DHANALAKSHMI SRINIVASAN ENGINEERING COLLEGE
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U20AE405 – AIR BREATHING PROPULSION

TWO MARKS WITH ANSWERS

UNIT-1- INTRODUCTION TO JET ENGINE AND DIFFUSER

1. What is meant by a jet propulsion system?

It is the propulsion of a jet aircraft (or) other missiles by the reaction of jet coming out with high velocity. The jet propulsion in used when the oxygen is obtained from the surrounding atmosphere.

2. Give the components of a turbo jet.

(i) Diffuser,
(ii) Mechanical compressor,
(iii) Combustion chamber,
(iv) Turbine and
(v) Exhaust nozzle.

3. Define specific fuel consumption?

It is the rate of fuel consumed per unit work output. The efficiency decreases with increase in specific fuel consumed. Its unit is kg/kw hr.

$$TSFC = m / F$$

4. Define propulsive efficiency.

Propulsive efficiency defined as the ratio of propulsive power or thrust power to the power output of the engine.

5. Define thermal efficiency.

Thermal efficiency defined as the ratio of the power output of the engine to the power input to the engine through fuel.

6. What are the conditions for maximum propulsive efficiency?

For max .propulsive efficiency the jet velocity must be twice more than free stream velocity for which the propulsive efficiency 66.7%.

7. Define intercooler?

In multistage compressor, the compressed air coming out of the first stage is cooled to the initial temperature with the help of the heat exchanger before being passed to the next stage .this heater exchanger is called intercooler.

8. Define specific impulse?

It is defined as the thrust produced per unit weight flow rate through the propulsive device.

9. Define specific thrust?

It is defined as the thrust produced per unit mass flow rate through the propulsive device.

10. Give the classification of air breathing engine?

Air breathing engine may be classified into reciprocating piston engine, turbojet engine, turboprop engine, pulsejet and ramjet engine.

11. Define work ratio?

Work ratio is defined as the ratio of net work done by the engine to the work done by the turbine.

12. Define thrust augmentation?

Increasing the thrust output of the aircraft power plant for a short interval of the time to achieve better take-off performance, higher rate of climb etc is called thrust augmentation.

13. Give the advantage of turbojet engine?

- it is suitable for long distance flight at high speed and altitude.
- lower frontal area and shorter landing gears.
- lower weight per unit thrust at design speed and altitude.
- pressure rise through the inlet diffuser is sufficient.
- reheat can be employed for increased thrust.

14. What are the disadvantage of turbojet engine?

- it requires a long run way.
- TSFC is comparatively high at low speed and altitude.
- uneconomical on short distance flight.
- lower thrust and propulsive efficiency at lower speed

15. What are the advantage of turboprop engine?

It is produced high thrust at lower speed. so it require short run way.

- The TSFC is based on thrust is low.
- propulsive efficiency within the range of operation is high.
- Thrust reversal is easily achieved with variable pitch propeller blades.

16. What are the disadvantage of the turboprop engine?

Application is limited to power speed and altitude.

- Due to large diameter propeller the landing gear should be long.
- engine is heavier and more complicated.
- higher weight per unit thrust.

17. Write the thrust equation?

Thrust = Sum of (momentum thrust) & (pressure thrust)

$F=ma(V_j-V_i)+(P_e-P_a)A_e$.

18. What are the various types of thrust augmentation?

The after burner, injection of water, alcohol mixtures and the bleed burn cycle are the different types of thrust augmentation

19. What are the two methods of rating and inlet duct?

Duct pressure efficiency ratio and ram recovery point are two methods of rating an inlet duct.

20. Define duct pressure efficiency ratio?

It is defined as the ability of the duct to convert the dynamic pressure at the inlet of the duct to static pressure at the energy at the inlet of the compressor without a loss of total pressure.

21.Define ram recover point?

It is the velocity of the aircraft at which the ram pressure is equal to the fractional pressure loss. For a good inlet duct the ram recover point is less.

22.What are the factor affecting the design of an inlet?

- inlet total pressure ratio.
- Drag to the design speed.
- location of the engine on the wing.
- nose suppression required

23.What are the three region of flow separation internal flow of subsonic inlet?

- outer surface of the nacelle.
- internal surface.
- on the centre body.

24.How is flow separation caused on the centre body in subsonic inlet?

For the internal flow in a subsonic inlet, flow separation may be caused in centre body due to in strong adverse pressure gradient; because flow accelerator as the temperature increase and decelerates as the curvature decrease.

25.Define external flow?

Flow which is passing through the external surface of the inlet or nacelle is called an external flow.

26.What are the uses of normal and oblique shock in supersonic inlet?

