Pressure Compounding or Rateau Staging

The Pressure - Compounded Impulse Turbine

To alleviate the problem of high blade velocity in the single-stage impulse turbine, the total enthalpy drop through the nozzles of that turbine are simply divided up, essentially in an equal manner, among many single-stage impulse turbines in series (Figure 24.1). Such a turbine is called a *Rateau turbine* , after its inventor. Thus the inlet steam velocities to each stage are essentially equal and due to a reduced Δh.

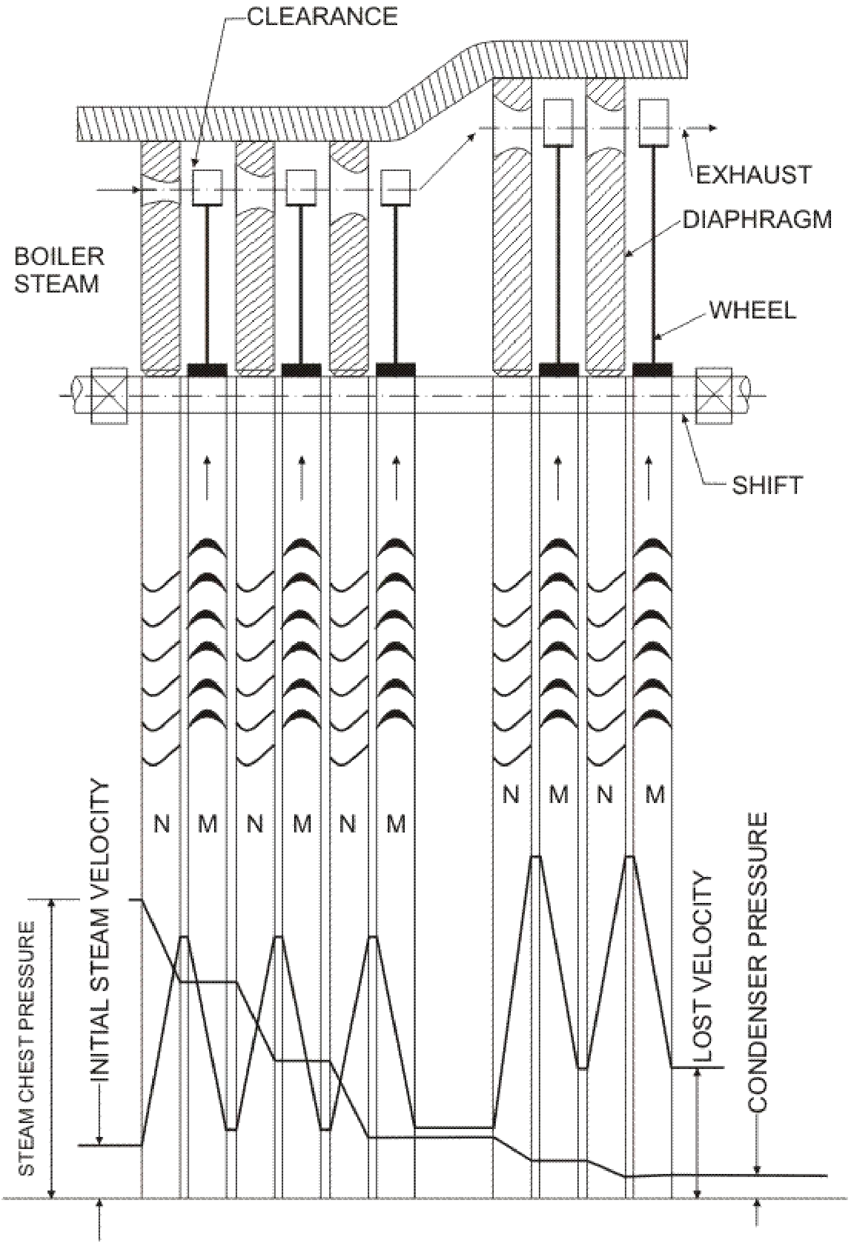

Figure 24.1 Pressure-Compounded Impulse Turbine

Pressure drop - takes place in more than one row of nozzles and the increase in kinetic energy after each nozzle is held within limits. Usually convergent nozzles are used

We can write

$$\underbrace{\frac{V_1^2}{2}+h_1}_{exit}=\underbrace{\frac{V_2^2}{2}+h_2}_{inlet} \qquad (24.1)$$

$$\eta_N=\frac{V_1^2-\varphi V_2^2}{2(\Delta h)_{isentropic}} \qquad (24.2)$$

where ϕ is carry over coefficient

Reaction Turbine

A ***reaction turbine***, therefore, is one that is constructed of rows of fixed and rows of moving blades.

