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Chapter 1 : Turbomachines: A Guide to Design Selection and Theory - O. E. Balje - Google Books

This is a classic text in turbomachinery literature and for good reason. Balje always has an interesting approach to sizing and selection of components as you may have seen in his many ASME papers.

Rather than attempt a general treatise on turbomachines, we shall focus attention on those special problems and design issues associated with the flow of liquid through a rotating machine. There are two characteristics of a liquid that lead to these special problems, and cause a significantly different set of concerns than would occur in, say, a gas turbine. These are the potential for cavitation and the high density of liquids that enhances the possibility of damaging unsteady flows and forces. In some respects, cavitation is similar to boiling, except that the latter is generally considered to occur as a result of an increase of temperature rather than a decrease of pressure. This difference in the direction of the state change in the phase diagram is more significant than might, at first sight, be imagined. It is virtually impossible to cause any rapid uniform change in temperature throughout a finite volume of liquid. Rather, temperature change most often occurs by heat transfer through a solid boundary. Hence, the details of the boiling process generally embrace the detailed interaction of vapor bubbles with a solid surface, and the thermal boundary layer on that surface. On the other hand, a rapid, uniform change in pressure in a liquid is commonplace and, therefore, the details of the cavitation process may differ considerably from those that occur in boiling. Much more detail on the process of cavitation is included in later sections. It is sufficient at this juncture to observe that cavitation is generally a malevolent process, and that the deleterious consequences can be divided into three categories. First, cavitation can cause damage to the material surfaces close to the area where the bubbles collapse when they are convected into regions of higher pressure. Cavitation damage can be very expensive, and very difficult to eliminate. For most designers of hydraulic machinery, it is the preeminent problem associated with cavitation. Frequently, one begins with the objective of eliminating cavitation completely. However, there are many circumstances in which this proves to be impossible, and the effort must be redirected into minimizing the adverse consequences of the phenomenon. The second adverse effect of cavitation is that the performance of the pump, or other hydraulic device, may be significantly degraded. In the case of pumps, there is generally a level of inlet pressure at which the performance will decline dramatically, a phenomenon termed cavitation breakdown. This adverse effect has naturally given rise to changes in the design of a pump so as to minimize the degradation of the performance; or, to put it another way, to optimize the performance in the presence of cavitation. One such design modification is the addition of a cavitating inducer upstream of the inlet to a centrifugal or mixed flow pump impeller. Another example is manifest in the blade profiles used for supercavitating propellers. These supercavitating hydrofoil sections have a sharp leading edge, and are shaped like curved wedges with a thick, blunt trailing edge. The third adverse effect of cavitation is less well known, and is a consequence of the fact that cavitation affects not only the steady state fluid flow, but also the unsteady or dynamic response of the flow. This change in the dynamic performance leads to instabilities in the flow that do not occur in the absence of cavitation. These instabilities can give rise to oscillating flow rates and pressures that can threaten the structural integrity of the pump or its inlet or discharge ducts. While a complete classification of the various types of unsteady flow arising from cavitation has yet to be constructed, we can, nevertheless, identify a number of specific types of instability, and these are reviewed in later chapters of this monograph. 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. Clearly this limit will be more stringent when the density of the fluid is larger. 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

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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. Thus the volume flow rate through the pump, Q , the total head rise across the pump, H , the torque, T , and the power absorbed by the pump, P , will scale according to Q .

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They are similarly defined for compressors and turbines, allowing for satisfactory efficiency pre- dictions of the turbomachinery block without entering into much detail on the actual geometry.

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