Types of Turbines

Turbines come in an array of shapes and sizes and in a substantial range of designs. Here we give just a few examples of turbines from a range of different technological contexts.

Turbines are conventionally classified as either "impulse" or "reaction". An impulse turbine is one in which the force imparted to the turbine wheel is provided by the change in momentum of the impacting fluid and there is little difference between the fluid total pressure (head) at inlet and discharge. Consequently the traditional undershot water wheel (Figure 1) is an impulse turbine. In contrast the fluid total head at discharge from a "reaction" turbine is significantly smaller than that at inlet. Consequently the traditional overshot water wheel (Figure 1) is a reaction turbine.

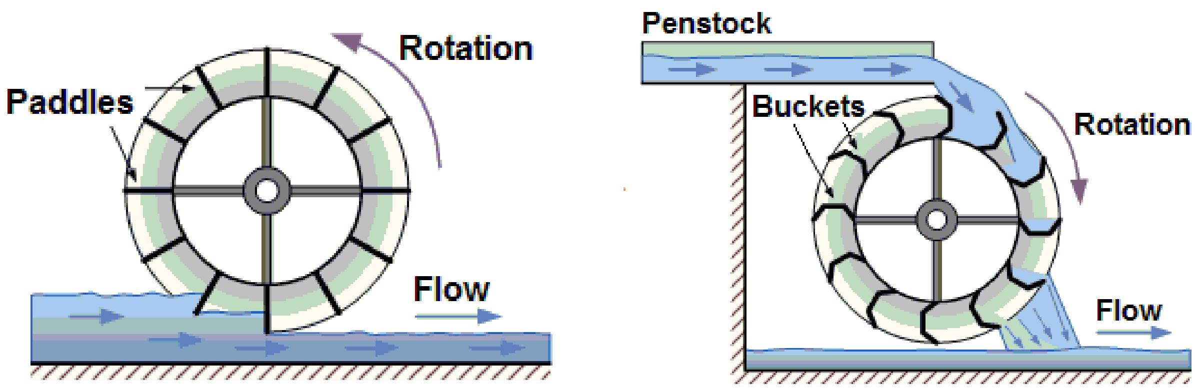

Figure 1: Undershot (left) and overshot (right) water wheels.

The modern descendant from the ancient water wheel is the Pelton wheel turbine (see Figure 2) in which a high speed water jet (or multiple jets) is directed tangentially toward the periphery of a large wheel to which are attached *buckets* that deflect the jets back in a direction opposite to that of the incident jets. It is a prime example of an impulse turbine. The wheel is forced into rotation by the change in the momentum of the jets impacting the buckets. All of this is enclosed in a container to control the inevitable splashing. However, the principle is very similar to that of the ancient water wheel except that the driving force is the momentum change or impulse of the jets rather than the force of gravity. The fact that the static pressure of the discharge is the same as the static pressure of the incident jet characterizes the Pelton wheel as belonging to the class of turbines known as *impulse* turbines. Other impulse turbines use a cascade of high deflection angle blades attached to the periphery of the wheel as sketched in the section which follows. In a contrasting class of turbines, referred to as *reaction* turbines, there is no free surface to constrain the liquid pressure and the entire inlet flow is deflected by the blades of an impeller such that the change in the total angular momentum is what generates the torque on the impeller. Further details of these fluid mechanical characteristics are provided in the sections that follow.

Other modern turbines come in an array of shapes and sizes and in a substantial range of designs. Here we give just a few examples of turbines from a range of different technological contexts. The presentation will begin with high specific speed turbines from conditions involving high flow rates and relatively modest head drops. Therefore we begin with modern, power generating turbines designed to drive electric generators. It transpires that at high head drops but low flow rates, the Pelton wheel is an optimal choice. However, in circumstances involving relatively high flows and low head drops the appropriate high specific speed turbine

Figure 2: Pelton wheel turbine.

is known as a propeller turbine or Kaplan turbine (see Figure 3). In a propeller turbine the inclination of the runner blades is fixed while those of a Kaplan turbine are adjustable, allowing for more flexible operation. On the other hand the appropriate turbine at somewhat lower specific speeds is a centrifugal