Even for the supersonic inlet the air entering the compressor must be subsonic. The normal shock reduced the velocity of the air supersonic to subsonic .while the oblique reduced the velocity of the air, but not less than M 1. The oblique shock are used scramjet engines.

27.What do you mean by reverse nozzle diffuser?

For achieving isentropic deceleration, the supersonic CD nozzle can be used as a diffuser by operating it in the reverse manner. But this type will

cause a greater flow instability due to the interaction of the normal with the boundary layer.

28. What are the factors affecting the range and performance of the supersonic inlet?

- Total pressure recovery
- cowling drag
- boundary layer bleed flow
- capture area ratio
- weight

29. How are supersonic inlets classified based on the percentage of compression?

Based on the percentage of compression, supersonic inlets are classified into internal compression, external compression and mixed compression inlets.

30. Define internal and external compression inlets?

If the pressure rise occurs due to change in the area between the cowl lip and the throat it is called internal compression inlet. Here compression is achieved by a series of internal oblique shock followed by a normal shock. If the pressure rise occurs due to the change in area in front of the cowl lip then it is called external compression inlet.

31. Define pilot inlet?

The external compressor inlet that achieves compression through a single normal shock is called the pilot inlet.

32. Define mixed compression inlets?

The compression inlet in which compression is achieved with the help of external oblique shocks, internal reflected shocks and terminal normal shocks are called mixed compression inlets.

33. Why is 2D supersonic inlet preferred over axis-symmetric supersonic inlet?

The 2D inlets are simple to design and it provides a large variation in inlet airflow. Also the axis-symmetric inlet a have the added design problem of getting boundary layer bleed air out from the centre body through the support struts.

34.How are supersonic inlets classified based on the mass flow required?

- subcritical inlet operation
- critical inlet operation
- supercritical inlet operation

35.Explain sub critical inlet operation?

In this operation, normal shock is produced external to the inlet, which reduces the mass of air entering into the inlet causes spillage. It matches the mass flow required by the engine.

36.Explain critical inlet operation?

In this operation, shock is produced just inside the inlet which increases the mass of air entering the inlet and decreases the mass of air flowing through the outer surface. It matches the mass flow required by the engine.

37.Explain supercritical operation?

In this operation, terminal of normal shock is sucked down into the diffuser which increases the mass flow of air and decrease the pressure rise. In this operation thrust produced is very low and SFC is very high.

38.Define the phenomena of buzz in supersonic inlets?

Buzz is a low frequency, high amplitude pressure oscillation that is liked through shock/shock interaction or shock/boundary layer at relatively low inlet mass flow rate.

UNIT-2 COMBUSTION CHAMBER AND EXHAUST NOZZLES

1. **What is the purpose of exhaust nozzle?**

   The purpose of the exhaust nozzle is to increase the velocity of the exhaust gas, before discharging from the nozzle. It also collects the gas from the turbine and straightens the gas flow.

2. **What are types of nozzles?**
   - convergent nozzle
   - convergent-divergent nozzle.
   - variable area nozzle
   - ejector nozzle

3. **Write about converging nozzle?**

   Converging nozzle is a simple converging duct, which is use when the nozzle pressure ratio is less than 4. It is generally used in engines for subsonic aircraft.

4. **What is the use variable area nozzle?**

   If the engine incorporates after burners, the nozzle must be designed in such a way that the operating conditions of the engine upstream of the after burner remains unchanged.

5. **What are the functions of nozzle?**
   - accelerates the flow to high velocity with minimum total pressure loss
   - match the exit and ambient pressure as closely as possible
   - allow thrust reversal if necessary
   - suppression of noise and infra-red radiation if desired.

6. **Define ejector nozzle?**

   In nozzle which contains bypass air passage for mixing of by-pass air with the hot gases before or after the nozzle based on the mass flow requirement is called ejector nozzle.

7. **Define chocking in nozzle?**

   In nozzle at the throat region the mach number is equal to 1. In this region the mass flow rate is maximum and this condition is called chocking.

8. **Explain the characteristics of supersonic after burner ejector nozzle?**
   - the flow inside the nozzle is secondary flow.

- there is a mixing layer between the primary and secondary stream.
- the primary flow is supersonic

9. Explain supersonic nozzle configuration with no after burner?

- the primary nozzle is at minimum area.
- there is a region of separation in external flow.
- secondary nozzle at minimum area.
- the primary flow is sonic.

10. Explain supersonic nozzle configuration with no after burner?

- the flow into the nozzle is tertiary flow.
- it consists of a reversible hinge or latch.
- it consists movable secondary nozzle.

