# A presentation on
# **Steam Turbines**

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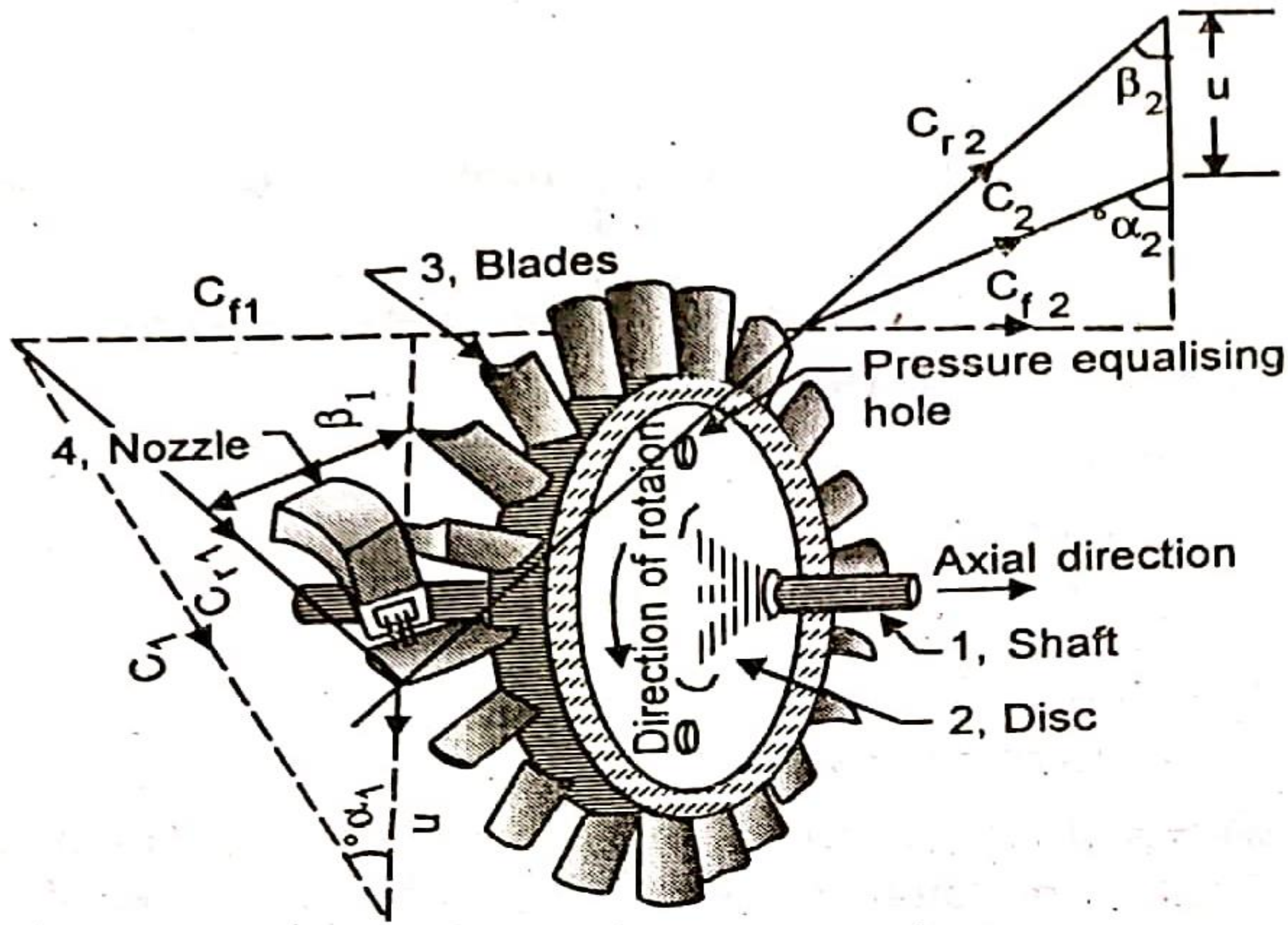
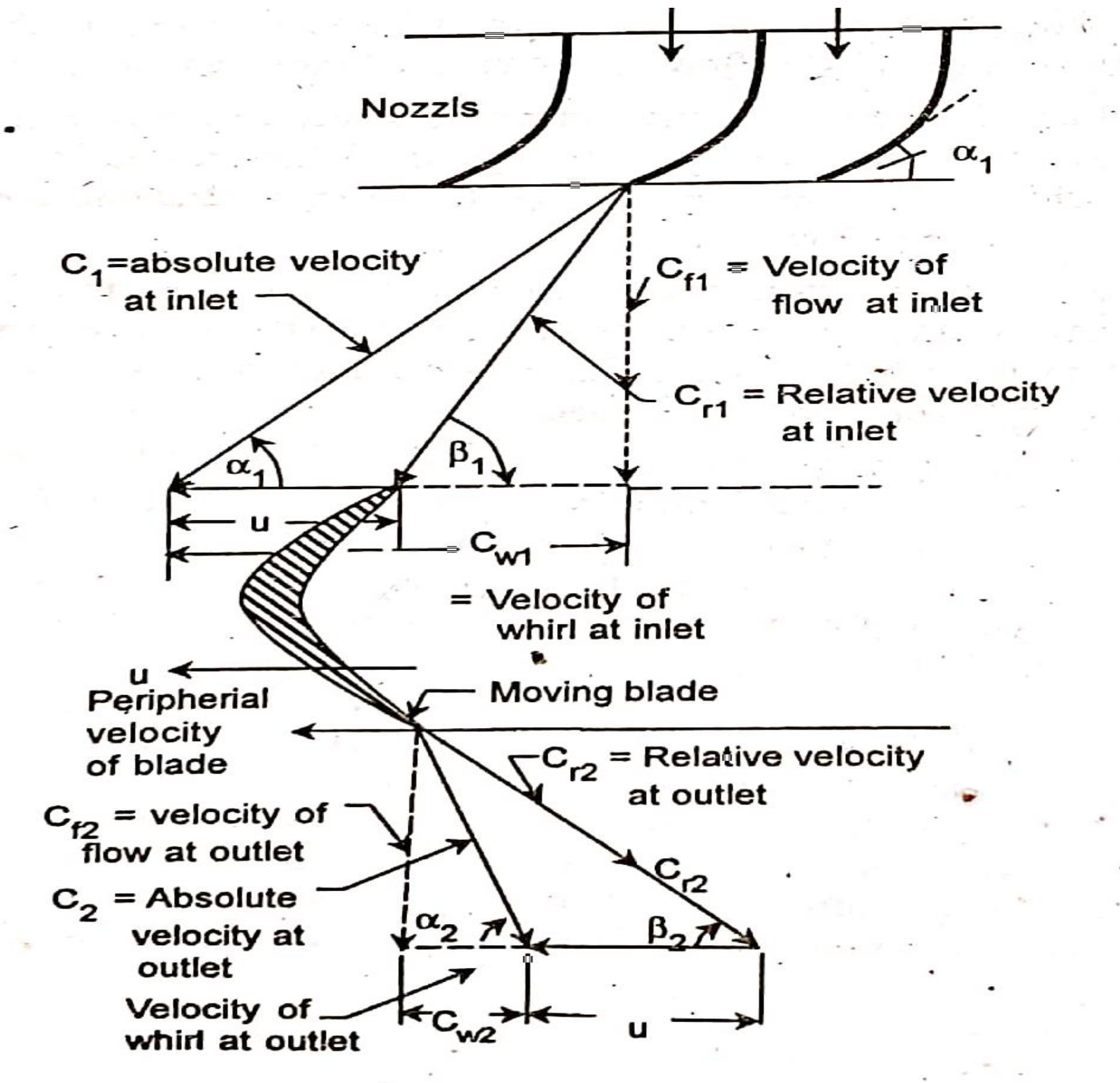