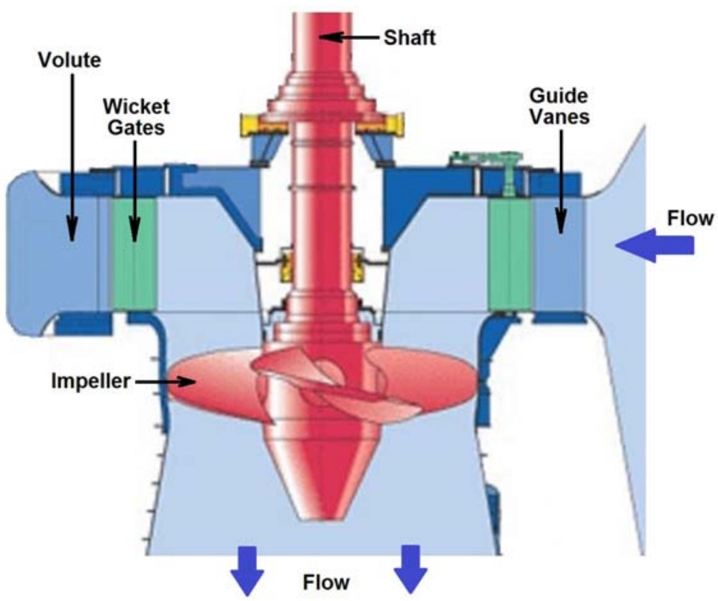

Figure 3: Schematic of a propeller turbine or Kaplan turbine.

machine known as a Francis turbine (Figure 4). At very low head drops the modern equivalent of a very ancient design due to Archimedes and called an Archimedes turbine is often used (see Figure 5). It has the advantage that, by reversing the direction of rotation of the impeller, it can be used as a pump (see section Mba).

Modern steam or gas turbines are primarily used either for power generation in tandem with electrical

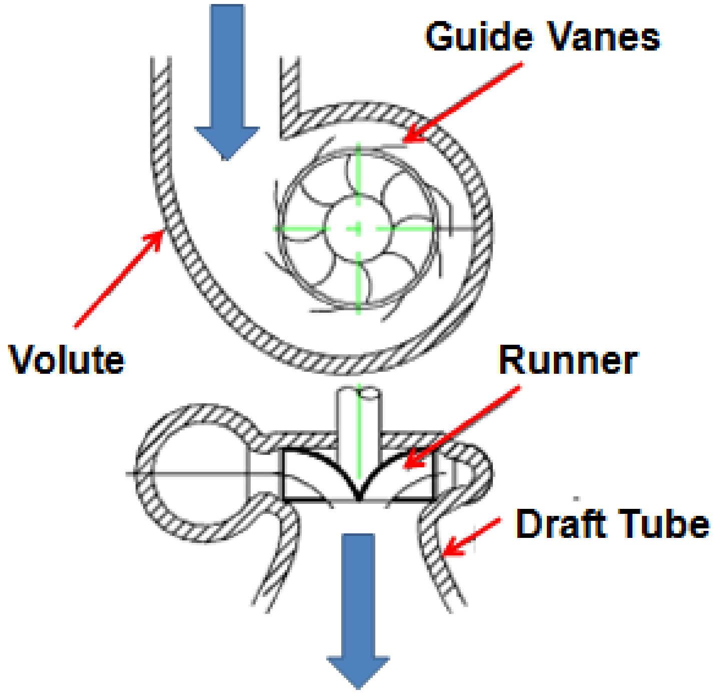

Figure 4: Schematic of a Francis turbine.

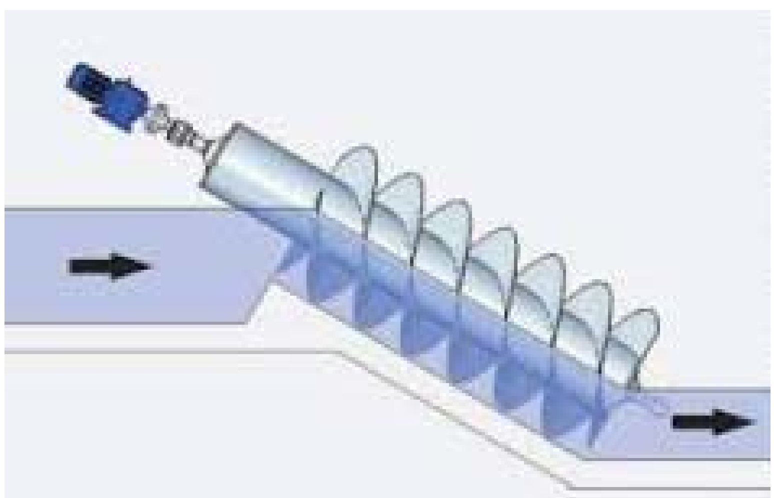

Figure 5: Schematic of an Archimedes turbine.

