UNIT-8

DE Laval Turbine

CLASSIFICATION OF STEAM TURBINES

According to the action of steam:

- *Impulse turbine:* In impulse turbine, steam coming out through a fixed nozzle at a very high velocity strikes the blades fixed on the periphery of a rotor. The blades change the direction of steam flow without changing its pressure. The force due to change of momentum causes the rotation of the turbine shaft. Ex: De-Laval, Curtis and Rateau Turbines

- *Reaction turbine:* In reaction turbine, steam expands both in fixed and moving blades continuously as the steam passes over them. The pressure drop occurs continuously over both moving and fixed blades.

- *Combination of impulse and reaction turbine*

CLASSIFICATION OF STEAM TURBINES

According to the number of pressure stages:

- *Single stage turbines:* These turbines are mostly used for driving centrifugal compressors, blowers and other similar machinery.
- *Multistage Impulse and Reaction turbines:* They are made in a wide range of power capacities varying from small to large.

According to the type of steam flow:

- *Axial turbines:* In these turbines, steam flows in a direction parallel to the axis of the turbine rotor.
- *Radial turbines:* In these turbines, steam flows in a direction perpendicular to the axis of the turbine, one or more low pressure stages are made axial.

CLASSIFICATION OF STEAM TURBINES

According to the number of shafts:

- *Single shaft turbines*
- *Multi-shaft turbines*

According to the method of governing:

- *Turbines with throttle governing:* In these turbines, fresh steam enter through one or more (depending on the power developed) simultaneously operated throttle valves.
- *Turbines with nozzle governing:* In these turbines, fresh steam enters through one or more consecutively opening regulators.
- *Turbines with by-pass governing:* In these turbines, the steam besides being fed to the first stage is also directly fed to one, two or even three intermediate stages of the turbine.

CLASSIFICATION OF STEAM TURBINES

According to the heat drop process:

- *Condensing turbines with generators:* In these turbines, steam at a pressure less than the atmospheric is directed to the condenser. The steam is also extracted from intermediate stages for feed water heating). The latent heat of exhaust steam during the process of condensation is completely lost in these turbines.
- *Condensing turbines with one or more intermediate stage extractions:* In these turbines, the steam is extracted from intermediate stages for industrial heating purposes.
- *Back pressure turbines:* In these turbines, the exhaust steam is utilized for industrial or heating purposes. Turbines with deteriorated vacuum can also be used in which exhaust steam may be used for heating and process purposes.
- *Topping turbines:* In these turbines, the exhaust steam is utilized in medium and low pressure condensing turbines. These turbines operate at high initial conditions of steam pressure and temperature, and are mostly used during extension of power station capacities, with a view to obtain better efficiencies.

CLASSIFICATION OF STEAM TURBINES

According to the steam conditions at inlet to turbine:

- *Low pressure turbines:* These turbines use steam at a pressure of 1.2 ata to 2 ata.
- *Medium pressure turbines:* These turbines use steam up to a pressure of 40 ata.
- *High pressure turbines:* These turbines use steam at a pressure above 40 ata.
  - *Very high pressure turbines:* These turbines use steam at a pressure of 170 ata and higher and temperatures of 550°C and higher.
- *Supercritical pressure turbines:* These turbines use steam at a pressure of 225 ata and higher.

CLASSIFICATION OF STEAM TURBINES

According to their usage in industry:

- *Stationary turbines with constant speed of rotation:* These turbines are primarily used for driving alternators.
- *Stationary turbines with variable speed of rotation:* These turbines are meant for driving turbo-blowers, air circulators, pumps, etc.
- *Non-stationary turbines with variable speed:* These turbines are usually employed in steamers, ships and railway locomotives.

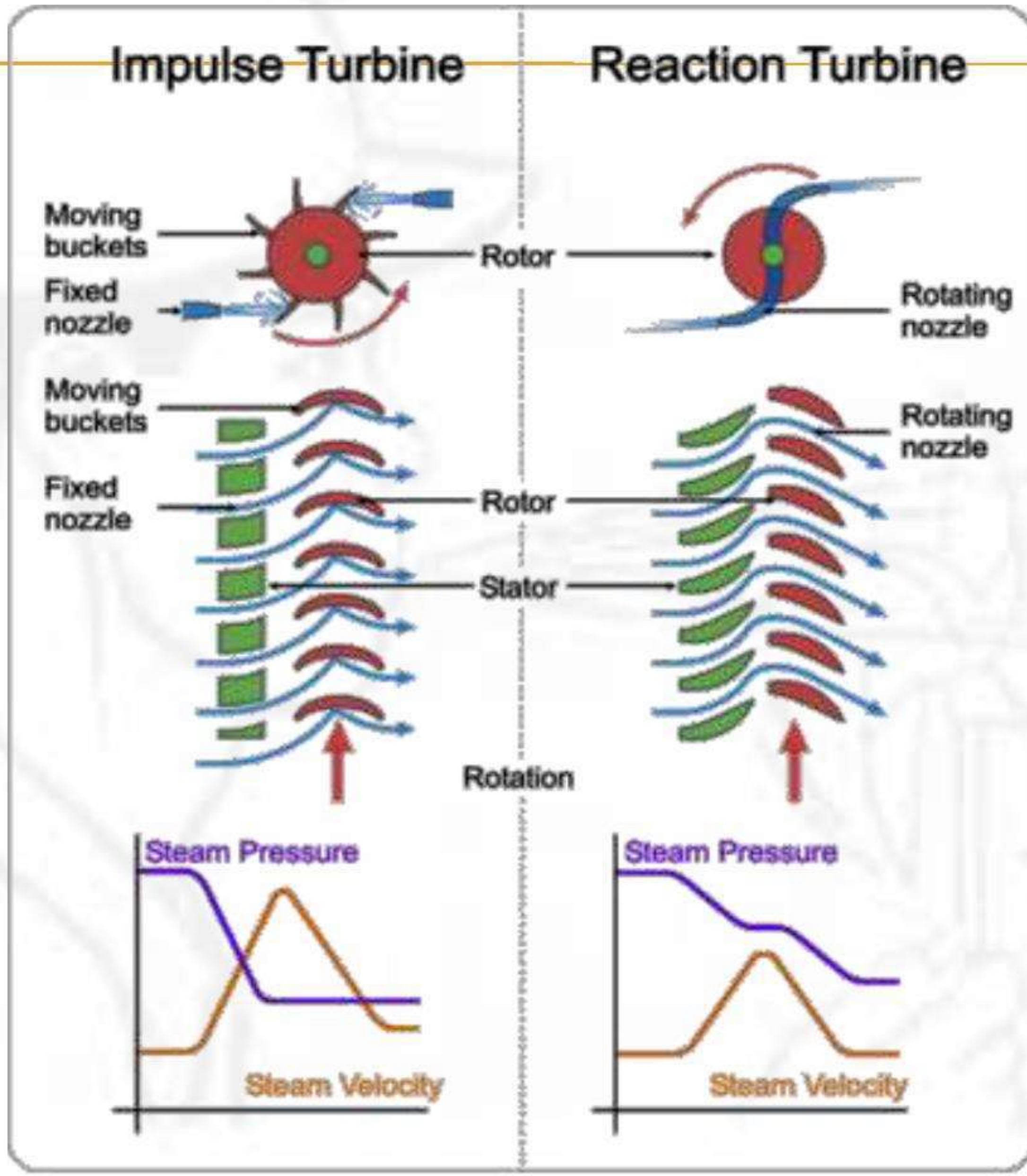
ADVANTAGES OF STEAM TURBINES OVER STEAM ENGINES

1. The thermal efficiency is much higher.
2. As there is no reciprocating parts, perfect balancing is possible and therefore heavy foundation is not required.
3. Higher and greater range of speed is possible.
4. The lubrication is very simple as there are no rubbing parts.
5. The power generation is at uniform rate & hence no flywheel is required.
6. The steam consumption rate is lesser.
7. More compact and require less attention during operation.
8. More suitable for large power plants.
9. Less maintenance cost as construction and operation is highly simplified due to absence of parts like piston, piston rod, cross head, connecting rod.
10. Considerable overloads can be carried at the expense of slight reductio in overall efficiency.

