SNS COLLEGE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

19MEB203 -THERMAL ENGINEERING

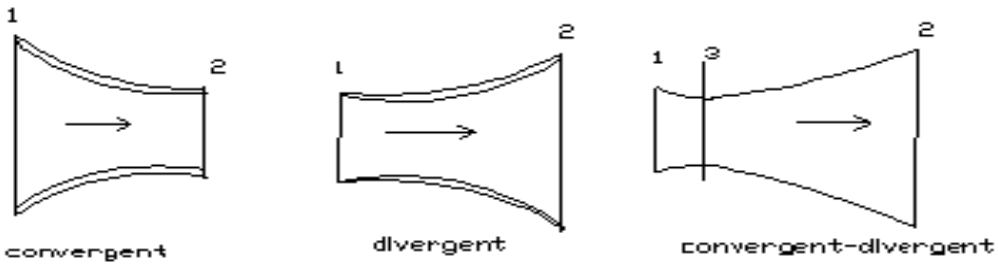
UNIT-III STEAM NOZZLE AND TURBINE

TWO MARK QUESTION

1. Define nozzle.
   A steam nozzle is a passage of varying cross section, which converts Heat Energy of steam into Kinetic Energy. During the first part of the nozzle, the steam increases its velocity. But in its later part, the steam gains more in the volume than in the velocity. Since the mass of steam, passing through any section of the nozzle remains constant, the variation of the steam pressure in the nozzle depends upon the velocity, specific volume and dryness fraction of the steam. A well designed nozzle converts the Heat Energy of steam into Kinetic Energy

2. What are the types of nozzles and their functions?

Following three types of nozzles are important from the subject point of view:



(i) Convergent Nozzle:

When the cross section of a nozzle decreases continuously from entrance to exit, it is called a convergent nozzle.

(ii) Divergent Nozzle :

When the cross section of a nozzle increases continuously from entrance to exit, it is called a divergent nozzle.

(iii) Convergent- Divergent Nozzle :

When the cross section of a nozzle first decrease from entrance to throat, and then increase from throat to exit, it is called a convergent

3. Write down the expression for velocity at exit from steam nozzle.

$$V_2 = \sqrt{V_1^2 + 2000(h_1 - h_2)} = \sqrt{V_1^2 + 2000h_d}$$

Where, h_d = Enthalpy or heat drop during expansion of steam in nozzle.

$$h_d = h_1 - h_2$$

$$V_2 = \sqrt{2 \times \frac{n}{n-1} \times p_1 v_1 \left(1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right)}$$

4. Define critical pressure ratio.

A nozzle is normally designed for maximum discharged by designing a certain throat pressure which produces this condition.

Let P_1 = Initial pressure of steam in N/m^2

P_2 = Pressure of steam at throat in N/m^2

V_1= Volume of 1kg of steam at pressure P_1 in m^3

V_2= Volume of 1kg of steam at pressure P_2 in m^3 ,and

A = cross sectional area of nozzle at throat, in m^2 .

$$m = A\sqrt{\frac{2n}{n-1}\times\frac{p_1}{v_1}\left(\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}}-\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right)}$$

There is only one value of the ratio P_2/P_1 , which produces maximum discharge from the nozzle. This ratio P_2/P_1, is obtained by differentiating the right hand side of the equation. We see from this equation that except P_2/P_1, all other values are constant. P_2/P_1 is differentiated and equated to zero for maximum discharge.

$$\frac{d}{d\left(\frac{p_2}{p_1}\right)}\left[\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}}-\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right]=0$$

5.

$$\frac{2}{n}\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}-1}-\frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}-1}=0$$

6.

$$\frac{2}{n}\left(\frac{p_2}{p_1}\right)^{\frac{2-n}{n}}-\frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}-1}=0$$

7.

$$\left(\frac{p_2}{p_1}\right)^{\frac{2-n}{n}}\times\left(\frac{p_2}{p_1}\right)^{-\frac{1}{n}}=\frac{n+1}{n}\times\frac{n}{2}$$

VALUES FOR CRITICAL PRESSURE RATIO

$$\frac{p_2}{p_1}=\text{Critical pressure ratio}=\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$$

For the following conditions Critical pressure ratios are,

(i) When the steam is initially saturated

We know that for dry saturated steam, n=1.135

$\frac{p_2}{p_1}$ =0.577 ; $P_2 = 0.577\ P_1$

(ii) When the steam is initially superheated:

