Acoustic Resonances

In the absence of cavitation or flow-induced vibration, flow noise generated within the turbomachine itself is almost never an issue when the fluid is a liquid. One reason for this is that the large wavelength of the sound in the liquid leads to internal acoustic resonances that are too high in frequency and, therefore, too highly damped to be important. This contrasts with the important role played by internal resonances in the production of noise in gas turbines and compressors (Tyler and Sofrin 1962, Cumpsty 1977). In noncavitating liquid turbomachinery, the higher acoustic velocity and the smaller acoustic damping mean that pipeline resonances play the same kind of role that the internal resonances play in the production of noise in gas turbomachinery.

In liquid turbomachines, resonances exterior to the machine or resonances associated with cavitation do create a number of serious vibration problems. As mentioned in the introduction, pipeline resonances with the acoustic modes of the inlet or discharge piping can occur when one of the excitation frequencies produced by the pump or hydraulic turbine happens to coincide with one of the acoustic modes of those pipelines. Jaeger (1963) and Strub (1963) document a number of cases of resonance in hydropower systems. Many of these do not involve excitation from the turbine but some do involve excitation at blade passing frequencies (Strub 1963). One of the striking features of these phenomena is that very high harmonics of the pipelines can be involved (20th harmonics have been noted) so that damage occurs at a whole series of nodes equally spaced along the pipeline. The cases described by Jaeger involve very large pressure oscillations, some of which led to major failures of the installation. Sparks and Wachel (1976) have similarly documented a number of cases of pipeline resonance in pumping systems. They correctly identify some of these as system instabilities of the kind discussed in section (Mbff) and in sections (Gb).

Cavitation-induced resonances and vibration problems are dealt with in other sections in this group. But it is appropriate in the context of resonances to mention one other possible cavitation mechanism even though it has not, as yet, been demonstrated experimentally. One might judge that the natural frequency, ω_P, of bubbles given in section (Mbei), being of the order of kHz, would be too high to cause vibration problems. However, it transpires that a finite cloud of bubbles may have much smaller natural frequencies that could resonant, for example, with a blade passage frequency to produce a problem. d'Agostino and Brennen (1983) showed that the lowest natural frequency, ω_C, of a spherical cloud of bubbles of radius, A, consisting of bubbles of radius, R, and with a void fraction of α would be given by

$$\omega_C = \omega_P \left[1 + \frac{4}{3\pi^2} \frac{A^2}{R^2} \frac{\alpha}{1-\alpha} \right]^{-\frac{1}{2}} \tag{Mbfk1}$$

It follows that, if $\alpha A^2/R^2 \gg 1$, then the cloud frequency will be significantly smaller than the bubble frequency. This requires that the void fraction be sufficiently large so that $\alpha \gg R^2/A^2$. However, this could be relatively easily achieved in large clouds of small bubbles. Though the importance of cloud cavitation in pumps has been clearly demonstrated (see section (Mbeh)), the role played by the basic dynamic characteristics of clouds has not, as yet, been elucidated.