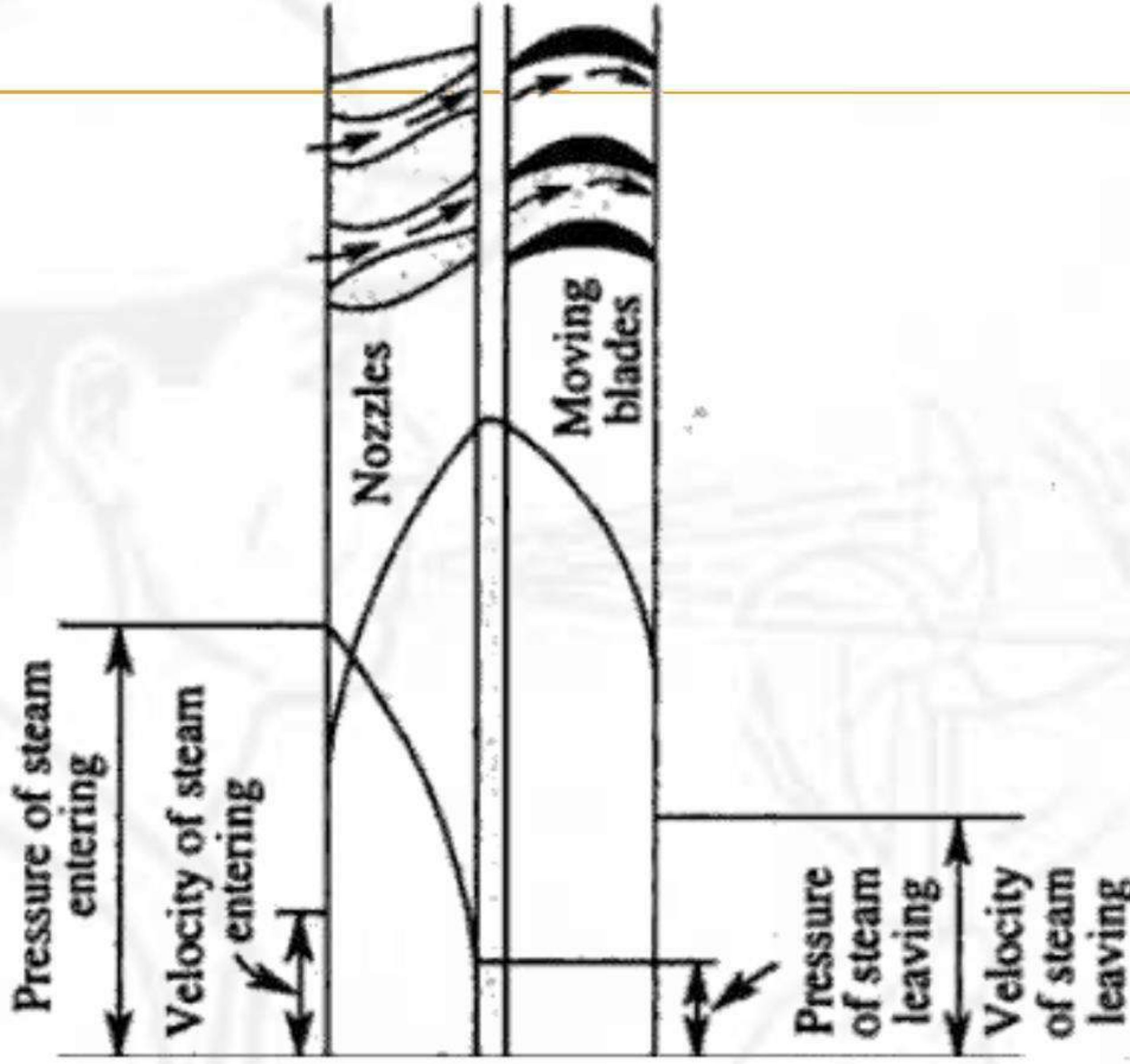
IMPULSE TURBINE VS REACTION TURBINE

Impulse turbine	Reaction turbine
The steam completely expands in the nozzle and its pressure remains constant during its flow through the blade passages	The steam expands partially in the nozzle and further expansion takes place in the rotor blades
The relative velocity of steam passing over the blade remains constant in the absence of friction	The relative velocity of steam passing over the blade increases as the steam expands while passing over the blade
Blades are symmetrical	Blades are asymmetrical
The pressure on both ends of the moving blade is same	The pressure on both ends of the moving blade is different
For the same power developed, as pressure drop is more, the number of stages required are less	For the same power developed, as pressure drop is small, the number of stages required are more
The blade efficiency curve is less flat	The blade efficiency curve is more flat
The steam velocity is very high and therefore the speed of turbine is high.	The steam velocity is not very high and therefore the speed of turbine is low.

IMPULSE TURBINE VS REACTION TURBINE



SIMPLE IMPULSE TURBINE



Diagrammatic sketch of a simple impulse turbine

IMPUSLE PRINCIPLE

- The impulse turbine consists basically of a rotor mounted on a shaft that is free to rotate in a set of bearings.
- The outer rim of the rotor carries a set of curved blades, and the whole assembly is enclosed in an airtight case.
- Nozzles direct steam against the blades and turn the rotor. The energy to rotate an impulse turbine is derived from the kinetic energy of the steam flowing through the nozzles.
- The term impulse means that the force that turns the turbine comes from the impact of the steam on the blades.

IMPULSE PRINCIPLE

- The toy pinwheel can be used to study some of the basic principles o turbines. When we blow on the rim of the wheel, it spins rapidly. The harder we blow, the faster it turns.
- The steam turbine operates on the same principle, except it uses the kinetic energy from the steam as it leaves a steam nozzle rather than air.
- Steam nozzles are located at the turbine inlet. As the steam passes through a steam nozzle, potential energy is converted to kinetic energy.
- This steam is directed towards the turbine blades and turns the rotor. The velocity of the steam is reduced in passing over the blades.
- Some of its kinetic energy has been transferred to the blades to turn the rotor.
- Impulse turbines may be used to drive forced draft blowers, pumps, and main propulsion turbines.

BASICS OF IMPULSE TURBINE

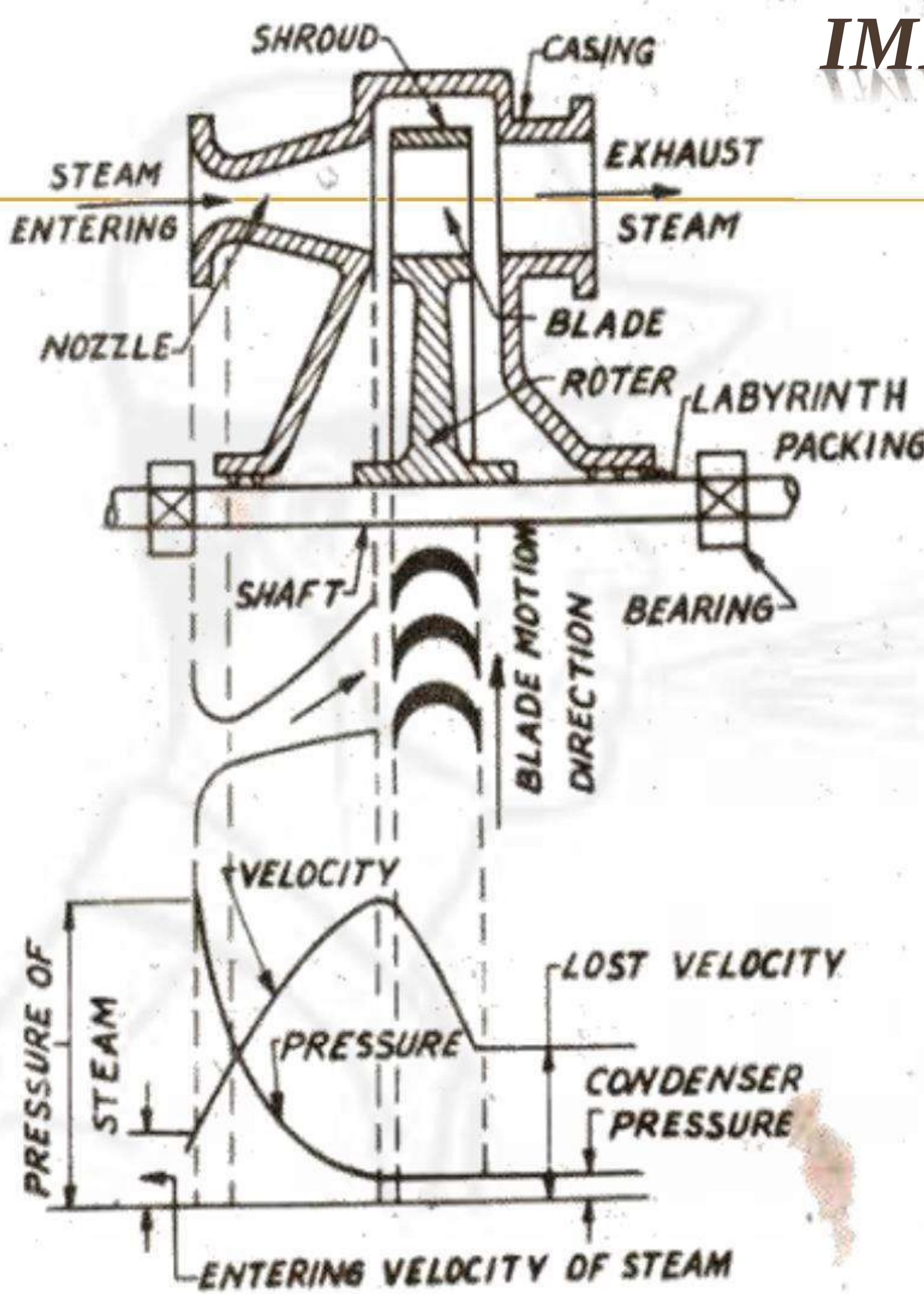
- In impulse turbine, steam coming out through a fixed nozzle at a very high velocity strikes the blades fixed on the periphery of a rotor.
- The blades change the direction of steam flow without changing its pressure.
- The force due to change of momentum causes the rotation of the turbine shaft.
- Examples: De-Laval, Curtis and Rateau turbines.