11. Define under expansion in nozzle?

When the exit pressure of the nozzle is greater than the ambient pressure, the expansion of gases does not take place to the desired extent and this condition is called under expansion.

12. Define over expansion in nozzle?

When the exit pressure from the nozzle is less than the ambient pressure, the expansion of the exhaust gas is more than the desired extent. This condition is called over expansion.

13. Define optimum expansion?

When the exit pressure is equal to the ambient pressure, the expansion of gases is optimum and it gives the desired velocity without affecting the performance of the aircraft.

14. Define nozzle efficiency?

Nozzle efficiency is defined as the ratio of actual drop in temperature to the theoretical temperature drop.

15. What are the various losses in a nozzle?

- boat drag loss
- pressure loss
- losses due to friction
- losses due to cooling
-

16.Give the shapes of nozzles based on air inlet condition?

- M<1(subsonic) : the nozzle is a convergent nozzle
- M=1(sonic) : the area is constant (throat)
- M>1(supersonic) : the nozzle is a divergent nozzle.

17.Define stagnation state?

Stagnation state is defined as the condition obtained when the fluid flow is decelerated to zero velocity at zero elevation in adiabatic or isentropic condition.

18.What are the limitations of the design of nozzle?

Diameter of the nozzle in the divergent portion should be less than the overall diameter of the engine. Otherwise there will be an external drag in the divergence portion due to thrust offset.

The angle of inclination of divergence portion should be less than 30' to avoid the formation of shock in the divergent portion.

19.What do you mean by thrust reversal?

When is the need for sudden reduction of lift or to attain sudden descent, the direction of the exhaust gas are changed which produces additional drag and thus acts as thrust reversers.

20.Define critical state?

The flow properties at the throat where the mach number is unity is called critical state.

21.What are the types of combustion chamber?

- can type
- annular type
- can-annular type

22.What are types of combustion mechanism?

- carbon preferential burning
- hydrogen preferential burning
- hydroxylation

23.Define annular combustor?

Annular combustor consists of a single combustion chamber co-axially connected with the engine axis.

24.Define can/tubular combustion chamber?

Can type combustor consists of a number of combustion chamber located around the engine axis, each combustion chamber getting air through separate pipelines.

25.Define can-annular combustor?

It consists of can and annular type combustion chamber getting air through a common pipeline.

26.What are the factor affecting combustion chamber design?

- gas temperature
- pressure loss in combustion chamber
- carbon formation
- combustion chamber inlet mass flow, density and velocity.

27.What are the factors affecting the performance of combustion chamber?

- pressure lose in combustion chamber
- combustion intensity
- efficiency of combustion

28.Name the losses in combustion chamber.

Pressure loss

1. Skin friction and turbulence
2. Rise in temperature due to combustion

Stagnation pressure drop called fundamental loss

No combustion take place cold loss

29.How is parasitic loss caused in combustion chamber?

- friction
- turbulence mixing

30.Define combustion intensity?

Combustion intensity is defined as the rate of heat released per unit volume for combustion taking place at constant pressure.

31. Define the efficiency of the combustor.

Combustion efficiency is defined as the ratio of actual temperature rise in the combustor to the theoretical temperature rise.

32. What are the requirements of combustion chamber?

- complete combustion must be activated
- pressure loss must be minimized
- carbon formation in inner wall surface must be prevented
- combustion should be reliable.

33. Explain in brief about dilution zone?

The dilution zone is used for cooling down the hot gases formed by combustion In this zone air is mixed with the product of combustion to cool it to the temperature required at the inlet of the turbine.

34. What are the various methods of flame stabilization?

Flame stabilization can be achieved using swirl vanes and using bluff bodies and upstream or reverse flow.

35. What is the flame function of swirl in combustion chamber?

Swirl vanes are used to provide proper mixing and flame stabilization in combustion chamber, by creating a region of back flow or recirculation within the central or forward part of combustion chamber.

36. How is flame stabilization achieved using a bluff body?

The bluff body creates a low pressure recirculation zone or wake region which helps in mixing of fuel in the recirculation zone and helps in flame stabilization.

37. What are the disadvantages of can type combustor?

- separate air pipelines are needed for each combustion chamber
- they do not make the best use of the space available and hence result in a large triangular engine.

38. What are the advantage of annular type combustor?

- improved exceed temperature distribution and increased durability
- less space to volume ratio
- has highest compressor efficiency

39. What are the main objectives of combustion chamber geometry?

- to get complete and stable combustion
- to reduce chamber size
- to increase chamber life

40. What is the purpose of primary air in combustion chamber?

About 15 -20% of the air is introduced around the jet of fuel in the primary zone to provide the necessary high temperature for rapid combustion.