We know that for superheated steam, n=1.3

$\frac{p_2}{p_1}$ =0.546 ; $P_2 = 0.546\ P_1$

(iii) When the steam is initially wet

It has been experimentally found for wet steam,

$\frac{p_2}{p_1}$ =0.582 ; $P_2 = 0.582\ P_1$

(iv) For gases:

We know that for gases, n=1.4

$\frac{p_2}{p_1}$ =0.528 ; $P_2 = 0.528\ P_1$

5. Define nozzle efficiency.
   Nozzle efficiency: It is defined as the ratio of actual enthalpy drop to the isentropic enthalpy drop.

   Nozzle efficiency= Actual enthalpy drop/ Isentropic enthalpy drop

6. Give any two effects of friction on the flow through a steam nozzle.

When the steam flows through a-nozzle the final velocity of steam for a given pressure drop induced due to the following reasons:

- the friction between the nozzle surface and steam
- the internal friction of steam itself and
- The shock losses.

Most of .these frictional losses occur between the throats and exit in convergent-divergent These frictional losses entail the following effects:

(i) The expansion is no more isentropic, and enthalpy drop is reduced.

ii) The final dryness friction of steam is increased as the kinetic energy gets converted into heat friction and is absorbed by steam.

ii) The specific volume of steam is increased as the steam becomes more dry due to this frictional power.

7. Explain the phenomenon of super saturated expansion in steam nozzle.

In a nozzle in which super saturation occurs the effects may be summarized as follows:

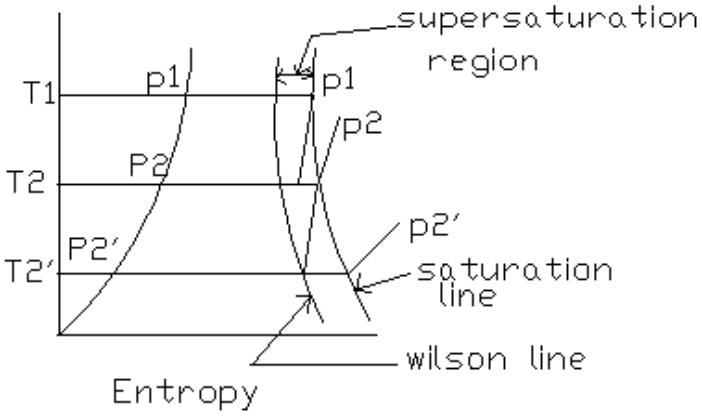
- There is an increase in the entropy and specific volume of steam. .
- The heat drop is reduced below that for thermal equilibrium as a consequence the Exit velocity of steam is reduced.
- Since the condensation does not take place during supersaturated expansion, so the temperature at which the super saturation occurs will be less than the
- Saturation temperature corresponding to the pressure. Therefore, the density Of supersaturated steam will be more than that the equilibrium conditions which gives the increase in the mass of steam discharged.
- The dryness fraction of steam is improved. The problems on supersaturated flow cannot be solved by Mollier chart unless Wilson line is drawn it.

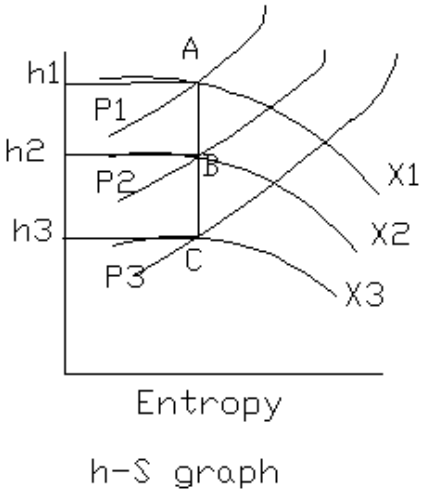
8. What are the conditions that produce super saturation of steam in nozzles?

When the superheated steam expands in the nozzle, the condensation will occur in the nozzle. Since, the steam has more velocity; the condensation will not take place at the expected rate. So, the equilibrium between the liquid and vapour phase is delayed and the steam continues to expand in a dry state.

The steam in such set of condition is said to be supersaturated or metastable flow.