CONSTRUCTION & WORK PRINCIPLE

OF IMPULSE PRINCIPLE

- It primarily consists of a nozzle or a set of nozzles, a rotor mounted on a shaft, one set of moving blades attached to the rotor and a casing.
- A simple impulse turbine is also called De-Laval turbine, after the name of its inventor
- This turbine is called *simple* impulse turbine since the expansion of the steam takes place in one set of nozzles.

IMPULSE PRINCIPLE



IMPULSE TURBINE

- The uppermost portion of the diagram shows a longitudinal section through the upper half of the turbine.
- The middle portion shows the actual shape of the nozzle and blading.
- The bottom portion shows the variation of absolute velocity and absolute pressure during the flow of steam through passage of nozzles and blades.
- The expansion of steam from its initial pressure (steam chest pressure) to final pressure (condenser pressure) takes place in one set of nozzles.
- Due to high drop in pressure in the nozzles, the velocity of steam in the nozzles increases.

IMPULSE TURBINE

- The steam leaves the noz
a very high velocity and
strikes the blades of the turb
mounted on a wheel with th
high velocity.

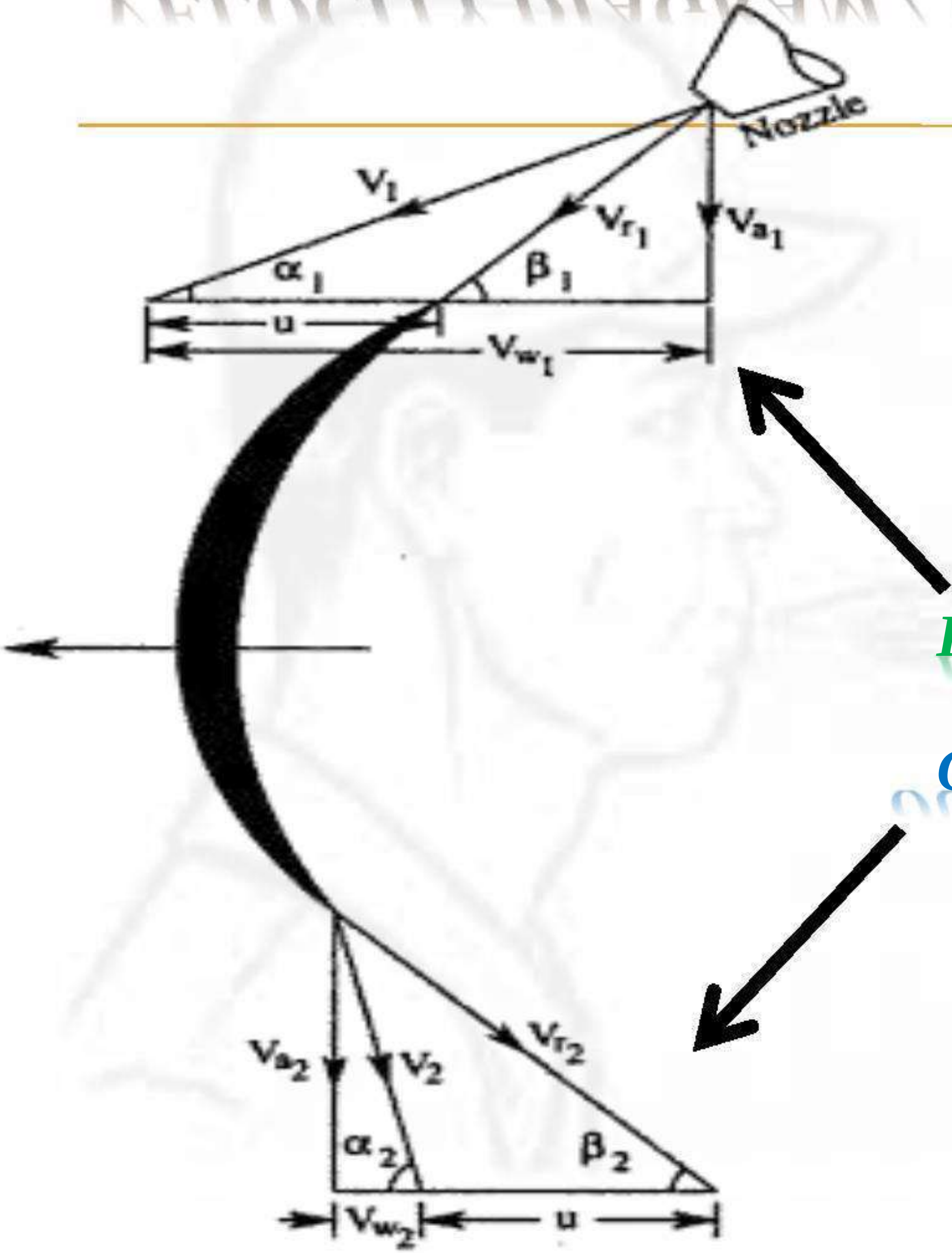
- The loss of energy due to this higher exit velocity is commonly known as *carry over loss* (or) *leaving loss*.
- The pressure of the steam when it moves over the blades remains constant but the velocity decreases.
- The exit/leaving/lost velocity may amount to 3.3 percent of the nozzle outlet velocity.
- Also since all the KE is to be absorbed by one ring of the moving blades only, the velocity of wheel is too high (varying from 25000 to 30000 RPM).
- However, this wheel or rotor speed can be reduced by adopting the method of compounding of turbines.

DISADVANTAGES OF IMPULSE TURBINE

1. Since all the KE of the high velocity steam has to be absorbed in only one ring of moving blades, the velocity of the turbine is too high i.e. up to 30000 RPM for practical purposes.