41. Define upstream injection?

In this type of flow, the fuel is injected in the direction opposite the direction opposite to that of the air flow. This results in better mixing of the air and fuel.

UNIT-3 COMPRESSOR

1. **What are the functions of compressors?**
   - to supply sufficient sir to the combustion chamber.
   - to increase the pressure and temperature of air entering the combustion chamber to the desired exhaust.
   - supply bleed air for various purposes in the engine and aircraft

2. **What are types of compressor?**
   - axial flow compressor
   - centrifugal compressors

3. **What is the centrifugal compressor?**

   If the air entering the compressor is in the radial direction and air leaves out in the axial direction then it is called centrifugal compressor.

4. **What is axial flow compressor?**

   If the air enters in and leaves out in the axial direction then it is called axial flow compressor.

5. **Define degree of reaction?**

   Degree of reaction is defined as the change in enthalpy in the rotor divided by the change in stagnation enthalpy in the stage.

6. **Define stage?**

   A pair of rotor and stator blade is together called a stage.

7. **Define blade profiles?**

   Compressor blade tips are reduced in thickness, by cutouts called profiles. These profiles prevent serious damage to the blades.

8. **What are the advantage of centrifugal compressors?**
   - high pressure rise per stage.
   - good efficiencies over wide rotational speed range.
   - low weight
   - low starting power requirements.

9. **What are the disadvantages of centrifugal compressors?**
   - large frontal area for given airflow.

- more than two stages are not possible, because of losses in turns between the stages.

10. What are the advantage of axial flow compressors?

- high peak efficiencies.
- small frontal area for given airflow.
- straight through flow, allowing high ram efficiency.

11. What are the disadvantages of axial flow compressors?

- good efficiencies only over narrow rotational speed range.
- difficulty of manufacture and high cost.
- relative heavy weight.
- high starting power requirements.

12. Distinguish between stall and surge.

Compressor stall is a local disruption of the airflow in a gas turbine or turbocharger compressor. Stalls range in severity from a momentary power drop

Complete breakdown of the steady through flow called surging

13. What are the causes for stalling in axial flow compressor?

- ingestion of foreign objects which results in damage, as well as sand and dirt erosion
- imbalance between the air flow supply and the airflow demand
- a pressure ratio that is incompatible with the engine RPM

14. What is the function of inlet guide vanes?

The variable inlet guide vanes deflect and direct the air entering into the compressor at a proper angle.

15. Define compressor efficiency?

Compressor efficiency is defined as the ratio of work done on the compressor to the work done by the compressor.

16. Define flow coefficient?

Flow coefficient is defined as the ratio of relative velocity to the velocity of jet.

17.Define pressure coefficient?

Pressure coefficient is defined as the ratio of the work done to the square of the outlet velocity.

18.Define stage efficiency?

Stage efficiency is defined as the ratio between ideal work done to actual work done.

19.Define slip factor?

Slip factor is the ratio between actual whirl velocity to the ideal whirl velocity.

20.What do you mean by eddy loss in compressor?

The energy transfer occurring in the impeller corresponding to thus velocity profile is less than that have been obtained with one dimensional flow. This reduction of flow or energy transfer is called eddy loss.

21. What are the applications of compressor?

- used for supercharger.
- used for turbo propeller units.
- refrigeration unit & petrochemical plants.

22. What are types of impeller blades?

- straight blades.
- curved blades.

23.What is mean by stagger angle in an axial flow machine?

The stagger angle is the angle between the chord line and the axial direction and represents the angle at which the blade is set in the cascade

UNIT-4 TURBINE

1. **Define stage efficiency.**

   The stage efficiency is defined as the ratio of work done in a stage to enthalpy drop in stage.

2. **Define reaction ratio.**

   Reaction ratio is defined as the ratio of static enthalpy drop across the rotor to static enthalpy drop across the stage.

3. **What is the difference between impulse and reaction turbines?**

   In impulse turbine, the fluid expanded completely in the nozzle and it remains at constant pressure during its passage through the moving blades. In reaction turbine, the fluid is only partially expanded in the nozzle and the remaining expansions take place in the rotor blades.

   The fluid velocity and blade speed for the reaction turbine are low as compared with those of an impulse turbine.

4. **What are the requirements should be satisfied when the gas turbine is to be used as an aircraft power plant?**

   - Low weight
   - Small frontal area.

5. **Define work ratio.**

   It is the ratio of the actual total head temperature drop to the isentropic total head temperature drop from the total heat inlet to static head outlet.

6. **Define total to static efficiency.**

   It is defined as the ratio between the actual shaft work to the ideal shaft work between the total conditions at the entry and static conditions at exit.