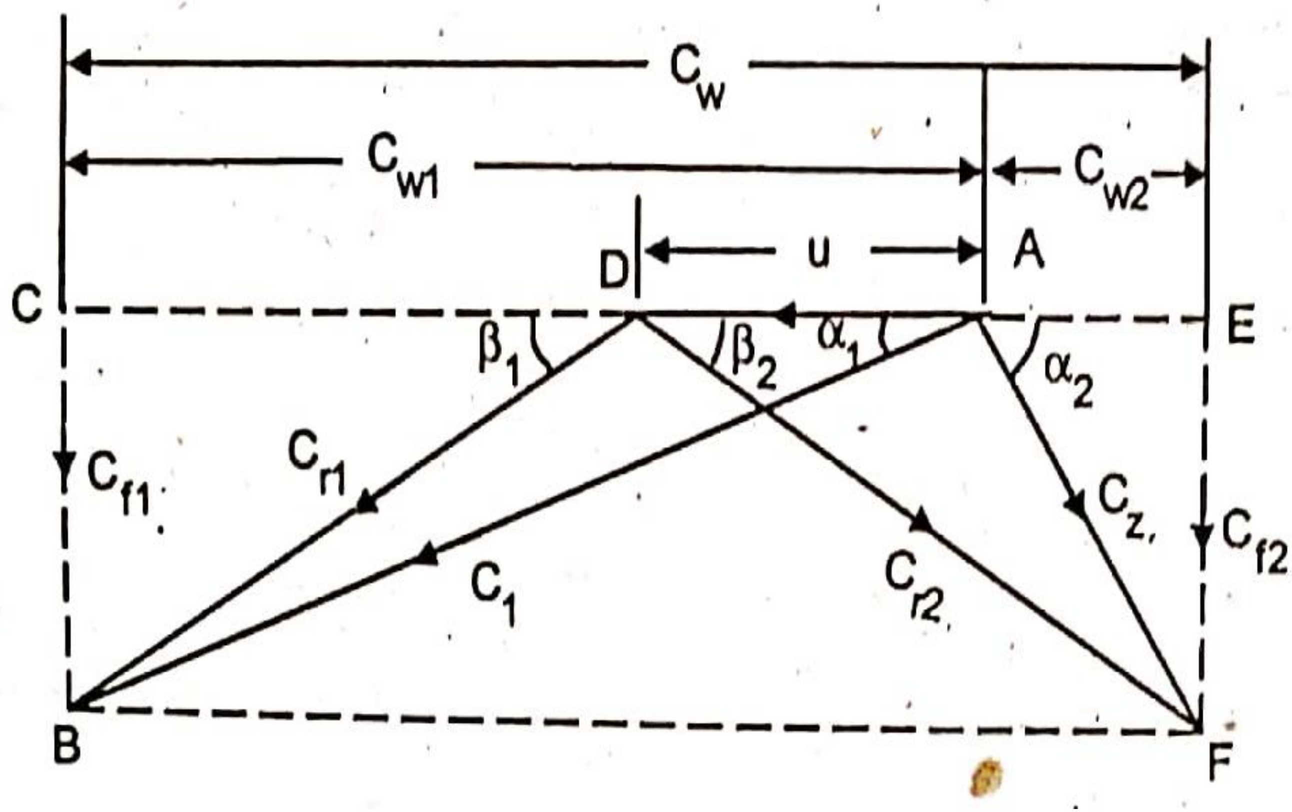
# IMPULSE TURBINE



