

Turbomachines

Pumps and turbines occur in a wide variety of configurations. In general, pumps add energy to the fluid—they do work on the fluid; turbines extract energy from the fluid—the fluid does work on them. The term “pump” will be used to generically refer to all pumping machines, including *pumps*, *fans*, *blowers*, and *compressors*. Fluid machines Figure 4.1, can be divided into two main categories: *positive displacement machines* (donated as the static types) and *turbomachines* (donated as the dynamics types)

Positive displacement machines force a fluid into or out of a chamber by changing the volume of the chamber. The pressures developed and the work done are a result of essentially static forces rather than dynamic effects. Typical examples shown in Figure 4.2. (the human heart, and the gear pump. In these cases the device does work on the fluid 1the container wall moves against the fluid pressure force on the moving wall). The internal combustion engine in your car is a positive displacement machine in which the fluid does work on the machine, the opposite of what happens in a pump. In the car engine the piston moves in the direction of the fluid pressure force acting on the piston face during the power stroke.

Turbomachines, on the other hand, involve a collection of blades, buckets, flow channels, or passages arranged around an axis of rotation to form a rotor. Rotation of the rotor produces dynamic effects that either add energy to the fluid or remove energy from the fluid. Examples of turbomachine-type pumps include simple window fans, propellers on ships or airplanes, squirrel-cage fans on home furnaces, axial-flow water pumps used in deep wells, and compressors in automobile turbochargers. Examples of turbines include the turbine portion of gas turbine engines on aircraft, steam turbines used to drive generators at electrical generation stations, and the small, high-speed air turbines that power dentist drills.

Function Type	Kinetic to potential energy	Potential to kinetic energy
Rotor Dynamic Machines	No housing – Fan Housing – Radial Flow (Centrifugal), Axial Flow and Mix Flow.	Impulse – Pelton Wheel and Wind turbine Reaction – Radial (Francis Turbine), Mixing, Axial (Kaplan Turbine)
Positive Displacement Machines	Centrifugal – Piston pump Rotary – Gear and Vane	Motor – Gear, Vane and piston.

Figure 4.1. Classification of Fluid machines

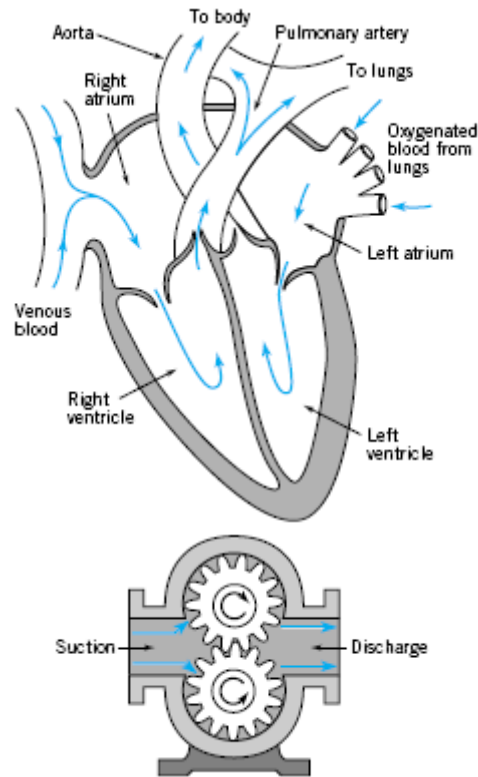


Figure 4.2 Typical positive displacement pumps: human heart and gear pump.

The Centrifugal Pump

One of the most common radial-flow turbomachines is the *centrifugal pump*. This type of pump has two main components: an *impeller* attached to a rotating shaft, and a stationary *casing, housing, or volute* enclosing the impeller. The impeller consists of a number of blades (usually curved), also sometimes called *vanes*, arranged in a regular pattern around the shaft. A sketch showing the essential features of a centrifugal pump is shown in Figure 4.3.

