Cavitation Surge of Cavitating Pumps

In many installations involving a pump that cavitates, violent oscillations in the pressure and flow rate in the entire system can occur when the cavitation number is decreased to a value at which the volume of vapor bubbles within the pump becomes sufficient to cause major disruption of the flow and therefore a decrease in the total pressure rise across the pump. While most of the detailed investigations have focused on axial pumps and inducers (Sack and Nottage 1965, Miller and Gross 1967, Kamijo *et al.* 1977, Braisted and Brennen 1980) the phenomenon has also been observed in centrifugal pumps (Yamamoto 1991). In the past this surge phenomenon was called *auto-oscillation* though the modern term *cavitation surge* is more appropriate. The phenomenon is described in detail in Brennen (1994). It can lead to very large flow rate and pressure fluctuations. For example in boiler feed systems, discharge pressure oscillations with amplitudes as high as 14 *bar* have been reported informally. It is a genuinely dynamic instability for it occurs when the slope of the pump total pressure rise/flow rate characteristic is still strongly negative and the system is therefore quasistatically stable.

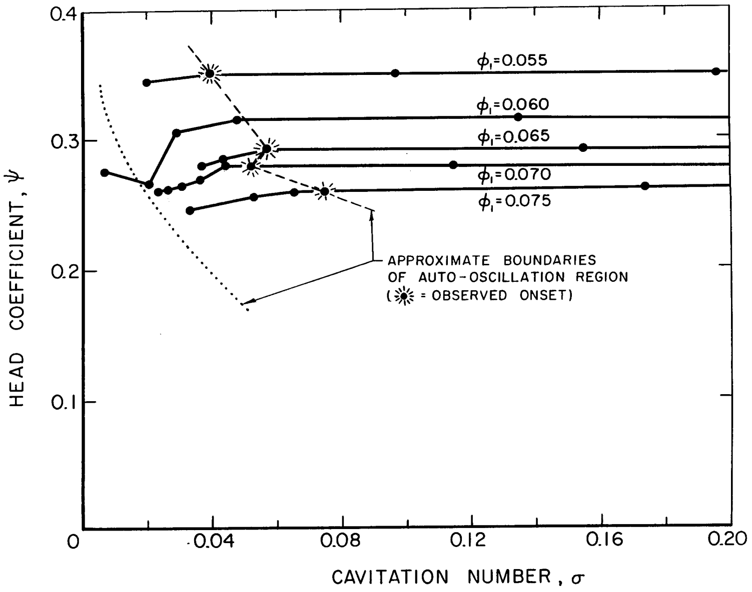

Figure 1: Cavitation performance of a SSME low pressure LOX pump model showing the approximate boundaries of the cavitation surge region for a pump speed of 6000 *rpm* (from Braisted and Brennen 1980). The flow coefficient, ϕ_1, is based on the impeller inlet area.

As described in the section on pumps, cavitation surge occurs when the region of cavitation head loss is approached as the cavitation number is decreased. Figure 1 provides an example of the limits of cavitation surge taken from the work of Braisted and Brennen (1980). However, since the onset is sensitive to the detailed dynamic characteristics of the system, it would not even be wise to quote any approximate guideline for onset. Our current understanding is that frequency domain methods using appropriate dynamic transfer functions are essential for any prediction of cavitation surge.

Unlike compressor surge, the frequency of cavitation surge, ω_i, scales with the shaft speed of the pump, Ω (Braisted and Brennen 1980). The ratio, ω_i/Ω, varies with the cavitation number, σ, the flow coefficient,

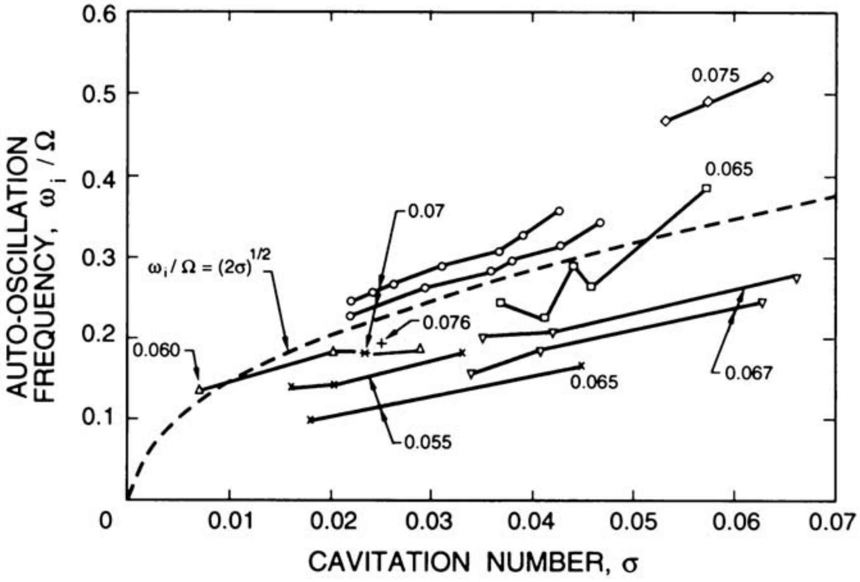

Figure 2: Data from Braisted and Brennen (1980) on the ratio of the frequency of cavitation surge, ω_i, to the frequency of shaft rotation, Ω, for several axial flow pumps: for SSME low pressure LOX pump models: 7.62 *cm* diameter: $\times$ (9000 *rpm*) and $+$ (12000 *rpm*), 10.2 *cm* diameter: $\odot$ (4000 *rpm*) and $\boxdot$ (6000 *rpm*); for 9° helical inducers: 7.58 *cm* diameter: $\ast$ (9000 *rpm*): 10.4 *cm* diameter: $\bigtriangledown$ (with suction line flow straightener) and $\triangle$ (without suction line flow straightener). The flow coefficients, ϕ_1, are based on the impeller inlet area.

ϕ, and the type of pump as illustrated in Figure 2. The most systematic variation is with the cavitation number and it appears that the empirical expression

$$\omega_i/\Omega = (2\sigma)^{\frac{1}{2}} \tag{Bneb1}$$

provides a crude estimate of the cavitation surge frequency. Yamamoto (1991) demonstrated that the frequency also depends on the length of the suction pipe thus reinforcing the understanding of cavitation surge as a system instability.