7. **State the conditions which should be satisfy free vortex design of turbine blades.**

   - Stagnation enthalpy constant across the annulus

- Axial velocity is constant
- Whirl velocity C_w is inversely proportional to the radius

8. What are the functions of the gas turbine?

- Turbine is the part of the jet engine which is used to increase the kinetic energy of gases.
- It is used to operate the compressor.

9. What are the primary parts of the turbines?

- The stator nozzles
- The turbine rotor blades

10. What are the classifications of the turbines?

- An impulse stage
- A reaction stage

11. What is meant by impulse turbine stage?

An impulse turbine stage is characterized by the expansion of the gasses which occurs only in the stator nozzles. The rotor blades act as directional vanes to deflect the direction of the flow. Further they convert the kinetic energy of the gas into work changing the momentum of the gas more or less at constant pressure.

12. What is meant by reaction turbine?

A reaction turbine is one which the expansion gas takes place both in the stator and in the rotor.

13. Define blade loading coefficient or temperature drop coefficient.

The blade loading coefficient is defined as the ratio of specific work done to square of blade velocity.

$$\psi = \frac{W}{\frac{1}{2} U^2}$$

14. Define degree of reaction.

It is defined as the ratio of isentropic change of enthalpy in the rotor to isentropic change in enthalpy in the stage.

R = Enthalpy drop in the moving blades / Enthalpy drop in the stage

$$R = \frac{(h1 - h2)}{(h1 - h3)}$$

15. Define optimum speed ratio.

The optimum speed ratio is the ratio of velocity of the blade to velocity of gas.

16. What is blade speed ratio and its significance.

It is the ratio between blade speed (U) to absolute velocity (C)

17. Write short notes on external cooling for turbine blades.

The external surface of the gas turbine blade is cooled by making use of compressed air from the compressor. The quantity of the air required for the purpose is from 1 to 3% of main flow entering the turbine stage by which blade metal temperature can be reduced by about 200 – 300 degrees.

18. Explain internal cooling method adopted for gas turbine blades?

Internal cooling of blades is achieved by passing air or liquid through internal cooling passages from hub towards the blade tip. The internal passages may be circular or elliptical. The cooling of the blades is achieved by conduction and convection.

19. What are the disadvantages of liquid cooling?

- This system is complex.
- Water is circulated at high pressure above its vapour pressure.
- It is impossible to eliminate formation of deposits.

20. Write short notes on air cooling adopted in turbine blades.

In this method, the air is bled from the high-pressure end of the compressor and delivered to the blades and vanes to be cooled. Quantity of the coolant required to about 1 to 3 % of engine air flow per turbine blade row.

21. What are the assumptions made while eliminating the flow through the stage?

- Flow conditions evaluated at the mean radius.
- Blade height / mean radius is small, allowing two-dimensional flow theories to be used.
- Radial velocities are zero.

22. **Define blade efficiency**.

It is defined as the ratio of work done per unit mass flow to work available per unit mass flow.

23. Define total to total efficiency.

Total to total efficiency is the ratio of actual work done by the gas to isentropic work done.

24. Define flow coefficient.

The flow coefficient $\varnothing$ is defined as the ratio of the inlet velocity C_a to the blade velocity

$$\varnothing = C_a / U$$

UNIT-5 RAMJET PROPULSION

1. **Briefly explain scramjet engine?**

   A scramjet is a variant of a ramjet air breathing jet engine in which combustion takes place in supersonic airflow.

2. **How a scramjet does differ from ramjet engine?**

   Scramjet engine combustion takes place in supersonic speed where in ramjet subsonic speed.

3. **Define thrust.**

   Thrust is a force which propels the engine in to the forward direction. Unit for thrust is Newton.

4. **What are the burners used in the ramjet engine?**
   - Can type burner
   - Baffle type burner

5. **What is meant by ram effect?**

   The function of the diffuser is to convert the kinetic energy of the entering air into pressure energy. This energy transformation is called ram effect.

6. **What are the assumptions made for calculate the ideal efficiency of the ramjet engine?**
   - Steady flow
   - One dimensional flow
   - Isentropic compression and expansion
   - Gas is perfect
   - Heat added at constant pressure
   - Very low Mach number in the combustion chamber.

7. Why ramjet engine does not require a compressor and a turbine?

In ramjet engine, due to subsonic and supersonic diffuser, the static pressure of the air is increased to ignition pressure. So there is no need of compressor and turbine.

8. What is the need for supersonic combustion?

A scramjet (supersonic combusting ramjet) is a variant of a ramjet airbreathing jet engine which works on supersonic to obtain desired pressure ration and hence the combustion also takes place in supersonic airflow.