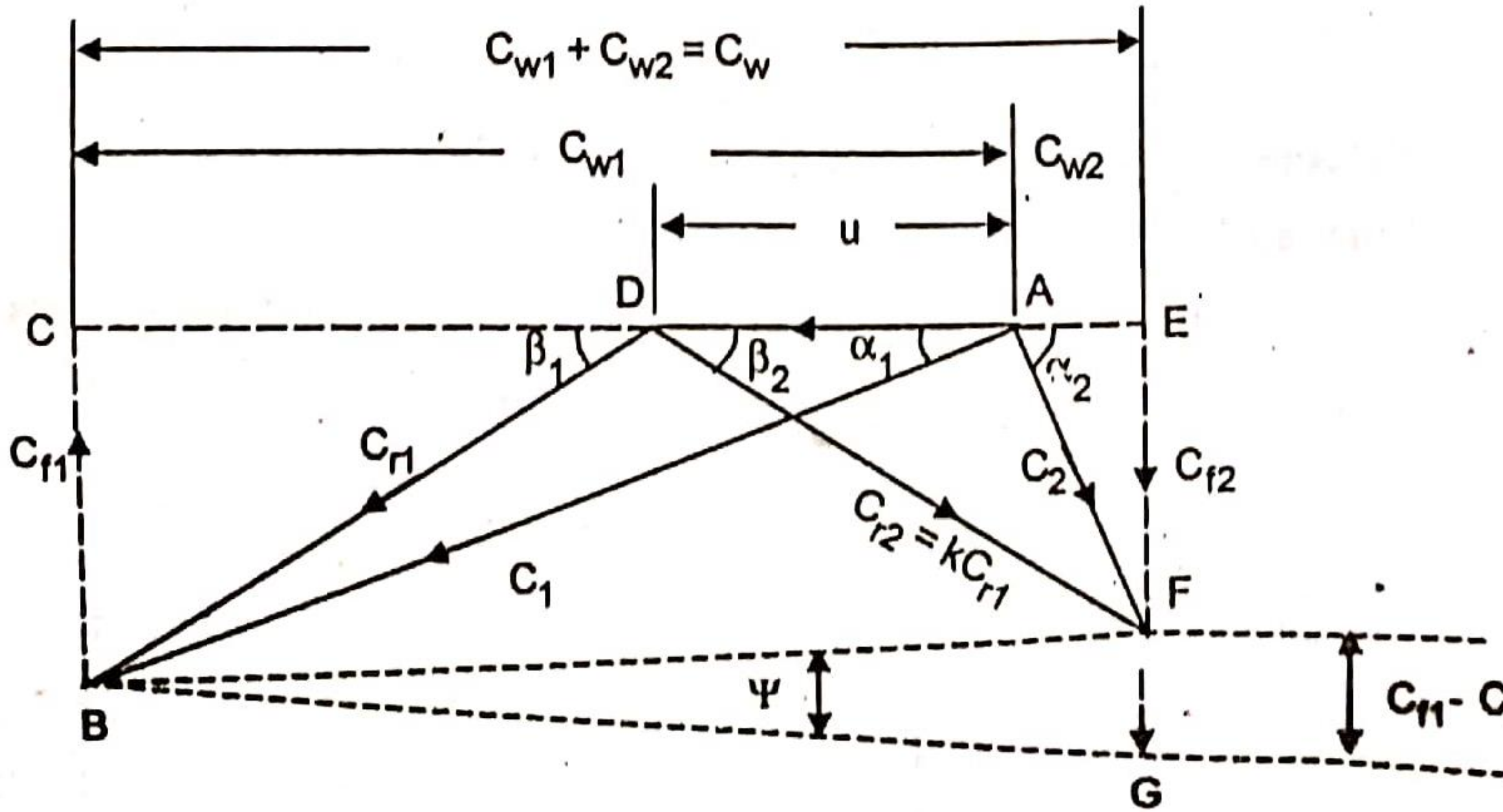
# Velocity diagram for impulse turbine



# Combine velocity diagram



# Velocity diagram showing effect of friction



# Force on the blade and Work done by blade

$$F_t = \dot{m}\,(C_{w1} \pm C_{w2})$$

$C_{w1}$ and $C_{w2}$ *is draw perpendiculars from B and F on the horizontal line*