2. The velocity of the steam at exit is sufficiently high which means that there is a considerable loss of KE.

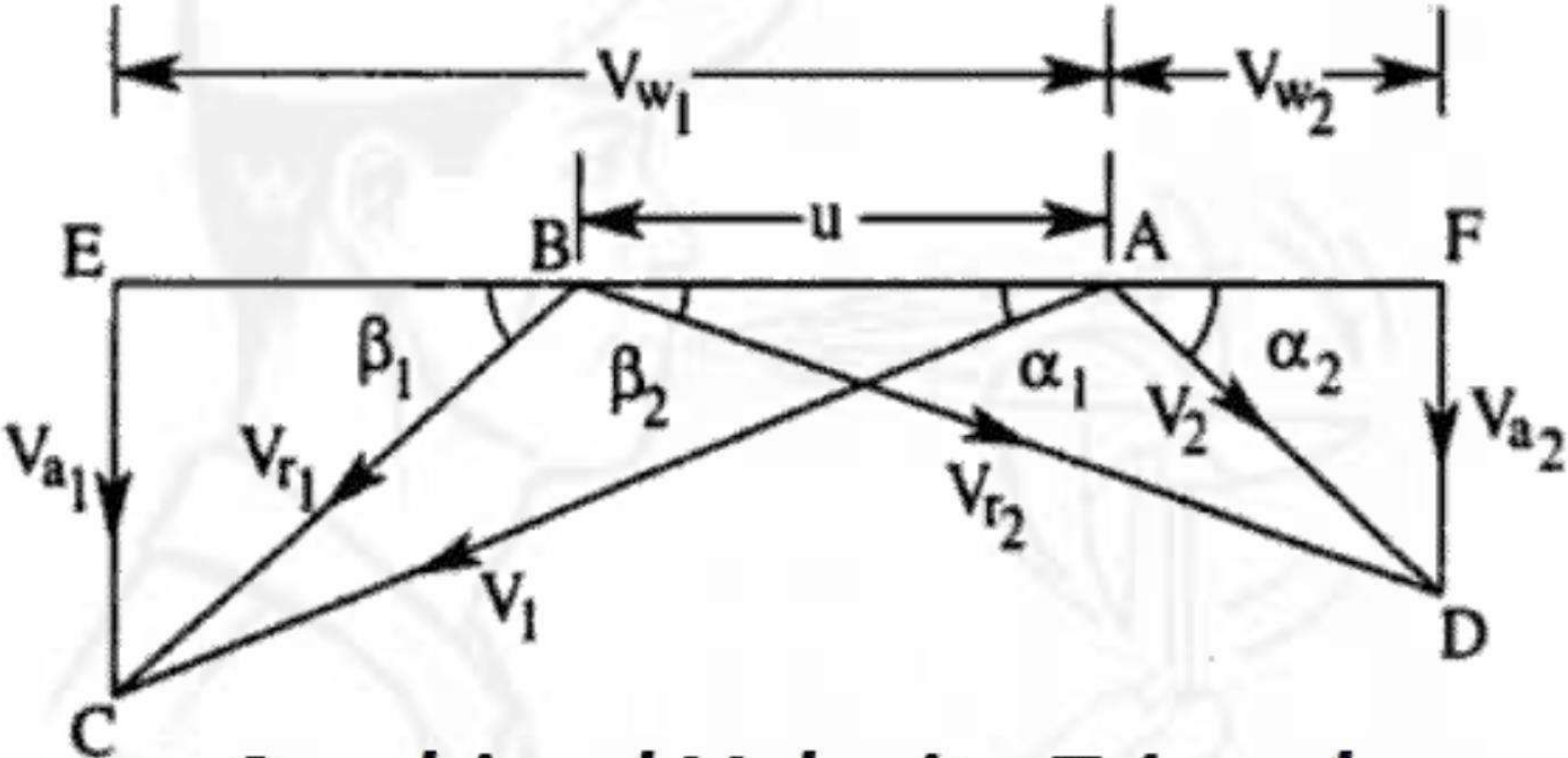
VELOCITY DIAGRAM / VELOCITY TRIANGLE



INLET VELOCITY TRIANGLE

OUTLET VELOCITY TRIANGLE

COMBINED VELOCITY TRIANGLE



Combined Velocity Triangle

NOTATIONS

V_1 = Absolute velocity of steam at inlet in *m/s*

α_1 = Nozzle inlet angle

u = Blade velocity in *m/s*

V_{r1} = Relative velocity of steam at inlet in *m/s*

V_{w1} = Tangential velocity of steam at inlet in *m/s*

V_{a1} = Axial velocity of steam at inlet in *m/s*

β_1 = Blade inlet angle

β_2 = Blade outlet angle

V_{r2} = Relative velocity of steam at outlet in *m/s*

V_{w2} = Tangential velocity of steam at outlet in *m/s*

V_{a2} = Axial velocity of steam at outlet in *m/s*

K = Blade velocity coefficient $= \frac{V_{r2}}{V_{r1}}$

V_2 = Absolute velocity of steam at outlet in *m/s*

α_2 = Angle made by absolute velocity V_2 with the tangent of the wheel at outlet

WORK OUTPUT, POWER, BLADE EFFICIENCY & STAGE EFFICIENCY

Forc ein the tangential direc tion = Rate of changeof mom tangential direc tion.

= Mas s per sec ond × c hangein veloc ity New tons

$= m(V_{w1} \pm V_{w2})$ New tons

Fo rce in the axial d irectio n = Rate of change of momentum in the axial direction.

(a xia l thrus t) $= m(V_{a1} - V_{a2})$ Newton s

W ork done by s team on blades $= m(V_{w1} \pm V_{w2})u$ N - m/s

Pow er developed by the turbine $= \dfrac{m(V_{w1} \pm V_{w2})u}{1000}\ kW$

Blad e effic ienc y $= \dfrac{\text{Work done on the blade(s)}}{\text{Energy supplied to the blade(s)}} = \dfrac{m(V_{w1} \pm V_{w2})u}{\frac{1}{2} m V_1^2} = \dfrac{2u(V_{w1} \pm V_{w2})u}{V_1^2}$

Energy lost due to blade fric tion $= \dfrac{1}{2} m\left(V_{r1}^2 - V_{r2}^2\right)$ N - m/s

Stage efficien cy $= \dfrac{\text{Work done on the blade(s)}}{\text{Total energy s upplied per stage}} = \dfrac{m(V_{w1} \pm V_{w2})u}{m(H_1 - H_2)} = \dfrac{(V_{w1} \pm V_{w2})u}{H_d}$

where $H_d = H_1 - H_2$ = Heat drop in the n o zzle rin g

MAXIMUM WORK & MAXIMUM DIAGRAM EFFICIENCY

From the combined velocity triangle (diagram), we have

$$V_{w1} = V_1\cos\alpha_1 = V_{r1}\cos\beta_1 + u \quad \text{and} \quad V_{w2} = V_2\cos\alpha_2 = V_{r2}\cos\beta_2 - u$$

$$\therefore V_{w1} + V_{w2} = V_{r1}\cos\beta_1 + V_{r2}\cos\beta_2 = V_{r1}\cos\beta_1\left[1 + \frac{V_{r2}\cos\beta_2}{V_{r1}\cos\beta_1}\right] = V_{r1}\cos\beta_1\left(1 + KC\right)$$

where $K = \dfrac{V_{r2}}{V_{r1}}$ and $C = \dfrac{\cos\beta_2}{\cos\beta_1}$

(or) $V_{w1} + V_{w2} = \left(V_1\cos\alpha_1 - u\right)\left(1 + KC\right)$

Rate of doing work per kg of steam per second = $\left(V_1\cos\alpha_1 - u\right)\left(1 + KC\right)u$

$\therefore$ Diagram efficiency, $\eta_b = \dfrac{\left(V_1\cos\alpha_1 - u\right)\left(1 + KC\right)}{V_1^2}$

Let, $\rho = \dfrac{u}{V_1}$ = Blade speed ratio

Then, Diagram efficiency, $\eta_b = 2\left(\rho\cos\alpha_1 - \rho^2\right)\left(1 + KC\right)$

MAXIMUM WORK & MAXIMUM DIAGRAM EFFICIENCY

From the above equation, it is evident that *diagram efficiency* depends on the following factors:

1) Nozzle angle, α_1
2) Blade speed ratio, ρ
3) Blade angles, β_1 & β_2
4) Blade velocity coefficient, K

- If the values of α_1, K and C are assumed to be constant, then diagram efficiency depends only on the value of blade speed ratio, ρ
- In order to determine the optimum value of for maximum diagram efficiency, $\frac{\partial \eta_b}{\partial \rho} = 0$
- Then, ρ becomes, $\rho = \frac{\cos\alpha_1}{2}$

MAXIMUM WORK & MAXIMUM DIAGRAM EFFICIENCY

Maximum diagram efficiency =

$$(\eta_b)_{max} = 2(1+KC)\left[\frac{\cos\alpha_1}{2}.\cos\alpha_1 - \frac{\cos^2\alpha_1}{4}\right] = (1+KC)\frac{\cos^2\alpha_1}{2}$$

Note: If the blade is symmetrical & friction is absent, then, we have $\beta_1 = \beta_2$ and $K = C = 1$

Then, maximum diagram efficiency, $(\eta_b)_{max} = \cos^2\alpha_1$

Work done/kg of steam/second = $(V_1\cos\alpha_1 - u)(1+KC)\,u$

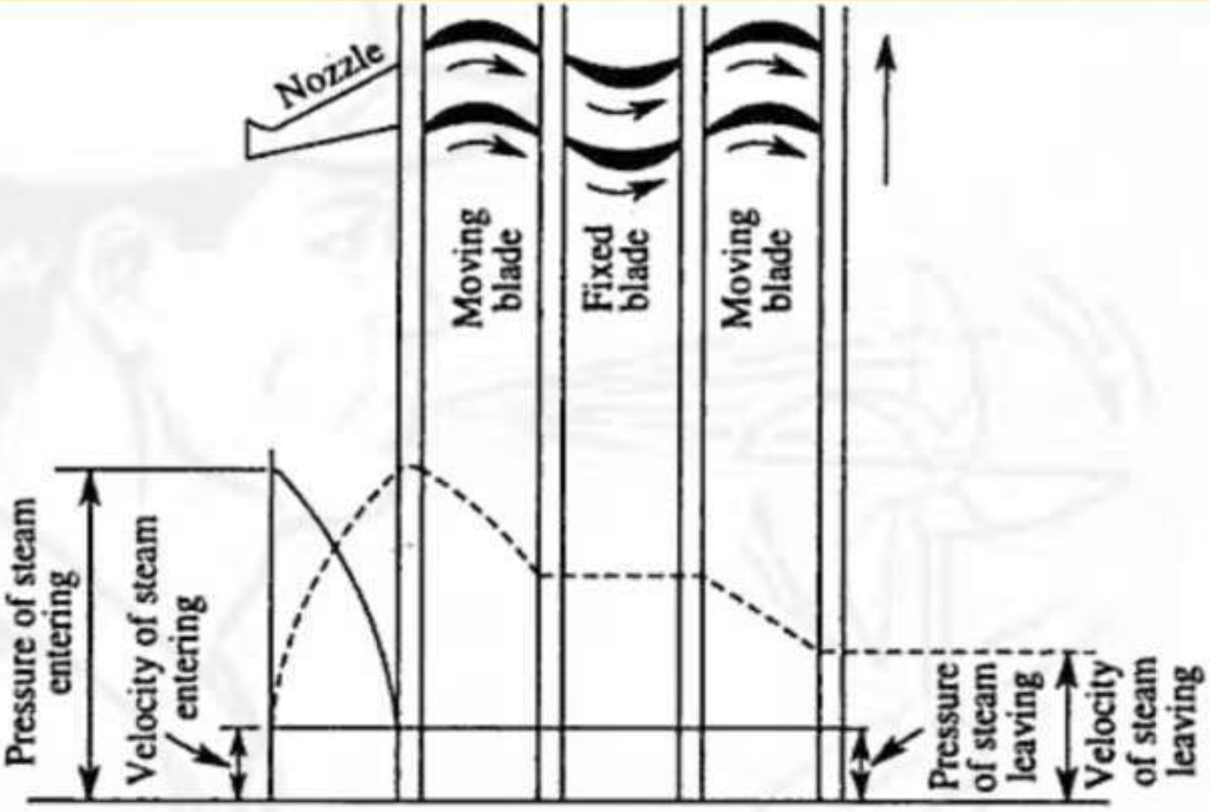
Then maximum rate of doing work/kg of steam/second $= 2u^2$