9. Sketch a scramjet engine with all the components.

A **scramjet** (*supersonic combustion ramjet*) engine is variant of a ramjet air breathing combustion jet engine in which the combustion process takes place in supersonic airflow.

- ***A Converging Inlet***, where incoming air is compressed and decelerated.
- ***A Combustor***, where gaseous fuel is burned with atmospheric oxygen to produce heat.
- ***A Diverging Nozzle***, where the heated air is accelerated to produce thrust.

10. What is the need for hypersonic vehicle?

A Hypersonic Vehicle is a vehicle that travels at least 5 times faster than the speed-of-sound, or greater than Mach 5. A hypersonic vehicle can be an airplane, missile, or spacecraft which is equipped with a special type of jet engine called a Supersonic Combustion Ramjet

11. Why hydrogen is the suitable fuel used for hypersonic propulsion?

- Hydrogen fuel can burn rapidly and generate a large amount of thrust.
- Hydrogen is extremely flammable; it only takes a small amount of energy to ignite it and make it burn.

12. Define propulsive efficiency of ramjet engine.

The propulsive efficiency of ramjet engine is defined as the ratio of thrust power to power output.

13.Define combustion efficiency.

The combustion efficiency is defined as the ratio of enthalpy rise of air to heat supplied to it.

14.Define diffuser efficiency.

Diffuser efficiency is defined as the ratio of actual pressure rise to ideal pressure rise.

15.What are the advantages of ramjet engine?

- Ramjet engine is very simple and does not have any moving part.
- Cost is low.
- Less maintenance.
- There is no upper limit for flight speed.
- Light weight when compared to turbojet engine.

16.What are the disadvantages of ramjet engine?

- Since the takeoff thrust is zero, it is not possible to start a ramjet engine without an external launching device.
- The combustor required flame holder to stabilize the combustion due to high speed of air.
- It has low thermal efficiency.
- It is very difficult to design a diffuser which will give good pressure recovery over a wide range of speeds.

17.What are the applications of ramjet engine?

- It is widely used in high speed aircrafts and missiles due to its high thrust and high operational speed.
- Subsonic ramjets are used in target weapons.

18.Explain critical inlet mode operation.

When the inlet can accept the mass flow of air required positioning the terminal shock just inside the cowl lip. This is called critical inlet operation.

19. What is subcritical operation?

When the inlet is not matched to the engine, the normal shock moves upstream. This is called as subcritical operation.

20. What is super critical operation?

When the inlet cannot capture the mass flow required by the engine, the terminal shock is sucked into the diffuser. This is called super critical operation.

21. What are the factors to be considered to select the fuel for ramjet engine?

- The calorific value of fuel
- The case with which it can be ignited
- Its physical properties
- Its storage ability
- Toxicity
- Corrosiveness

22. What are the factors affecting the combustion process?

- The burner geometry
- Physical and chemical characteristics of fuel
- The air fuel ratio
- The velocity of working fluid

23. Why doesn't ramjet engine need a compressor and turbine?

Flight speed of the ramjet engine is very high, say M=2 to 4, due to this pressure rise in diffuser (Ram pressure) is very high, at this flight speed contribution of the compressor to the total static pressure rise insignificant. Thus the ram jet engine has a no compressor and turbine.

DEPARTMENT OF AERONAUTICAL ENGINEERING

U20AE405 – AIR BREATHING PROPULSION

PART -B QUESTIONS

UNIT -I

1. Find specific thrust and SFC of a simple turbojet engine, having the following components performance at which the cruise speed and altitude are M 0.8 and 10000m. Select ambient condition from the gas table. Assume data if necessary.
    - Compressor pressure ratio 8
    - Isentropic efficiency of compressor 87%,
    - Isentropic efficiency of intake 93%,
    - Pressure loss in combustion chamber 4% of compressor delivery pressure,
    - Calorific value of fuel 43000 KJ/Kg,
    - Combustion efficiency 98%,
    - Mechanical transmission efficiency 99%,
    - Isentropic efficiency of turbine 90%,
    - Propelling nozzle efficiency 95%,
    - Turbine inlet temperature 1200K

    (NOV –DEC 2016)

2. A turbojet engine is traveling at 270 m/s at an altitude of 5000m. The compressor pressure ratio is 8:1 and maximum cycle temperature is 1200K.
   By assuming the following data
    - Ram efficiency 93%,
    - Isentropic efficiency of compressor 87%,
    - Pressure loss in combustion chamber 4% of compressor delivery pressure,
    - Calorific value of fuel 43100 KJ/Kg,
    - Combustion efficiency 98%,
    - Mechanical transmission efficiency 99%,
    - Isentropic efficiency of turbine 90%,
    - Propelling nozzle efficiency 95%,
    - Ambient conditions at 5000m are .5405 bar and 255.7K

