

Turbomachinery

Introduction:

The most common practical engineering application for fluid mechanics is the design of fluid machinery. The most numerous types are machines which add energy to the fluid (the pump family), but also important are those which extract energy (turbines). Both types are usually connected to a rotating shaft, hence the name turbomachinery.

Turbomachines divide naturally into those which add energy (**pumps**) and those which extract energy (**turbines**). The prefix turbo- is a Latin word meaning “spin” or “whirl,” appropriate for rotating devices.

Machines which deliver liquids are simply called **pumps**, but if gases are involved, three different terms are in use, depending upon the pressure rise achieved. If the pressure rise is very small (a few inches of water), a gas pump is called a **fan**; up to 1 atm, It is usually called a **blower**; and above 1 atm it is commonly termed a **compressor**.

1-TURBINES:

1.1-CLASSIFICATION OF TURBINES:

The main classification depends upon the type of action of the water on the turbine. These are:

- (i) **Impulse turbine.**
- (ii) **Reaction Turbine.**

In the case of impulse turbine all the potential energy is converted to kinetic energy in the nozzles. The impulse provided by the jets is used to turn the turbine wheel. The pressure inside the turbine is atmospheric. This type is found suitable when the available potential energy is high and the flow available is comparatively low. Some people call this type as tangential flow units. Later discussion will show under what conditions this type is chosen for operation.

(ii) In reaction turbines the available potential energy is progressively converted in the turbines rotors and the reaction of the accelerating water causes the turning of the wheel. These are again divided into radial flow, mixed flow and axial flow machines. Radial flow machines are found suitable for moderate levels of potential energy and medium quantities of flow. The axial machines are suitable for low levels of potential energy and large flow rates. The potential energy available is generally denoted as “head available”. With this terminology plants are designated as “high head”, “medium head” and “low head” plants.

1.2-SIMILITUDE AND MODEL TESTING:

Hydraulic turbines are mainly used for power generation and because of this these are large and heavy. The operating conditions in terms of available head and load fluctuation vary considerably. In spite of sophisticated design methodology, it is found the designs have to be validated by actual testing. In addition to the operation at the design conditions, the characteristics of operation under varying in put output conditions should be established. It is found almost impossible to test a full size unit under laboratory conditions. In case of variation of the operation from design conditions, large units

cannot be modified or scrapped easily. The idea of similitude and model testing comes to the aid of the manufacturer.

In the case of these machines more than three variables affect the characteristics of the machine, (speed, flow rate, power, head available etc.). It is rather difficult to test each parameter's influence separately. It is also not easy to vary some of the parameters. Dimensional analysis comes to our aid, for solving this problem.

The relevant parameters in the case of hydraulic machines have identified as:

1. The head coefficient, gH/N^2D^2 (1)
2. The flow coefficient, Q/ND^3 (2)
3. The power coefficient, $P/\rho N^3D^5$ (3)
4. The specific speed, $N p^{1/2}/\rho^{1/2}(gH)^{5/4}$ (4)

Consistent sets of units should be used to obtain numerical values. All the four dimensionless numbers are used in model testing. The last parameter has particular value when it comes to choosing a particular type under given available inputs and outputs. It has been established partly by experimentation and partly by analysis that the specific speed to some extent indicates the possible type of machine to provide the maximum efficiency under the given conditions. Figure (1-1) illustrates this idea. The representation is qualitative only. Note that as head decreases for the same power and speed, the specific speed increases.

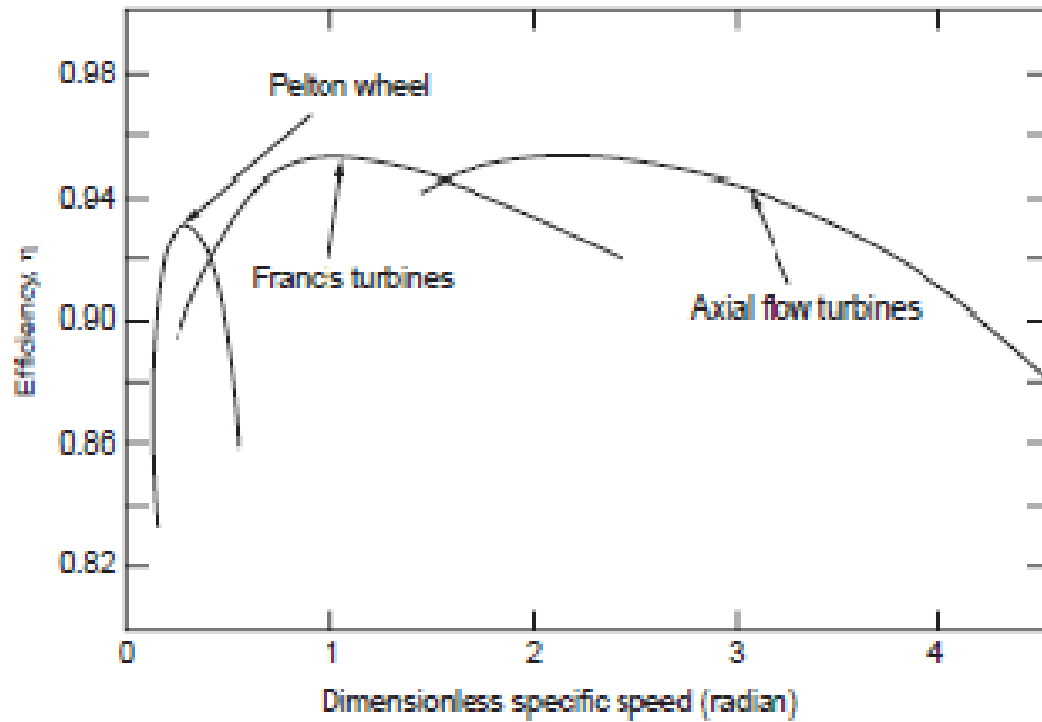


Figure (1-1) Variation of efficiency with specific speed

Figure (1-2) gives another information provided by the specific speed. As flow rate increases for the same specific speed efficiency is found also to increase. For the same flow rate, there is an increase in efficiency with specific speed.

