Introduction

Historically turbines were the first form of mechanical power to be developed to replace animal power. In ancient times water turbines took the form of wheels driven by water diverted from a stream or river source as depicted by the example in Figure 1 (left) . In parallel, air turbines in the form of windmills were

Figure 1: Left: Ancient Chinese water wheel of the kind used in the Han dynasty. Right: Modern windmill in the Netherlands.

also a major source of power particularly for grain mills and, even today, can be seen in countries like the Netherlands (see Figure 1 (right)).

Modern turbines come in a great array of shapes and sizes and in a large range of designs. In the section (Mcb) that follows we give just a few examples of turbines from a range of different technological contexts. However an essential preamble is to recognize the basic turbomachine design parameters presented in section (Mac), particularly the specific speed, N, which, as depicted in Figure 2, provides a universal framework in which to present these examples. In practice these different types of turbines are optimal in specific ranges of flow rate and head. Figure 3 presents the common understanding of the ranges of head and flow where individual types of turbines are commonly used.

Hydraulic (or water) turbines are almost always used to generate electricity. Small independent hydropower systems are often operated "wild", in that their speed is unregulated and the generator is connected to

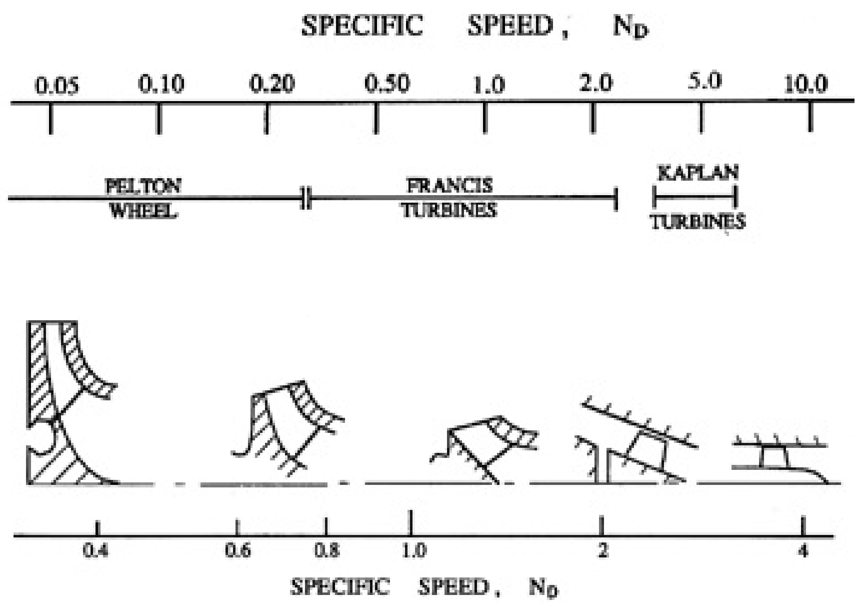

Figure 2: Typical turbine geometries for a range of specific speeds (from Sabersky, Acosta and Hauptmann 1989).

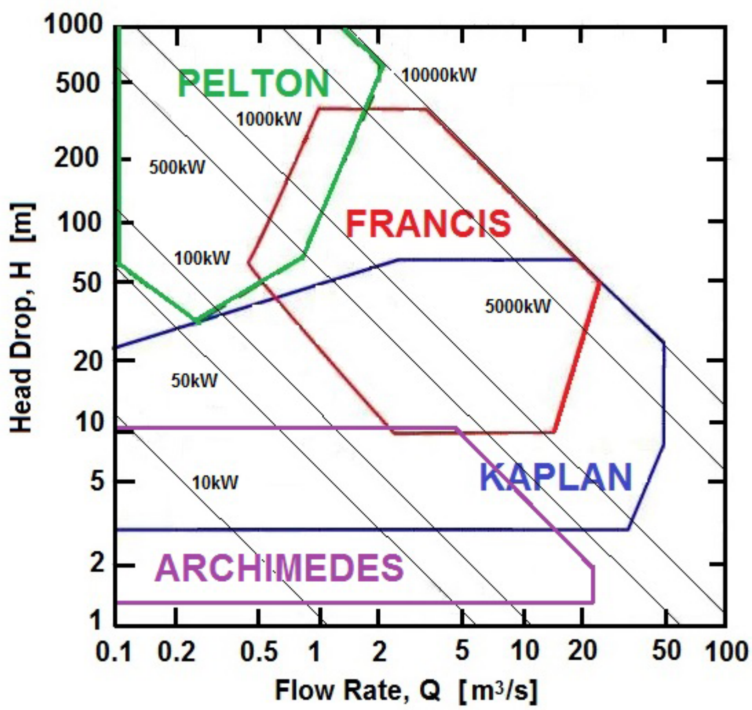

Figure 3: Ranges of head and flow in which the various turbine types are commonly used.

a rectifier that converts the signal from AC to DC to charge batteries. However large hydraulic turbines normally drive generators that supply power to an electrical grid and the electrical signal must therefore be closely controlled and match the grid frequency, $50Hz$ in Europe or $60Hz$ in North America. The rotation speed of the turbine is therefore fixed by this grid frequency and by the number of poles in the generator. Generally the rotation speed of large hydro turbines is in the range $35 - 75rpm$ though small units may operate as fast as $150rpm$. Thus control is a critical component of a hydraulic turbine system. The speed sensor must be linked to an actuator that controls the flow of water through the turbine and thus regulates the speed of rotation. Control of the flow is achieved in several ways. First, all turbines must have an inlet valve some distance upstream of the turbine in order to shut down the flow in the case of emergency or maintenance. This is usually a butterfly or ball valve. More sensitive flow control in a Pelton or impulse turbine (see section (???)) is normally achieved by means of a needle valve that controls the flow of water. In a large reaction turbine, a Francis or Kaplan turbine (see section (???)), flow control is achieved by means of a set of inlet guide vanes called ”wicket gates” whose inclination is varied to control the inlet flow angle, β, and therefore the flow rate.

The term ”gas turbine” is used not only for the device that extracts mechanical energy from compressed gas but also for the entire machine consisting of a compressor, combustor and turbine that drive a jet engine or power generator. Here we address only the former, namely the unit that converts the energy a gas stream into mechanical energy. Normally these are made up of one, two or more ”stages” each of which contains a non-rotating set of vanes called a ”stator” followed by a ”rotor” set into motion by the flow. The stator turns the flow to generate angular momentum that is converted to torque on the rotor. Each stage is characterized by a pressure ratio (ratio of the discharge pressure to the inlet pressure) that is usually in the range ?? - ??.