proceeds from the lower left to the upper right. The leading edge of the blade is just outside the field of view on the upper left. Reproduced from Soyama, Kato and Oba (1992) with permission of the authors.

In hydraulic devices such as pump impellers or propellers, cavitation damage is often observed to occur in quite localized areas of the surface. This is frequently the result of the periodic and coherent collapse of a cloud of cavitation bubbles. Such is the case in magnetostrictive cavitation testing equipment (Knapp, Daily, and Hammitt 1970). In many pumps, the periodicity may occur naturally as a result of regular shedding of cavitating vortices, or it may be a response to a periodic disturbance imposed on the flow. Examples of the kinds of imposed fluctuations are the interaction between a row of rotor vanes and a row of stator vanes, or the interaction between a ship's propeller and the nonuniform wake behind the ship. In almost all such cases, the coherent collapse of the cloud can cause much more intense noise and more potential for damage than in a similar nonfluctuating flow. Consequently, the damage is most severe on the solid surface close to the location of cloud collapse. An example of this phenomenon is included in figure 4 taken from Soyama, Kato and Oba (1992). In this instance, clouds of cavitation are being shed from the leading edge of a centrifugal pump blade, and are collapsing in a specific location as suggested by the pattern of cavitation in the left-hand photograph. This leads to the localized damage shown in the right-hand photograph.

Currently, several research efforts are focussed on the dynamics of cavitation clouds. These studies suggest that the coherent collapse can be more violent than that of individual bubbles, but the basic explanation for the increase in the noise and damage potential is not clear.