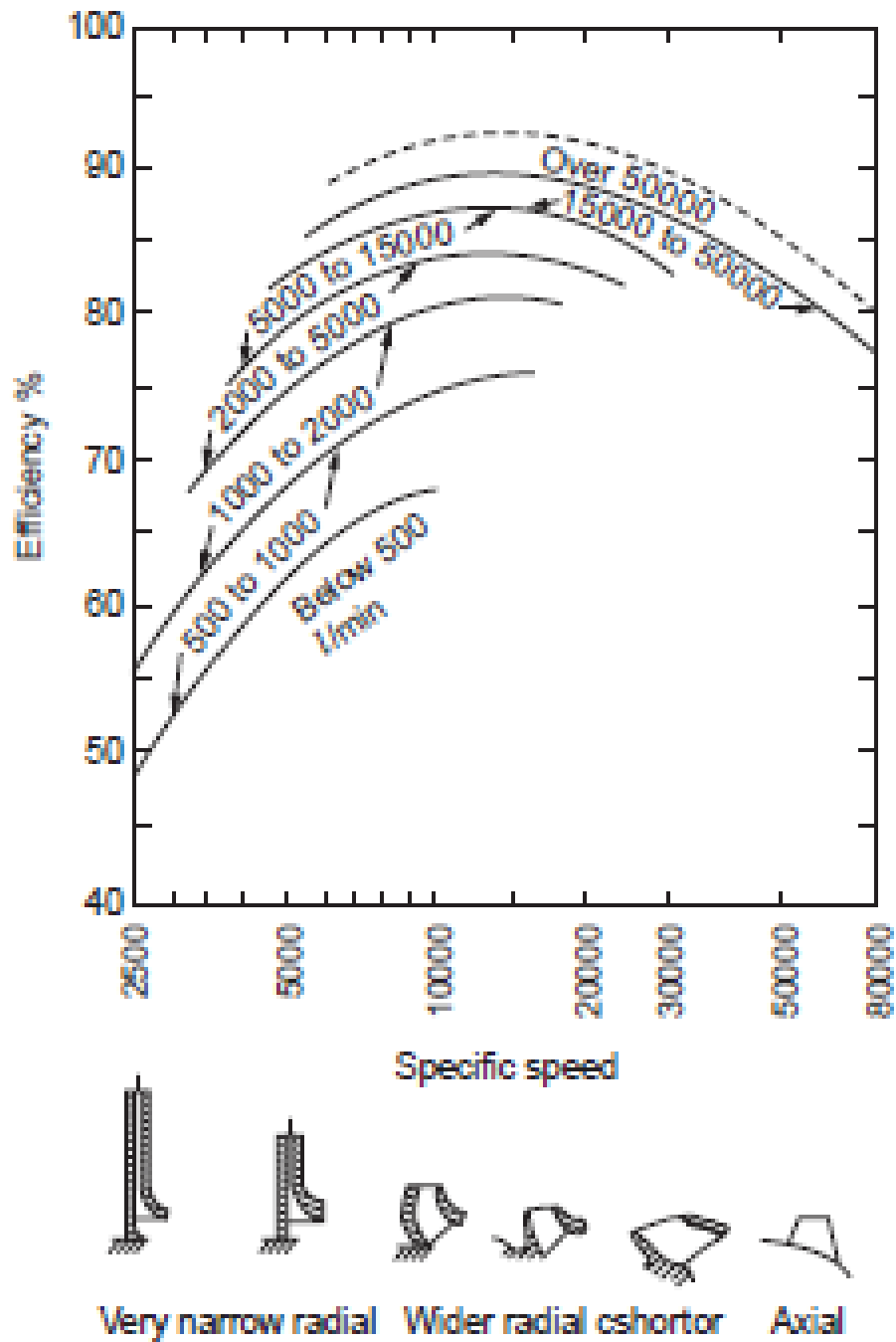


Figure (1-2): Variation of efficiency and flow passage with specific speed.

The expressions given in the equation (1) to (4) are dimensionless and will give the same numerical value irrespective of the system of units adopted. In practice dimensional specific speed is popularly used:

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

Where **N** is in rps, **P** in W and **H** in m.

Table (1-1) provides some guidance about the type of turbine suitable at various ranges of specific speeds.

Dimensionless specific speed range	Dimensional specific speed in SI system	Type of turbine having the best efficiency at these values
0.015—0.053	8—29	Single jet Pelton turbine
0.047—0.072	26—40	Twin jet Pelton turbine
0.72—0.122	40—67	Multiple jet Pelton turbine
0.122—0.819	67—450	Radial flow turbine Francis type ($H < 350\text{m}$)
0.663—1.66	364—910	Axial flow Kaplan turbine. ($H < 60\text{m}$)