The fixed blades act as nozzles. The moving blades move as a result of the impulse of steam received (caused by change in momentum) and also as a result of expansion and acceleration of the steam relative to them. In other words, they also act as nozzles. The enthalpy drop per stage of one row fixed and one row moving blades is divided among them, often equally. Thus a blade with a 50 percent degree of reaction, or a 50 percent reaction stage, is one in which half the enthalpy drop of the stage occurs in the fixed blades and half in the moving blades. The pressure drops will not be equal, however. They are greater for the fixed blades and greater for the high-pressure than the low-pressure stages.

The moving blades of a reaction turbine are easily distinguishable from those of an impulse turbine in that they are not symmetrical and, because they act partly as nozzles, have a shape similar to that of the fixed blades, although curved in the opposite direction. The schematic pressure line (Fig. 24.2) shows that pressure continuously drops through all rows of blades, fixed and moving. The absolute steam velocity changes within each stage as shown and repeats from stage to stage. Figure 24.3 shows a typical velocity diagram for the reaction stage.

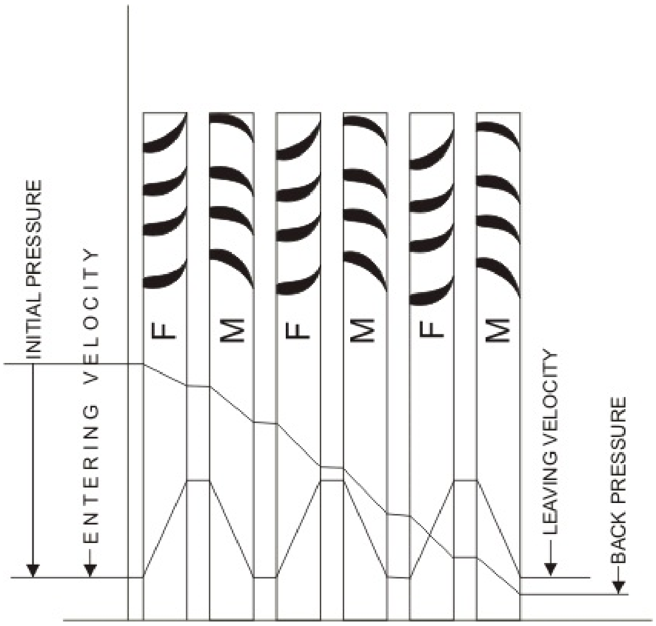

Figure 24.2 Three stages of reaction turbine indicating pressure and velocity distribution

Pressure and enthalpy drop both in the fixed blade or **stator** and in the moving blade or **Rotor**

$$\text{Degree of Reaction} = \frac{\textit{Enthalpy drop in Rotor}}{\textit{Enthalpy drop in Stage}}$$

$$\text{or,} \qquad R = \frac{h_1 - h_2}{h_0 - h_1} \qquad (24.3)$$

A very widely used design has half degree of reaction or 50% reaction and this is known as Parson's Turbine. This consists of symmetrical stator and rotor blades.

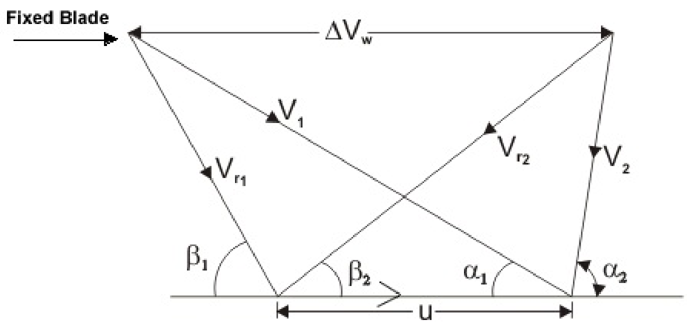

Figure 24.3 The velocity diagram of reaction blading

The velocity triangles are symmetrical and we have

$$\alpha_1 = \beta_2 \quad , \quad \beta_1 = \alpha_2$$

$$V_1 = V_{r2} \quad , \quad V_{r1} = V_2$$

Energy input per stage (unit mass flow per second)

$$E = \frac{V_1^2}{2} + \frac{V_{r2}^2 - V_{r1}^2}{2}$$

$$E = V_1^2 - \frac{V_{r1}^2}{2} \qquad (24.4)$$

$$E = V_1^2 - \frac{V_1^2}{2} - \frac{U^2}{2} + \frac{2V_1 U \cos\alpha_1}{2}$$

$$E = \left(V_1^2 - U^2 + 2V_1 U \cos\alpha_1\right)/2 \qquad (24.5)$$

From the inlet velocity triangle we have,

$$V_{r1}^2 = V_1^2 - U^2 - 2V_1 U \cos\alpha_1$$

Work done (for unit mass flow per second) $= W = U\Delta V_W$

$$= U(2V_1 \cos\alpha_1 - U) \qquad (24.6)$$

Therefore, the Blade efficiency

$$= \eta_b = \frac{2U(2V_1 \cos\alpha_1 - U)}{V_1^2 - U^2 + 2V_1 U \cos\alpha_1} \qquad (24.7)$$