9. Draw the T-s and h-s plot of supersaturated expansion of steam in a nozzle.





h-S graph

10. What are the effects of super saturation in a steam nozzle?
    - The dryness fraction of the steam is increased
    - Entropy and specific volume of the steam are increased.
    - Exit velocity of the steam is increased.
    - Mass of steam discharged is increased.

11. Write the general equation for a steady flow system and from this obtain the energy equation for nozzle.

    From the steady flow energy equation

12. $$\frac{V_1^2}{2} + gz_1 + h_1 + Q - W = \frac{V_2^2}{2} + gz_2 + h_2 \qquad .....(1)$$

    For the steam flowing through the nozzle it is assumed that z1= z2 and there is no heat transfer i.e. Q=0 and work done is zero (W=0). Therefore we get

13. $$\frac{V^2_1}{2} - \frac{V^2_2}{2} = h_2 - h_1$$

    Neglecting inlet velocity

$$\frac{V^2_2}{2} = h_1 - h_2$$

$$\Rightarrow V^2_2 = \sqrt{2 \times 1000 \times (h_1 - h_2)}$$

Enthalpy given is in kJ/kg; it must be multiplied by 1000 inside the root.

If nozzle efficiency (□n) is given, then

$$V^2_2 = \sqrt{2 \times 1000 \times (h_1 - h_2) \times \eta_n}$$

14. What are the difference between super statured flow and isentropic flow through steam nozzle?

SUPERSATURATED FLOW	ISENTROPIC FLOW
Entropy is not constant	Entropy is constant
Reduce in enthalpy drop	No reduce in enthalpy drop
We cannot use Mollier diagram to solve problems	We can use Mollier diagram to solve problems

15. What is a steam turbine?

    Steam turbine is a device which is used to convert kinetic energy of steam into mechanical energy.

16. What are the different methods of governing in steam turbines?
    - Nozzle Governing
    - Throttle governing
    - By pass governing
    - Combination of throttle and nozzle governing
    - Combination of throttle and By-pass governing

17. Classify steam turbine.

    The steam turbines may be classified into the following types:

    (i) According to the mode of steam action
        - Impulse turbine
        - Reaction turbine

    (ii) According to the direction of steam flow
        - Axial flow turbine
        - Radial flow turbine

    (iii) According to exhaust condition of steam

        - Condensing turbine
        - Non condensing turbine

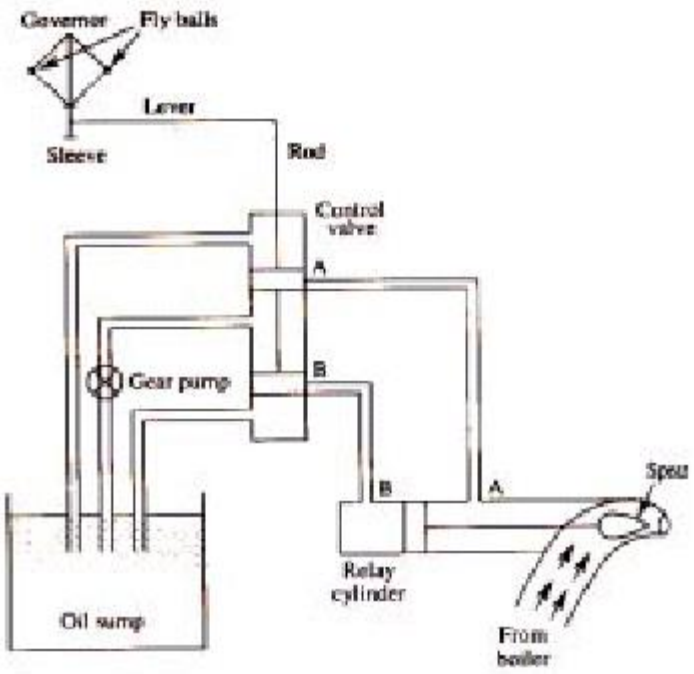
(iv) According to pressure of steam

- High pressure turbine
- Medium pressure turbine
- Low pressure turbine

(v) According to the number of stages

- Single stage turbine
- Multi stage turbine

18. Draw the diagram of nozzle governor?



19. What are the functions of governors?

The control and regulation of output of a turbine in accordance with the variable demand require a positive and accurate control of speed, pressure and mass flow of steam through the turbine.

The aim of governing the power station turbines, which are coupled to alternators, is to maintain constant speed under varying load so as to have constancy of frequency. In

extraction turbines for industrial purposes, the flow must be regulated and the pressure of the extracted steam must be maintained constant. Then, a second or pressure control governor is required in addition to the main or operating governor.

