

## Unsteady Flows

While it is true that cavitation introduces a special set of fluid-structure interaction issues, it is also true that there are many such unsteady flow problems which can arise even in the absence of cavitation. One reason these issues may be more critical in a liquid turbomachine is that the large density of a liquid implies much larger fluid dynamic forces. Typically, fluid dynamic forces scale like  $\rho\Omega^2 D^4$  where  $\rho$  is the fluid density, and  $\Omega$  and  $D$  are the typical frequency of rotation and the typical length, such as the span or chord of the impeller blades or the diameter of the impeller. These forces are applied to blades whose typical thickness is denoted by  $\tau$ . It follows that the typical structural stresses in the blades are given by  $\rho\Omega^2 D^4/\tau^2$ , and, to minimize structural problems, this quantity will have an upper bound which will depend on the material. Clearly this limit will be more stringent when the density of the fluid is larger. In many pumps and liquid turbines it requires thicker blades (larger  $\tau$ ) than would be advisable from a purely hydrodynamic point of view.

This monograph presents a number of different unsteady flow problems that are of concern in the design of hydraulic pumps and turbines. For example, when a rotor blade passes through the wake of a stator blade (or vice versa), it will encounter an unsteady load which is endemic to all turbomachines. Recent investigations of these loads will be reviewed. This rotor-stator interaction problem is an example of a local unsteady flow phenomenon. There also exist global unsteady flow problems, such as the auto-oscillation problem mentioned earlier. Other global unsteady flow problems are caused by the fluid-induced radial loads on an impeller due to flow asymmetries, or the fluid-induced rotordynamic loads that may increase or decrease the critical whirling speeds of the shaft system. These last issues have only recently been addressed from a fundamental research perspective, and a summary of the conclusions is included in this monograph.