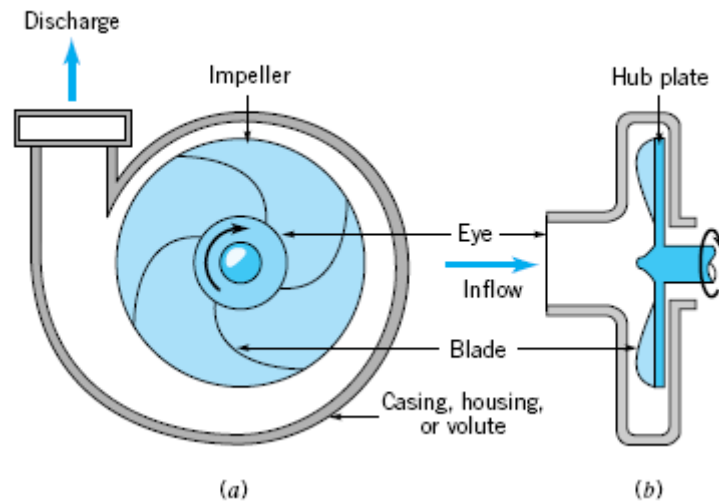


Figure 4.3 Schematic diagram of basic elements of a centrifugal pump.

Centrifugal pumps come in a variety of arrangements (open or shrouded impellers, volute or diffuser casings, single- or double-suction, single- or multistage), but the basic operating principle remains the same. Work is done on the fluid by the rotating blades (centrifugal action and tangential blade force acting on the fluid over a distance) creating a large increase in kinetic energy of the fluid flowing through the impeller. This kinetic energy is converted into an increase in pressure as the fluid flows from the impeller into the casing enclosing the impeller. A simplified theory describing the behavior of the centrifugal pump was introduced in the previous section and is expanded in the following section.



Figure 4.4 (a) Open impeller, (b) enclosed or shrouded impeller. (Courtesy of Ingersoll Dresser Pump Company.)

Theoretical

Although flow through a pump is very complex (unsteady and three-dimensional), the basic theory of operation of a centrifugal pump can be developed by considering the

average one dimensional flow of the fluid as it passes between the inlet and the outlet sections of the impeller as the blades rotate. As shown in Figure 4.4,

the absolute velocity, V

fluid entering the passage is the vector sum of the velocity of the blade, U

rotating in a circular path with angular velocity ω

the relative velocity, V_r

whirl component velocity, V_w

radial velocity, V_f

blade angle, β

Inlet pump, 1 and outlet pump, 2

Note that $U_1 = r_1 \omega$ and $U_2 = r_2 \omega$. Fluid velocities are taken to be average velocities over the inlet and exit sections of the blade passage. The relationship between the various velocities is shown graphically in Figure 4.5.

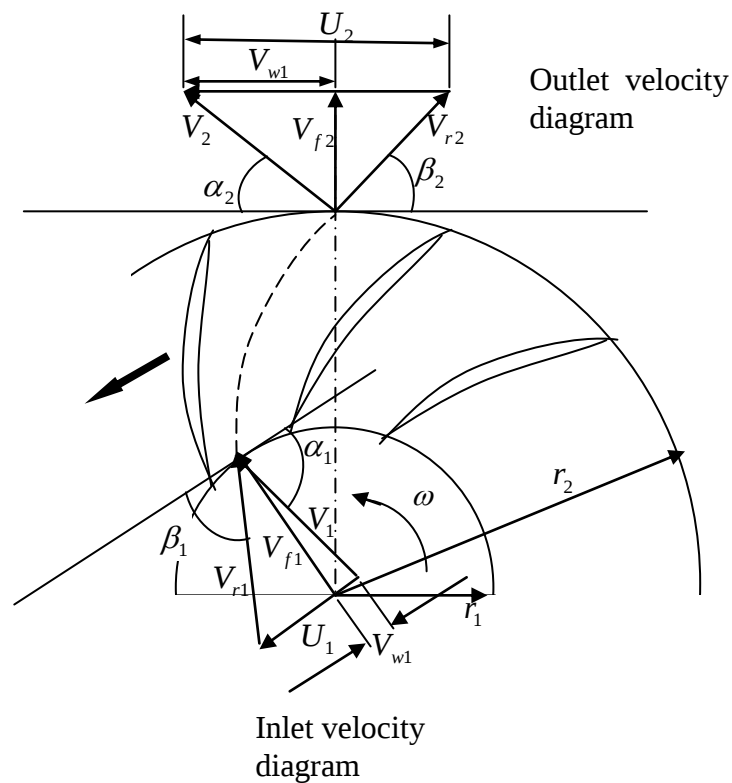


Figure 4.5 Velocity diagrams at the inlet and exit of a centrifugal pump impeller.

The moment-of-momentum equation indicates that the shaft torque, required to rotate the pump impeller is given by equation Eq. 12.2 applied to a pump with That is