METHODS OF REDUCING ROTOR SPEED

METHODS OF REDUCING ROTOR SPEED (COMPOUNDING OF TURBINES)

- If high velocity of steam is allowed to flow through one row of moving blades, it produces a rotor speed of about **30000** rpm which is too high for practical use.
- It is therefore essential to incorporate some improvements for practical use and also to achieve high performance.
- This is possible by making use of more than one set of nozzles, and rotors, in a series, keyed to the shaft so that either the steam pressure or the jet velocity is absorbed by the turbine in stages. This is called *compounding of turbines*.
- The high rotational speed of the turbine can be reduced by the following methods of compounding:
    1) Velocity compounding
    2) Pressure compounding, and
    3) Pressure-Velocity compounding

METHODS OF REDUCING ROTOR SPEED
(VELOCITY COMPOUNDING)



Velocity compounding

METHODS OF REDUCING ROTOR SPEED

- It consists of a set of nozzles and a few rows of moving blades which are fixed to the shaft and rows of fixed blades which are attached to the casing.
- As shown in figure, the two rows of moving blades are separated by a row of fixed blades.
- The high velocity steam first enters the first row of moving blades, where some portion of the velocity is absorbed.
- Then it enters the ring of fixed blades where the direction of steam is changed to su the second ring of moving blades. There is no change in the velocity as the steam passes over the fixed blades.
- The steam then passes on to the second row of moving blades where the velocity is further reduced. Thus a fall in velocity occurs every time when the steam passes over the row of moving blades. Steam thus leaves the turbine with a low velocity.
- The variation of pressure and velocity of steam as it passes over the moving and fixed blades is shown in the figure. It is clear from the figure that the pressure drop takes place only in the nozzle and there is no further drop of pressure as it passes over the moving blades.
- This method of velocity compounding is used in Curtis turbine after it was first proposed by C.G. Curtis

METHODS OF REDUCING ROTOR SPEED

(VELOCITY COMPOUNDING)

ADVANTAGES

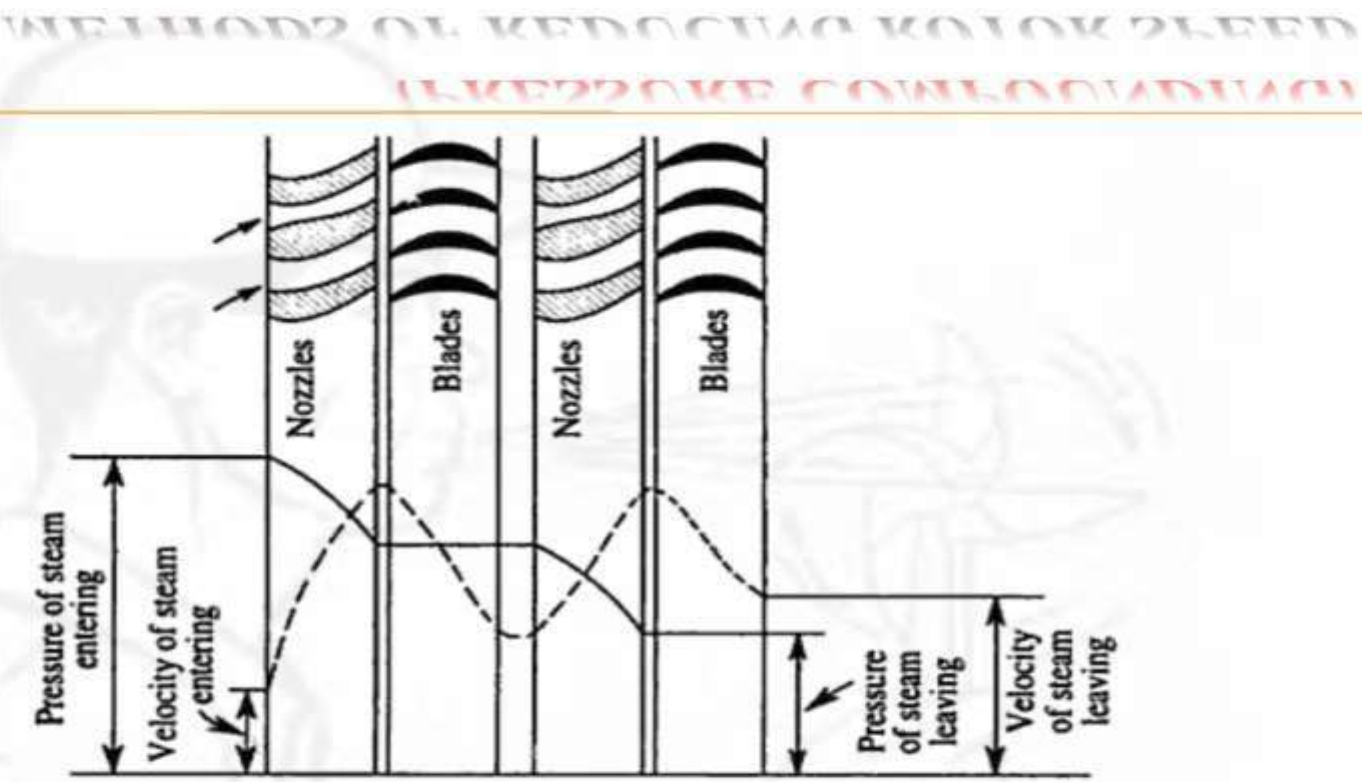
1) The arrangement has less number of stages and hence less initial cost
2) The arrangement requires less space
3) The system is reliable and easy to operate
4) The fall of pressure in the nozzle is considerable, so the turbine itself need not work in high pressure surroundings and the turbine housing need not be very strong

DISADVANTAGES

1) More friction losses due to very high velocity in the nozzles
2) Less efficiency because ratio of blade velocity to steam velocity is not optimum
3) Power developed in the later rows is only fraction of first ro[w]
Still all the stages require same space, material and cost.

METHODS OF REDUCING ROTOR SPEED

(PRESSURE COMPOUNDING)



Pressure Compounding

METHODS OF REDUCING ROTOR SPEED

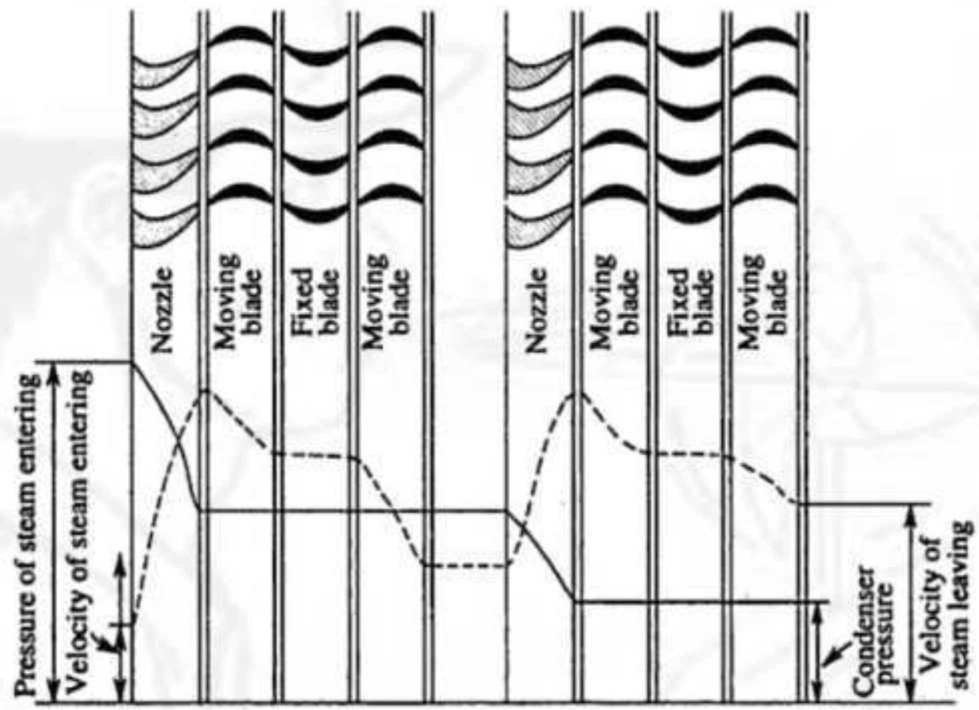
(PRESSURE COMPOUNDING)