   Calculate the specific thrust and TSFC

   (NOV –DEC 2015)

3. Compare the characteristics, advantage and disadvantage of turbojet, turboprop and turbofan engines

(NOV –DEC 2016)

4. Discuss the typical turbojet cycle performance with suitable sketches.

(NOV –DEC 2016)

5. Describe with the aid of illustrative sketches the working of turboprop engine?

(NOV –DEC 2015)

6. What is thrust augmentation? Explain various methods of thrust augmentation with sketches.

(MAY 2019) (MAY 2016)

7. Explain with neat sketch operating principles of turbofan engine.

(NOV –DEC 2016)

8. Drive the relation between minimum area ratio and external deceleration ratio for subsonic inlets

(NOV –DEC 2015)

9. With the help of neat sketches explain the step-by-step procedure to start a fixed geometry supersonic intake.

(MAY – JUNE 2016)

10. Give the detail about subsonic and supersonic compression

(MAY 2015)

UNIT –II

1. Plot the Mach number, static temperature, static pressure variation along the longitudinal axis of a convergent-divergent nozzle.

(MAY – JUNE 2016) (NOV –DEC 2016)

2. A converging-diverging is designed to operate with an exit Mach number of 1.75. The nozzle is supplied from an air reservoir at 68bar.
   Assuming 1-D flow, calculate
   - Maximum back pressure to choke the nozzle
   - Range of back pressure over which a normal shock will appear in the nozzle
   - Back pressure for the nozzle to be perfectly expanded to design M.

(NOV –DEC 2016)

3. A De Laval nozzle has to be designed for an exit Mach number of 1.5 with exit diameter of 200mm. Find the ratio of throat area / exit area necessary. The reservoir condition is given as $P_O = 10^6$ Pa, $T_o = 20^oC$. Find also the maximum mass flow rate through the nozzle. What will be the exit pressure and temperature?

(MAY – JUNE 2016) (NOV –DEC 2015)

4. What are the types of nozzles? Explain various operating conditions of a C-D nozzle with suitable sketch.

(NOV –DEC 2015)

5. Explain the various methods of thrust reversing

(MAY 2019)

6. Name the material used for combustion chamber and discuss the special qualities of the material used for combustion chamber.

(NOV –DEC 2016)

7. Explain the methods of flame stabilization with neat sketches.

(NOV –DEC 2015)

8. What are factors affecting combustion chamber design

(MAY – JUNE 2016)

9. What are the types of combustion chamber? Compare its advantages and disadvantages

(MAY – JUNE 2016)

10. What are factors affecting combustion chamber performance

(MAY – JUNE 2017)

UNIT - III

1. An axial compressor stage has a mean diameter of 60 cm and runs at 15000rpm. If the actual temperature rise and pressure ratio develop are 30 ºC and 1.4 respectively.
    - The power required to drive the compressor while delivering 57kg/s of air; assume mechanical efficiency of 86% and an initial temperature of 35ºC
    - The stage loading coefficient
    - The stage efficiency and
    - The degree of reaction if the temperature at the rotor exits is 55 ºC

(MAY – JUNE 2016)

2. A sixteen-stage axial flow compressor is to have a pressure ratio of 6.3. Tests have shown that a stage total-to total efficiency of 0.9 can be obtained for each of the first six stages and 0.89 for each of the remaining ten stages. Assuming constant work done in each stage and similar stages find the compressor overall total –total efficiency. For a mass flow rate of 40 kg/s determine the power required by the compressor. Assume an inlet total temperature of 288K

(MAY – JUNE 2016)

3. Explain the working of a centrifugal compressor and draw the velocity triangle.

(NOV –DEC 2015)

4. Discuss stall and surge of axial compressor? What are the methods for avoiding surge of axial compressor?

(NOV –DEC 2015)

5. An axial flow compressor stage is designed to give free vortex tangential velocity distribution for all radii before and after the rotor blade row. The tip diameter is constant and 1.0m; the hub diameter is 0.9m and constant for the stage. At the rotor tip the flow angles are as follow:

Absolute inlet angle $\alpha_1 = 30^0$

Relative inlet angle $\beta_1 = 60^0$
Absolute outlet angle $\alpha_2 = 60^0$
Relative outlet angle $\beta_2 = 30^0$
Determine,

1. The axial velocity
2. The mass flow rate
3. The power absorbed by the stage
4. The flow angle at the hub
5. The reaction ratio of the state at the hub

(NOV –DEC 2015)

