Turbines
(Most material from Fluid Mechanics, Çengel and Cimbala, Chapter 14)

Introduction and Terminology:

- “Turbine” is a general term for any device that extracts mechanical energy from a fluid – generally converting it to rotating energy of a turbine wheel.
- For liquids, we usually call them “hydraulic turbines” or “hydroturbines”.
- For gases, we usually call them “wind turbines”, “gas turbines”, or “steam turbines”, depending on the type of gas being used.
- Just as with pumps, there are two basic types of turbine:
  - Positive displacement turbines – fluid is forced into a closed volume, and then the fluid is pushed out.
  - Dynamic turbines – no closed volume is involved; instead, rotating blades called runner blades or buckets extract energy from the fluid.
- In general, positive-displacement turbines are used for flow measurement, rather than for production of power, whereas dynamic turbines are used for both power generation and flow measurement.

Positive-Displacement Turbines:

- The nutating disc flowmeter, commonly used to measure the volume of water supplied to a house, is an example of a positive-displacement turbine.

![Diagram of a nutating disc flowmeter]

**FIGURE 14–80**
The nutating disc fluid flowmeter is a type of positive-displacement turbine used to measure volume flow rate:

(a) cutaway view and (b) diagram showing motion of the nutating disc. This type of flowmeter is commonly used as a water meter in homes.

*Photo courtesy of Niagara Meters, Spartanburg, SC.*
• Other geometries are also used for positive-displacement turbines; e.g., a flowmeter that uses a double helical three-lobe impeller design, as discussed in Chapter 8:

A positive displacement flowmeter with double helical three-lobe impeller design.

*Courtesy Flow Technology, Inc.*

*Source: www.ftimeters.com.*

**Dynamic Turbines:**

• Dynamic turbines do not have closed volumes. Instead, spinning blades called *runners* or *buckets* transfer kinetic energy and extract momentum from the fluid.

• Dynamic turbines are used for both flow measurement and power production. For example, turbine flowmeters for air and water are discussed in Chapter 8.
There are two main types of dynamic turbines: *impulse turbines* and *reaction turbines*.

- **Impulse turbines**: Fluid is sent through a nozzle that then impinges on the rotating blades, called buckets. Compared to reaction turbines, impulse turbines require higher head, and work with a lower volume flow rate.
- The most common example is the *Pelton wheel turbine*.

![Pelton wheel turbine](image)

- **Reaction turbines**: Instead of using water jets, reaction turbines fill a *volute* with swirling water that rotates the runner blades. Compared to impulse turbines, reaction turbines...
require a lower head, and work with a higher volume flow rate. They are used primarily for electricity production (hydroelectric dams).

In many modern Francis mixed-flow hydroturbines, the flow exiting the turbine swirls a direction opposite to that of the runner itself. This is called reverse swirl, and is designed to extract the maximum possible momentum from water, similar to how a Pelton wheel turbine bucket turns the water nearly 180° around.

The **stay vanes** are fixed guide vanes that induce swirl to the water.

The **wicket gates** are adjustable vanes that control the volume flow rate through the turbine. They can usually be completely closed in order to shut off flow to the turbine.

**FIGURE 14–87**

A *reaction turbine* differs significantly from an impulse turbine; instead of using water jets, a *volute* is filled with swirling water that drives the runner. For hydroturbine applications, the axis is typically vertical. Top and side views are shown, including the fixed *stay vanes* and adjustable *wicket gates*.

There are various types of hydroturbine designs, as discussed in the text: radial flow, mixed flow, propeller mixed flow, and propeller axial flow.
Here is a typical setup for a hydroelectric plant that produces electricity with a hydroturbine and generator. Note that net head $H$ across the turbine is measured from just upstream of the turbine to just downstream of the draft tube, while gross head $H_{\text{gross}}$ is measured from the upstream reservoir surface to the downstream tailrace surface.

A draft tube is a combination of an elbow and a diffuser.

**Turbine efficiency:**

$$\text{Turbine efficiency: } \eta_{\text{turbine}} = \frac{\dot{W}_{\text{shaft}}}{\dot{W}_{\text{water horsepower}}} = \frac{\text{bhp}}{\rho g H \dot{V}} \quad (14-44)$$

The efficiency of a turbine is the reciprocal of the efficiency of a pump!

Thus, for a pump,

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

and for a turbine,

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

Efficiency is always defined as

$$\eta = \text{efficiency} = \frac{\text{actual output}}{\text{required input}}$$