Whatever may be the application, each turbine in addition to the main governor will have an over speed or emergency trip governor which will protect the turbine against destructive over speeding that may be caused by sudden throw of load or failure of main governor.

20. What is the fundamental difference between the operation of impulse and reaction steam turbines?

S. No.	Impulse Turbine	Reaction turbine
1	The steam flows through the nozzles and impinges on the moving blades.	The steam first through guide mechanism and then through the moving blades.
2	The steam impinges on the buckets with kinetic energy.	The steam guides over the vanes with pressure and kinetic energy.
3	The steam may or may not be admitted over the whole circumference.	The steam must be admitted over the whole circumference.
4	The steam pressure remains constant during its flow through the moving blades.	The steam pressure is reduced during its flow through the moving blades.
5	The relative velocity of steam while gliding over the blades remains constant (assuming no friction).	The relative velocity of steam while gliding over the blades increases (assuming no friction).
6	The blades are symmetrical.	The blades are not symmetrical.
7	The numbers of stages required are less for the same power developed.	The numbers of stages required are more for the same power developed.

21. Explain the purpose of compounding in steam turbines.

In order to reduce the rotor speed, various methods are employed. All of these methods consist of a multiple system of rotors, in series, keyed to a common shaft and the steam

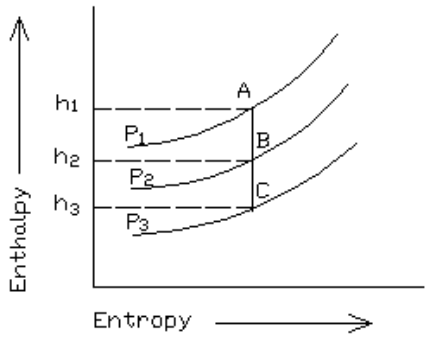
pressure or the jet velocity is absorbed in stages as it flows over the rotor blades. This process is known as compounding. The following three methods are commonly employed for reducing the rotor speed:

1. Velocity compounding, 2. Pressure compounding and 3. Pressure - velocity compounding

22. Define degree of reaction.

In a reaction turbine, the pressure drop takes place in both the fixed and moving blades. In other words, there is an enthalpy drop in both the fixed and moving blades as shown on h-s diagram in the figure. The ratio of the enthalpy or heat drop in the moving blades to the total enthalpy or heat drop in the stage is known as "degree of reaction". Mathematically,

$$\text{Degree of reaction} = \frac{Enthalpy\ or\ heat\ drop\ in\ themoving\ blades}{Total\ enthalpy\ or\ heat\ drop\ in\ the\ stage} = \frac{h_2 - h_3}{h_1 - h_3}$$



Degree of reaction

23. Define impulse turbine.

An impulse turbine, as the name indicates, is a turbine, which runs by the impulse of steam jet. In this turbine, the steam is first made to flow through a nozzle. Then the steam jet impinges on the turbine blades (which are curved like buckets) and is mounted on the circumference of the wheel. The steam jet after impinging glides over the concave surface of the blades and finally leaves the turbine.

24. Condition for Maximum Efficiency of an Impulse Turbine.

$$V_b = \frac{1}{2} V_w = 0.5 V_w$$
$$= 0.5 V \cos\alpha$$
$$\eta_{max} = \frac{2 \times V_w \times 0.5 V_w}{V^2} = \frac{V_w}{V^2} = \cos^2\alpha$$

25. Condition for maximum efficiency of a Reaction Turbine.

$$\eta_{max} = \frac{2\left(2\cos^2\alpha - \cos^2\alpha\right)}{\left(1 - \cos^2\alpha + 2\cos^2\alpha\right)} = \frac{2\cos^2\alpha}{1 + \cos^2\alpha}$$

26. Define blade efficiency.

$$\eta_b = \frac{\text{work done per kg steam}}{\text{energy supplied to blades by 1 kg of steam}}$$

If there were any losses in the fixed blades or nozzle, then

$$\text{Stage efficiency, } \eta_s = \frac{\text{work done perkg steam}}{\text{heat drop in the stage}}$$

$$= \frac{u(V_{w1} \pm V_{w2})}{(h_0 - h_2)}$$

27. What is pure substance?

Pure substance is a substance which has a fixed chemical composition throughout its mass. Examples: Water, nitrogen, carbon dioxide, and helium. A pure substance does not have to be a single chemical element or compound. A mixture of various chemical elements or compounds is also called as pure substance as long as the mixture is homogeneous.