- It consists of a number of fixed nozzles which are incorporated between the rings of moving blades. The moving blades are keyed to the shaft.
- Here the pressure drop is done in a number of stages. Each stage consists of a set of nozzles and a ring of moving blades.
- Steam from the boiler passes through the first set of nozzles where it expands partially. Nearly all its velocity is absorbed when it passes over the first set of moving blades.
- It is further passed to the second set of fixed nozzles where it is partially expanded again and through the second set of moving blades where the velocity of steam is almost absorbed. This process is repeated till steam leaves at condenser pressure.
- By reducing the pressure in stages, the velocity of steam entering the moving blades is considerably reduced. Hence the speed of the rotor is reduced. Rateau & Zoelly turbines use this method of compounding.

METHODS OF REDUCING ROTOR SPEED (PRESSURE-VELOCITY COMPOUNDING)

1) In this method of compounding, both pressure ar velocity compounding methods are utilized.
2) The total drop in steam pressure is carried out in two stages and the velocity obtained in each stage is also compounded.
3) The ring of nozzles are fixed at the beginning of each stage and pressure remains constant during each stage.
4) This method of compounding is used in *Curtis* and *More* turbines.

METHODS OF REDUCING ROTOR SPEED
(PRESSURE-VELOCITY COMPOUNDING)

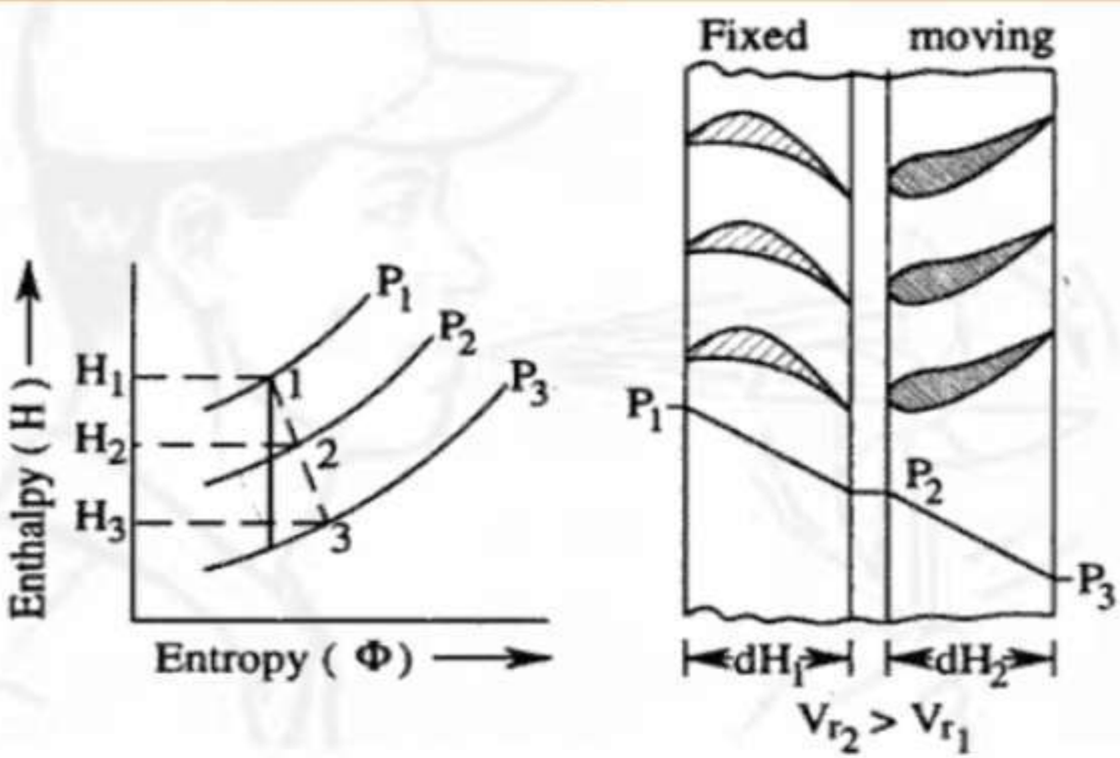


Pressure-Velocity Compounding

REACTION TURBINE

- A turbine in which steam pressure decreases gradually while expanding through the moving blades as well as the fixed blades is known as *reaction turbine*.
- It consists of a large number of stages, each stage consisting of set of fixed and moving blades. The heat drop takes place throughout in both fixed and moving blades.
- No nozzles are provided in a reaction turbine. The fixed blades act both as nozzles in which velocity of steam increased and direct the steam to enter the ring of moving blades. As pressure drop takes place both in the fixed and moving blades, all the blades are nozzle shaped.
- The steam expands while flowing over the moving blades and thus gives reaction to the moving blades. Hence the turbine is called *reaction turbine*.
- The fixed blades are attached to the casing whereas moving blades are fixed with the rotor.
- It is also called *Parson's reaction turbine*.

REACTION TURBINE



Isentropic expansion in Reaction Turbine

DEGREE OF REACTION IN REACTION TURBINE

DEGREE OF REACTION

The degree of reaction is defined as the ratio of isentropic heat drop in the moving blades to the isentropic heat drop in the entire stage of reaction turbine. It is denoted by R.

$$R = \frac{\text{Enthalpy drop in the moving blade}}{\text{Enthalpy drop in the stage}} = \frac{dH_2}{dH_1 + dH_2}$$

Where, dH_1 = Enthalpy drop in the fixed blade per kg of steam $= \frac{V_1^2 - V_2^2}{2} kJ/kg = H_1 - H_2$

dH_2 = Enthalpy drop in the moving blade per kg of steam $= \frac{V_{r2}^2 - V_{r1}^2}{2} kJ/kg = H_2 - H_3$

Also, $dH_1 + dH_2$ = Enthalpy drop in the stage per kg of steam

$= H_1 - H_3$

= Work done by the steam in the stage

$= u(V_{w1} + V_{w2})$

$$\therefore \text{Degree of Reaction}, R = \frac{V_{r2}^2 - V_{r1}^2}{2u(V_{w1} + V_{w2})}$$

Note-1: In Pearson's turbine, the degree of reaction, R=0.5, then, $\alpha_1 = \beta_2$ and $\alpha_2 = \beta_1$. This means that moving blade and fixed blade have the same shape.

Note-2: If degree of reaction, R=0, then the turbine is a simple impulse turbine.

Note-3: If degree of reaction, R=1, then the turbine is a pure reaction turbine.

WORK DONE & EFFICIENCY IIN REACTION TURBINE

BLADE EFFICIENCY AND STAGE EFFICIENCY

The condition for maximum efficiency is calculated considering the following assumptions:

- The degree of reaction, R = 0.5, i.e. $\alpha_1 = \beta_2 \, and \, \alpha_2 = \beta_1$
- The fixed and moving blades are symmetrical, i.e. $V_1 = V_{r2} \,\&\, V_2 = V_{r1}$

The kinetic energy supplied to the fixed blade per kg of steam = $\dfrac{V_1^2}{2}$

The kinetic energy supplied to the moving blade per kg of steam = $\dfrac{V_{r2}^{\,2} - V_{r1}^{\,2}}{2}$

Total energy supplied in the stage per kg of steam = $\dfrac{V_1^2}{2} + \dfrac{V_{r2}^{\,2} - V_{r1}^{\,2}}{2}$

Since blades are symmetrical, $V_1 = V_{r2} \,\&\, V_2 = V_{r1}$ & from velocity triangles, $V_{r1}^{\,2} = V_1^2 + u^2 - 2 \cdot V_1 \cdot u \cdot \cos\alpha_1$

Therefore, total energy supplied in the stage per kg of steam = $V_1^2 - \dfrac{V_1^2 + u^2 - 2 \cdot V_1 \cdot u \cdot \cos\alpha_1}{2}$

Work done per kg of steam is given by,

$$
\begin{aligned}
\text{Work Done} &= u(V_{w1} + V_{w2}) \\
&= u(V_1 \cos\alpha_1 + V_{r2}\cos\beta_2 - u) \\
&= u(2V_1 \cos\alpha_1 - u) \quad (\because \alpha_1 = \beta_2 \, \text{and} \, V_1 = V_{r2})
\end{aligned}
$$