***Work and power***

$$W = F_t \,.\, u = \dot{m}\,(C_{w1} + C_{w2})u\,; \qquad \text{W}$$

$$\text{Power} = \text{P} = \frac{\dot{m}\,.\,(C_{w1} + C_{w2})\,.\,u}{1000} = \frac{\dot{m}\;.\;C_w\,.\,u}{1000}\,; \qquad \text{kW}$$

- Blade or Diagram efficiency

$$\eta_b = \frac{\dot{m}\, u\, C_w}{\dot{m}\, C_1^2/2} = \frac{2\, u\, C_w}{C_1^2}$$

- Axial thrust or End thrust of the rotor

$$\text{Axial force} = F_a = \dot{m}\,(C_{f1} - C_{f2}) \quad ; N$$

- Gross stage efficiency

$$\eta_{gs} = u\ .\ C_w / \Delta h_{isen} = \left(\frac{2u\ .\ C_w}{C_1^2}\right)\left(\frac{C_1^2}{2\,\Delta h_{iesn}}\right)$$

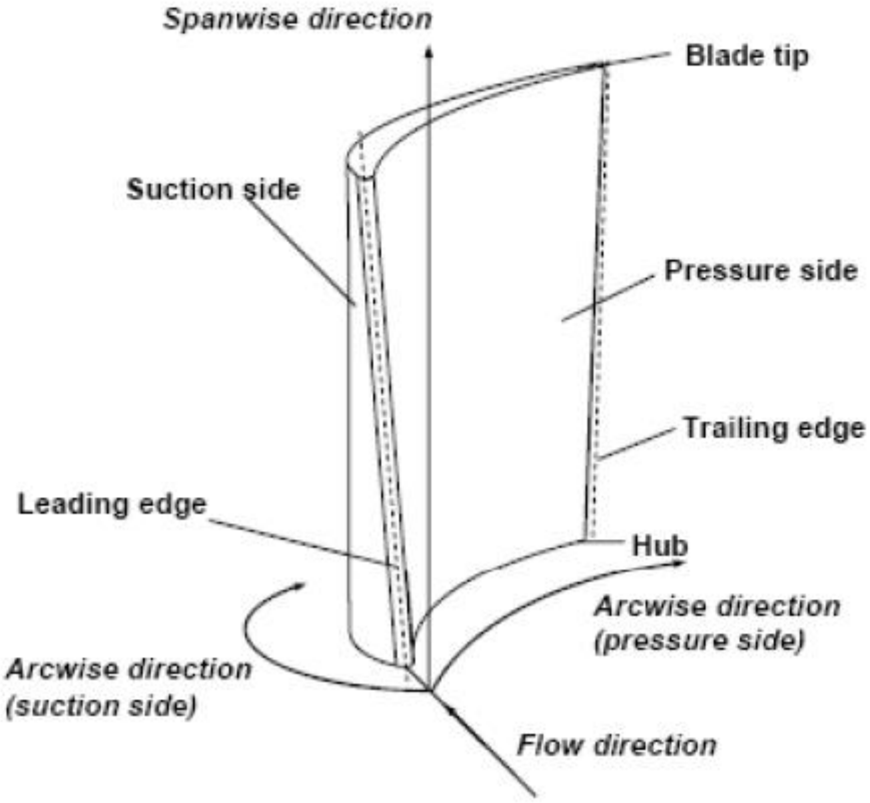
- Energy converted to heat by blade friction

$$Q_{friction} = \dot{m}\left(\frac{C_{r1}^2 - C_{r2}^2}{2}\right), \qquad W$$

# Velocity Triangles

- The three velocity vectors namely, blade speed, absolute velocity and relative velocity in relation to the rotor are used to form a triangle called velocity triangle.
- Velocity triangles are used to illustrate the flow in the bladings of turbo machinery.
- Changes in the flow direction and velocity are easy to understand with the help of the velocity triangles.
- Note that the velocity triangles are drawn for the inlet and outlet of the rotor at certain radii.