28. Define the term 'Boiling point' and 'Melting point'.

BOILING POINT: It is the temperature at which the liquid starts to change its state from liquid to vapour.

MELTING POINT: It is the temperature at which the solid starts to change its state from solid to liquid.

29. Define heat of vaporization

The amount of heat required to convert the liquid water completely into vapour under this condition is called the heat of vaporization

30. How the throttle governor done?

    Steam pressure at inlet turbine is reduced by throttling process to maintain the speed of the turbine constant at part load.

31. Where nozzle control governing is used?

    Nozzle control governing is used in large power steam turbine to which very high pressure steam is supplied.

32. Where by-pass governing is more suitable?

    By-pass governing is most suitable for reaction turbine and a single by-pass value.

33. What are the different losses involved in steam turbines?

- Losses in regulating valves.
- Losses in steam friction.
- Losses due to mechanical friction.
- Losses due to leakage.
- Residual velocity losses.
- Carry over losses.
- Losses due to wetness of steam.
- Losses due to radiation

34. What is saturation temperature and saturation pressure?

    At a given pressure, the temperature at which a liquid boils is called the saturation temperature. At a given temperature, the pressure at which the liquid boils is called the saturation pressure. It is also called as vapour pressure.

35. Give the working principle of a turbine.

    The high velocity jet of steam which is obtained from the nozzle impinges on the blades fixed on a rotor. The blades change the direction of the flow without changing its pressure. This causes change in momentum and the force developed drives the turbine rotor.

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Boiling point: It is the temperature at which the liquid starts to change its state from liquid to vapour.

Melting point: It is the temperature at which the solid starts to change its state from solid to liquid.

38. What is meant by super heated steam? And indicate its use.

If the dry steam is further heated, then the process is called superheating and steam obtained is known as super heated steam.

Uses: i. Superheated steam has more heat energy and more work can be obtained using it.

ii. Thermal efficiency increase as the temperature of superheated steam is high.

iii. Heat losses be to condensation of steam a cylinder wall is reduced.

39. Define: Sensible heat of water.

The amount of heat required to raise the temperature of unit mass of water from 0^0C to the saturation temperature under a constant pressure. It is denoted by $h_{f.}$

40. Explain heat of super heat or super heat enthalpy.

The heat added to dry steam at 100^oC to convert it into super heated steam at the temperature T_{sup} is called as heat of superheat or super heat enthalpy.

41. Define dryness fraction (or) what is the quality of steam?

It is defined as the ratio of mass of the dry steam to the mass of the total steam.

42. Define triple point.

The triple point is merely the point of intersection of sublimation and vaporization curves.

43. Define heat of vaporization.

The amount of heat required to convert the liquid water completely into vapour under this condition is called the heat of vaporization.

44. Explain the terms, Degree of super heat, degree of sub-cooling.

The difference between the temperature of the superheated vapour and the saturation temperature at the same pressure.

The temperature between the saturation temperature and the temperature in the sub cooled region of liquid.

45. What is the purpose of reheating?

The purpose of reheating is to increase the dryness fraction of the steam passing out of the later stages of the turbine

46. Define the term Efficiency ratio.

The ratio of actual cycle efficiency to that of ideal cycle efficiency is termed as efficiency ratio. Efficiency ratio= Actual cycle efficiency/ Ideal Rankine efficiency

47. What is mean by isentropic efficiency?

For an expansion process

$$\text{Efficiency ratio: } \frac{\text{Actual work done}}{\text{Isentropic work done.}}$$

For compression process:

$$\text{Isentropic efficiency: } \frac{\text{Isentropic work done}}{\text{Actual work done}}$$

48. Define specific steam consumption of an ideal Rankine Cycle.

It is defined as the mass flow of steam required per unit power output.

$$\text{Specific steam consumption: } \frac{\text{Steam work done}}{\text{Power in KW}}$$

49. What is meant by work ratio? What is the importance of work ratio in vapour cycles?

Work ratio is defined as the ratio of network transfer to the positive work transfer.

Work ratio affects the actual cycle efficiency comparing two cycles with the same ideal

Efficiency having smaller work ratio would have smaller actual efficiency.