WORK DONE & EFFICIENCY
IN REACTION TURBINE

$$\text{Diagram efficiency,} \quad = \eta_d = \frac{\textit{Work done per kg of steam}}{\textit{Total energy supplied per kg of steam}}$$

$$= \frac{u(2V_1\cos\alpha_1 - u)}{V_1^2 - \dfrac{V_1^2 + u^2 - 2\cdot V_1\cdot u\cdot\cos\alpha_1}{2}}$$

$$= \frac{2u(2V_1\cos\alpha_1 - u)}{V_1^2 - u^2 + 2\cdot V_1\cdot u\cdot\cos\alpha_1}$$

$$= \frac{2uV_1\left(2\cos\alpha_1 - \dfrac{u}{V_1}\right)}{V_1^2\left(1 - \dfrac{u^2}{V_1^2} + 2\cdot\dfrac{u}{V_1}\cdot\cos\alpha_1\right)}$$

$$= \frac{2\dfrac{u}{V_1}\left(2\cos\alpha_1 - \dfrac{u}{V_1}\right)}{\left(1 - \dfrac{u^2}{V_1^2} + 2\cdot\dfrac{u}{V_1}\cdot\cos\alpha_1\right)}$$

$$\boxed{\therefore \eta_d = \frac{2\rho(2\cos\alpha_1 - \rho)}{(1 - \rho^2 + 2\cdot\rho\cdot\cos\alpha_1)}}$$

$$\text{where } \rho = \frac{u}{V_1} = \text{Blade speed ratio}$$

WORK DONE & EFFICIENCY IN REACTION TURBINE

The efficiency is maximum when the term $\left(1-\rho^2+2\cdot\rho\cdot\cos\alpha_1\right)$ is minimum or when $\dfrac{d\eta_d}{d\rho}=0$

$$\frac{d}{d\rho}\left(1-\rho^2+2\cdot\rho\cdot\cos\alpha_1\right)=0$$

(or) $\quad \left(-2\rho+2\cos\alpha_1\right)=0$

(or) $\quad \boxed{\rho=\cos\alpha_1}$

Therefore efficiency is maximum when $\boxed{\rho=\cos\alpha_1}$

Then, $\therefore (\eta_d)_{\max}=\dfrac{2\cos\alpha_1\left(2\cos\alpha_1-\cos\alpha_1\right)}{\left(1-\cos^2\alpha_1+2\cdot\cos\alpha_1\cdot\cos\alpha_1\right)}=\dfrac{2\cos^2\alpha_1}{\left(1+\cos^2\alpha_1\right)}$

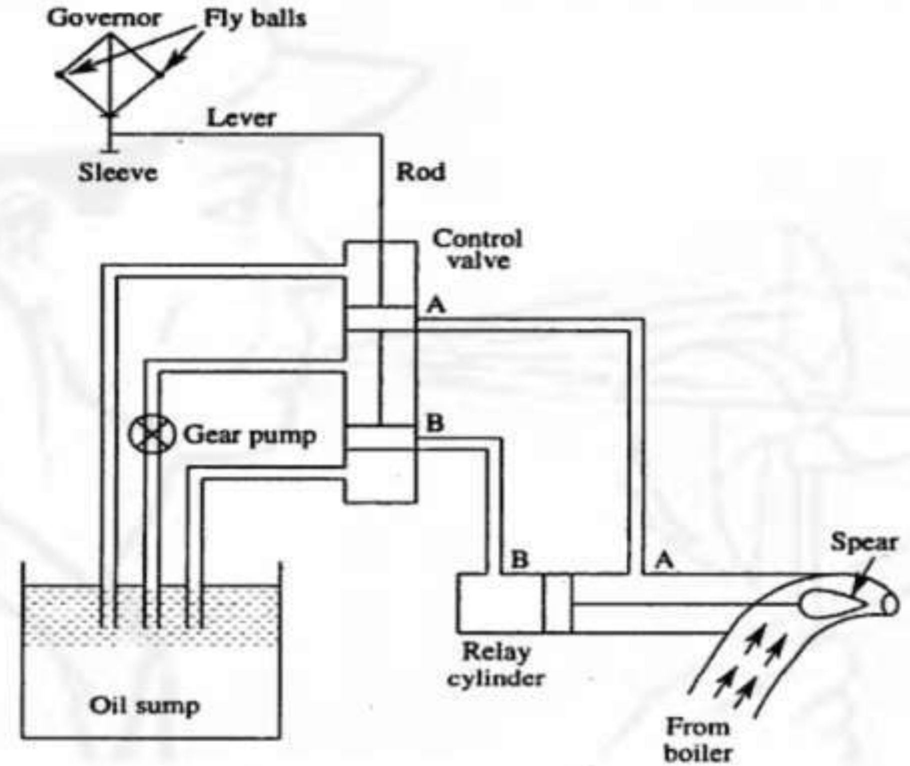
$$\boxed{\therefore (\eta_d)_{\max}=\frac{2\cos^2\alpha_1}{\left(1+\cos^2\alpha_1\right)}}$$

GOVERNING OF TURBINES

- *Governing* is the method of maintaining the speed of the turbine constant irrespective of variation of the load on the turbine.
- A *governor* is used for achieving this purpose which regulates the supply of steam to the turbine in such a way that the speed of the turbine is maintained as far as possible a constant under varying load conditions.
- The various methods of governing of steam turbines are:

1) Throttle governing
2) Nozzle governing
3) By-pass governing
4) Combination of (1) & (2) or (2) & (3)

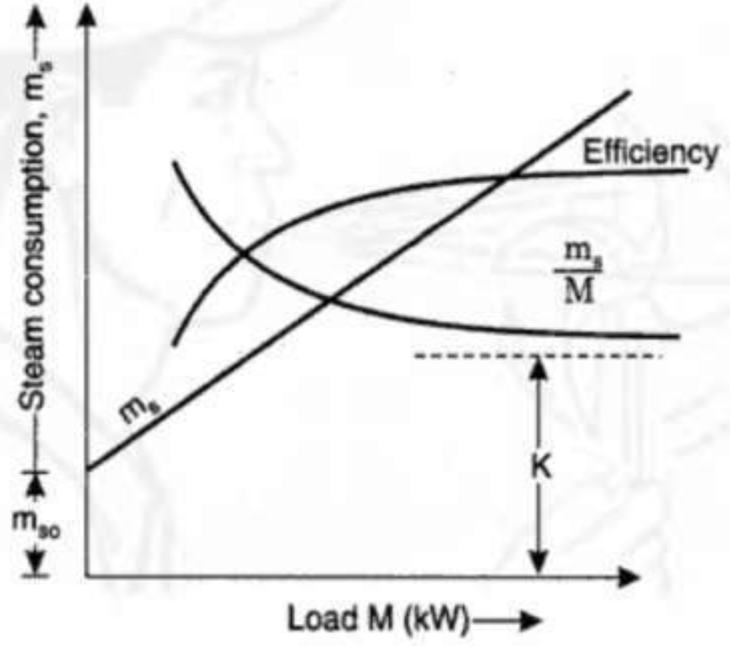
GOVERNING OF TURBINES
(THROTTLE GOVERNING)



Throttle Governing

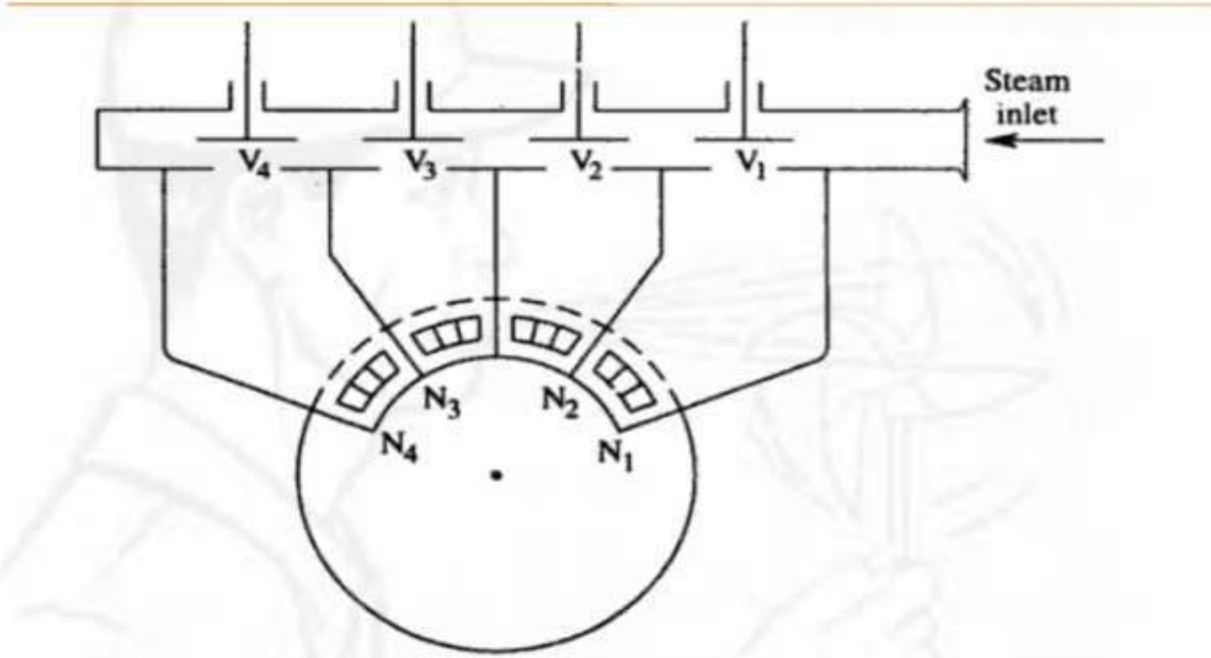
GOVERNING OF TURBINES
(THROTTLE GOVERNING)