# Steam Turbine Blade Terminology



# Degree of reaction

- **Degree of reaction** is a parameter that describes the relation between the energy transfer due to the static pressure change and the energy transfer due to dynamic pressure change.
- **Degree of reaction** is defined as the ratio of static pressure drop in the rotor to the static pressure drop in the stage. It is also defined as the ratio of static enthalpy drop in the rotor to the static enthalpy drop in the stage

# Degree of reaction

$$\Lambda = \frac{(h_1 - h_2)}{\left(h_{00} - \frac{V_0^2}{2C_p}\right) - \left(h_{02} - \frac{V_2^2}{2C_p}\right)}$$

**Zero reaction stage**

Let us first discuss the special case of zero reaction. According to the definition

of reaction, When Λ = 0, equation (upper) reveals that h1 = h2 and equation (lower) that

β1 = β2.

$$\Lambda = \frac{1}{2} + \frac{V_a}{2U}(\tan\beta_2 + \tan\alpha_2)$$

Putting Λ = 0 in equation we get

$(\beta_2 = \beta_1)$ And $V_1 = V_2$ and for Λ = 0.5, $(\beta_2 = \alpha_1)$

**Fifty percent reaction stage**

From equation (16) for Λ = 0.5 α1 = β2 and the velocity diagram is symmetrical Because of symmetrical. symmetry, it is also clear that α2 = β1. For Λ=1/2,

the enthalpy drop in the nozzle row equals the enthalpy drop in the rotor.

h0 - h1 = h1 - h2

# Blade Height in Axial Flow turbine

The continuity equation $\dot{m} = \rho AV$ may be used to find the blade height 'h'. The annular area of flow = πDh. Thus the mass flow rate through an axial flow turbine is

$$\dot{m} = \rho \pi D h V_a$$

$$h = \frac{\dot{m}}{\rho \pi D V_a}$$

Blade height will increase in the direction of flow in a turbine and decrease in the direction of flow in a compressor.

# Losses in Steam Turbine

- **Profile loss:** Due to formation of boundary layer on blade surfaces. Profile loss is a boundary layer phenomenon and therefore subject to factors that influence boundary layer development. These factors are Reynolds number, surface roughness, exit Mach number and trailing edge thickness.
- **Secondary loss**: Due to friction on the casing wall and on the blade root and tip. It is a boundary layer effect and dependent upon the same considerations as those of profile loss.
- **Tip leakage loss:** Due to steam passing through the small clearances required between the moving tip and casing or between the moving blade tip and rotating shaft. The extend of leakage depends on the whether the turbine is impulse or reaction. Due to pressure drop in moving blades of reaction turbine they are more prone to leakages.
- **Disc windage loss**: Due to surface friction created on the discs of an impulse turbine as the disc rotates in steam atmosphere. The result is the forfeiture of shaft power for an increase in kinetic energy and heat energy of steam

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- **Lacing wire loss**: Due to passage blockage created by the presence of lacing wires in long blade of LP Stages.
- **Wetness loss**: Due to moisture entrained in the low pressure steam at the exit of LP turbine. The loss is a combination of two effects; firstly, reduction in efficiency due to absorption of energy by the water droplets and secondly, erosion of final moving blades leading edges.
- **Annulus loss**: Due to significant amount of diffusion between adjacent stages or where wall cavities occur between the fixed and moving blades. The extent of loss is greatly reduced at high annulus area ratios (inlet/outlet) if the expansion of the steam is controlled by a flared casing wall.
- **Leaving loss**: Due to kinetic energy available at the steam leaving from the last stage of LP turbine. In practice steam does slow down after leaving the last blade, but through the conversion of its kinetic energy to flow friction losses.
- **Partial admission loss**: Due to partial filling of steam, flow between the blades is considerably accelerated causing a loss in power.

# THANK YOU