SUMMARY

We classify turbomachinery into two broad categories, *pumps* and *turbines*. The word *pump* is a general term for any fluid machine that *adds* energy *to* a fluid. We explain how this energy transfer occurs for several types of pump designs—both *positive-displacement pumps* and *dynamic pumps*. The word *turbine* refers to a fluid machine that *extracts* energy *from* a fluid. There are also *positive-displacement turbines* and *dynamic turbines* of several varieties.

The most useful equation for preliminary turbomachinery design is the *Euler turbomachine equation*,

$$T_{\text{shaft}} = \rho\dot{V}(r_2V_{2,\,t} - r_1V_{1,\,t})$$

Note that for pumps, the inlet and outlet are at radii r_1 and r_2, respectively, while for turbines, the inlet is at radius r_2 and the outlet is at radius r_1. We show several examples where blade shapes for both pumps and turbines are designed based on desired flow velocities. Then, using the Euler turbomachine equation, the performance of the turbomachine is predicted.

The *turbomachinery scaling laws* illustrate a practical application of dimensional analysis. The scaling laws are used in the design of new turbomachines that are geometrically similar to existing turbomachines. For both pumps and turbines, the main dimensionless parameters are head coefficient, capacity coefficient, and power coefficient, defined respectively as

$$C_H = \frac{gH}{\omega^2D^2} \qquad C_Q = \frac{\dot{V}}{\omega D^3} \qquad C_P = \frac{\text{bhp}}{\rho\omega^3D^5}$$

In addition to these, we define *pump efficiency* and *turbine efficiency* as reciprocals of each other,

$$\eta_{\text{pump}} = \frac{\dot{W}_{\text{water horsepower}}}{\dot{W}_{\text{shaft}}} = \frac{\rho g\dot{V}H}{\text{bhp}}$$

$$\eta_{\text{turbine}} = \frac{\dot{W}_{\text{shaft}}}{\dot{W}_{\text{water horsepower}}} = \frac{\text{bhp}}{\rho g\dot{V}H}$$

Finally, two other useful dimensionless parameters called *pump specific speed* and *turbine specific speed* are defined, respectively, as

$$N_{\text{Sp}} = \frac{C_Q^{1/2}}{C_H^{3/4}} = \frac{\omega\dot{V}^{1/2}}{(gH)^{3/4}} \qquad N_{\text{St}} = \frac{C_P^{1/2}}{C_H^{5/4}} = \frac{\omega(\text{bhp})^{1/2}}{\rho^{1/2}(gH)^{5/4}}$$

These parameters are useful for preliminary selection of the type of pump or turbine that is most appropriate for a given application.

Turbomachinery design assimilates knowledge from several key areas of fluid mechanics, including mass, energy, and momentum analysis (Chaps. 5 and 6); dimensional analysis and modeling (Chap. 7); flow in pipes (Chap. 8); differential analysis (Chaps. 9 and 10); and aerodynamics (Chap. 11). In addition, for gas turbines and other types of turbomachines that involve gases, compressible flow analysis (Chap. 12) is required. Finally, computational fluid dynamics (Chap. 15) plays an ever-increasing role in the design of highly efficient turbomachines.

REFERENCES AND SUGGESTED READING

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