generators or in jet engines downstream of the combustion chamber in order to drive the compressor and fan upstream of the combustion chamber. Typically these are all multistage axial machines as illustrated, for example, by the steam turbine depicted in Figure 6. Note in that case the high pressure steam is fed to the midpoint of the turbine and expand through identical stages on either side of the midpoint. The purpose of this is to help balance the axial thrust on the rotor. Other turbines have flow in just one direction as can be seen in the gas turbines in the rocket engines in section (Mbb). Another example is the typical jet engine compressor shown in Figure 7. Several important and challenging technical problems face the gas turbines. In both the jet engine and power generation business, fuel efficiency is a key issue and, in seeking to improve the cycle efficiency it is clearly advantageous to develop machines that can operate with higher and higher inlet temperatures. This creates severe thermal problems for the first stage

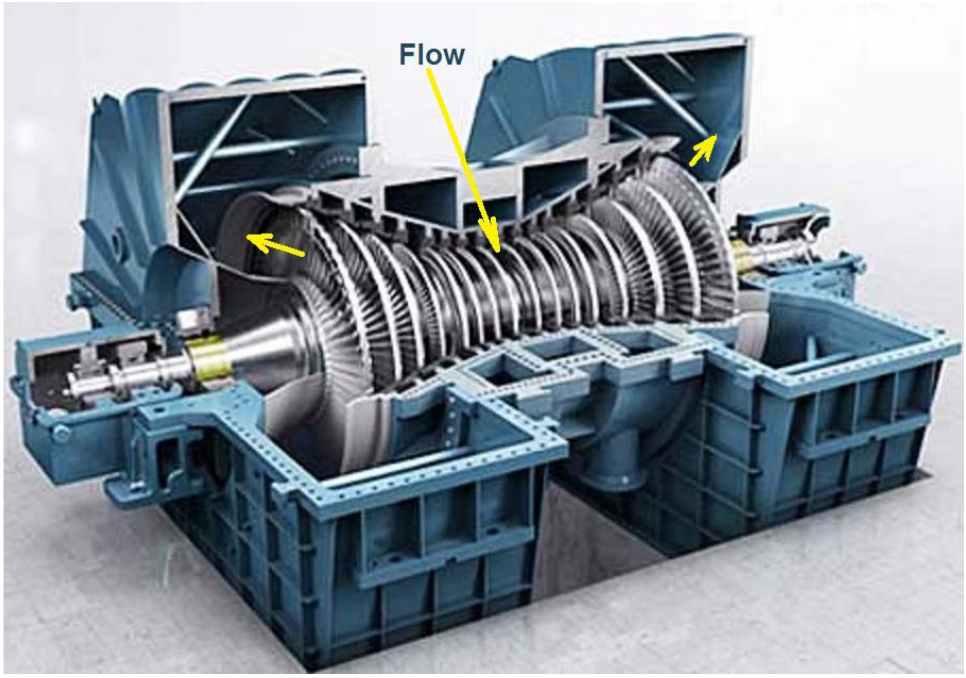

Figure 6: Schematic of an axial flow steam turbine.

of the gas turbine, problems that demand innovative surface cooling techniques. Jet engines also face the

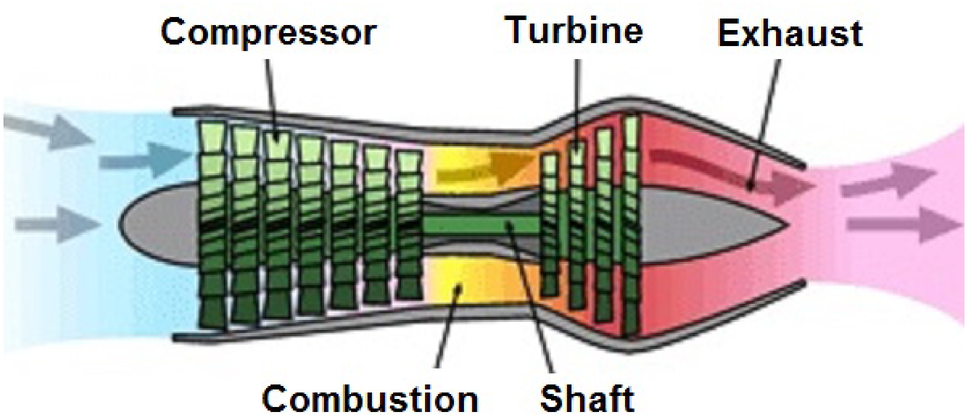

Figure 7: Schematic of a typical jet engine.

challenge of noise generation and, addressing this requires knowledge of the complex turbulent flows at the blade tips and in the interaction between rotor and stator stages.