WILLIAN'S LINE



GOVERNING OF TURBINES

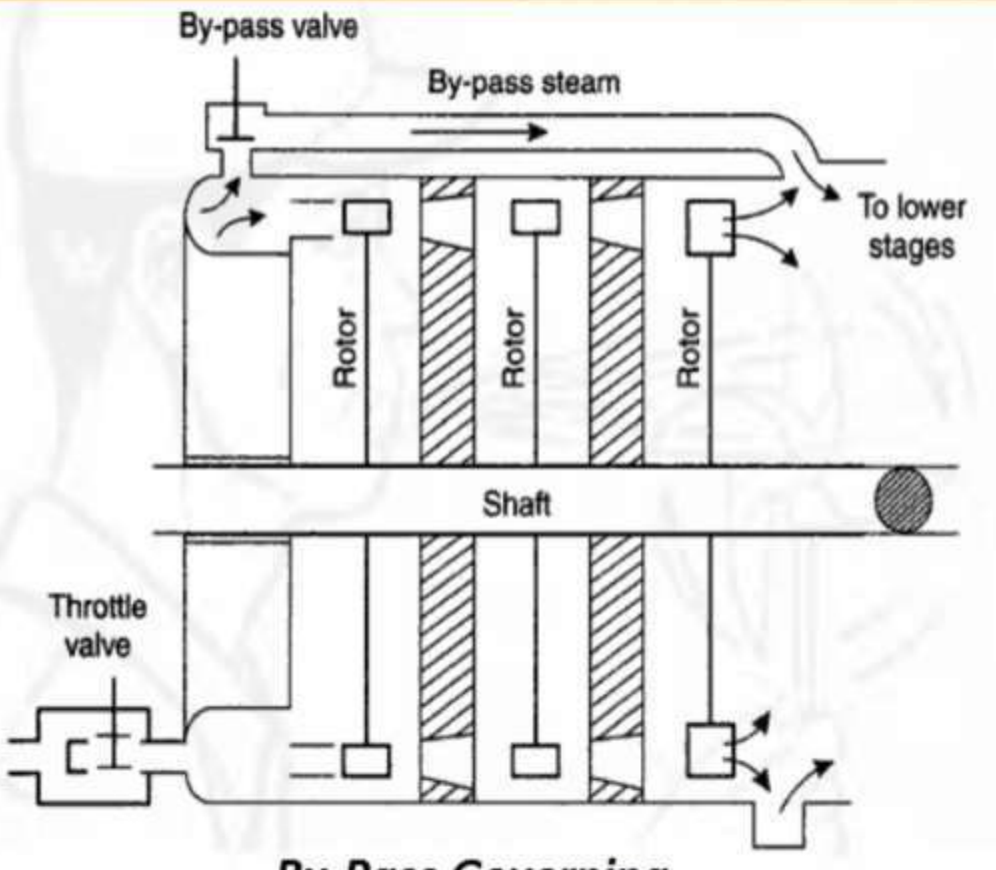
(NOZZLE GOVERNING)



Nozzle Control governing

GOVERNING OF TURBINES

(BY-PASS GOVERNING)

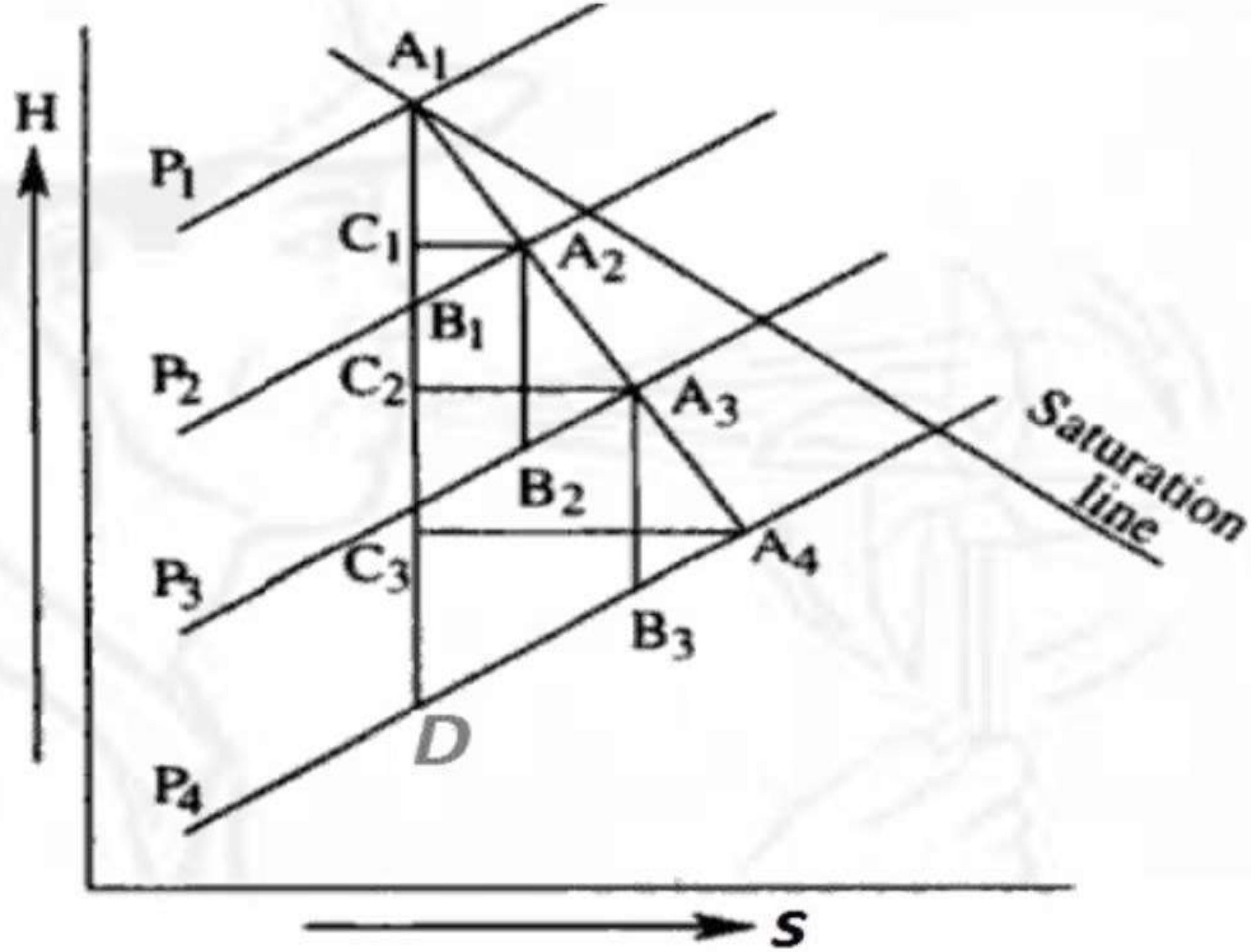


By-Pass Governing

LOSSES IN STEAM TURBINES

- Residual velocity loss
- Losses in regulating valves
- Loss due to steam friction in nozzle
- Loss due to leakage
- Loss due to mechanical friction
- Loss due to wetness of steam
- Radiation loss

EFFECT OF BLADE FRICTION IN STEAM TURBINES



OVERALL EFFICIENCY & REHEAT FACTOR

Reheat factor:

It is defined as the ratio of cumulative heat drop to the adiabatic heat drop in all the stages of the turbine. The value of reheat factor depends on the type and efficiency of the turbine, the average value being 1.05.

$$\text{Reheat factor} = \frac{\text{Cumulative heat drop}}{\text{Adiabatic heat drop}} = \frac{A_1B_1 + A_2B_2 + A_3B_3}{A_1D}$$

Overall efficiency:

It is defined as the ratio of total useful heat drop to the total heat supplied.

$$\text{Overall efficiency} = \frac{\text{Total useful heat drop}}{\text{Total heat supplied}} = \frac{A_1C_1 + A_2C_2 + A_3C_3}{H_{A1} - h_D}$$