6. The first stage of an axial flow compressor is designed with no IGVs. N=6000rpm, stagnation temperature rise of the stage is 20^0C. Hub to tip ratio is 0.6. Work done =0.93. Isentropic efficiency of stage =0.89. Inlet velocity is 140m/s, P_{01}=1.01 bar, T_{01}=288K, Compute the following:
   - The tip radius and corresponding rotor air angles, if the Mach number relative to tip is limited to 0.95.
   - The mass flow entering the stage, stagnation pressure ratio and power required

7. A single sided centrifugal compressor has the following data:
   Power input factor = 1.04, No of vanes = 20, RPM = 15000, overall diameter of impeller = 0.5m, Eye root diameter =0.15m, Mass flow rate = 9kg/s, Stagnation temperature at inlet =295K, Stagnation pressure at inlet = 1 bar, Isentropic efficiency of compressor =0.75
   Assume the velocity of air at inlet is axial and constant across the Eye annulus. Determine
   - The pressure ratio & Inlet angle of the impeller vanes at root and tip.
   - Power required to drive compressor,

8. A single stage gas turbine operates at its design condition with an axial absolute flow at entry and exit from the stage. The absolute flow angle at nozzle exit is 68^0. At stage entry the total pressure and temperature are 4 bar and 800^0C respectively. The exhaust static pressure is 1bar, the total-to-static efficiency is 0.85 and the mean blade speed is 480m/s. Assuming constant axial velocity through the stage determine:
   - The specific work done
   - The Degree of reaction
   - The axial velocity
   - The total-to-total efficiency

   Assume γ=1.33 and Cpg = 1.147 kJ/kg K

9. Air at 1.0132 bar and 288K enters an axial flow compressor stage with an axial velocity 150m/s. There are no inlet guide vanes. The rotor stage has a tip diameter of 60cm and hub diameter of 50cm and rotates at 100 rps. The air enters the rotor and leaves the stator in the axial direction with no change in velocity or radius. The air is turned through 30.2° as it passes through rotor. Assume a stage pressure ratio of 1.2. Assume the constant specific heats and that the air enters and leaves the blade at the blade angles
   - construct the velocity diagram at mean diameter for this stage,
   - mass flow

- power required
- degree of reaction

10. Explain the working of a axial compressor and draw the velocity triangle.

UNIT –IV

1. Discuss turbine blade cooling methods with merits and demerits

(JUNE 2016) (NOV – DEC 2016)

2. Write down the matching of compressor and turbine

(JUNE 2016)

3. Mention the losses which are associated to define the overall blade loss co-efficient. Explain them

(NOV – DEC 2016)

4. Show that for zero degree of reaction, blade loading coefficient $\psi=2$

(NOV – DEC 2016)

5. Derive the relation for degree of reaction in terms of pressure, velocity, enthalpy and flow geometry

(NOV – DEC 2015)

6. A single stage gas turbine operates at its design condition with an axial absolute flow at entry and exit from the stage. The absolute flow angle at nozzle exit is 68^0. At stage entry the total pressure and temperature are 4 bar and 800^0C respectively. The exhaust static pressure is 1bar, the total-to-static efficiency is 0.85 and the mean blade speed is 480m/s. Assuming constant axial velocity through the stage determine:
    1. The specific work done
    2. The Degree of reaction
    3. The axial velocity
    4. The total-to-total efficiency

    Assume $\gamma=1.33$ and Cpg = 1.147 kJ/kg K

(NOV – DEC 2016)

7. List the merit and demerits of axial turbine

(MAY 2018)

8. A single stage gas turbine operates at its design condition with an axial absolute flow at entry and exit from the stage. The absolute flow angle at nozzle exit is 70^0. At stage entry the total pressure and temperature are 311 kPa and 850^0C respectively. The exhaust static pressure is 100 kPa, the total-to-static efficiency is 0.87 and the mean blade speed is 500m/s. Assuming constant axial velocity through the stage determine:
    i. The specific work done
    ii. The Mach number leaving the nozzle
    iii. The axial velocity
    iv. The total-to-total efficiency
    v. The stage reaction
9. Discuss the liming factors of turbine design
10. What are the various stresses in gas turbine blade? Describe the procedure of evaluating stresses

(MAY 2018)

UNIT - V

1. A ramjet is to propel an aircraft at Mach number 1.5 at high altitude where ambient pressure is 11.6 kPa and ambient temperature is 205K. The maximum temperature in the engine is 2500 K. The heating value of used is 45 MJ/kg. Assume γ=1.4 and Cp = 1.0 kJ/kg K. If all components are frictionless, Determine (i) TSFC (ii) Thermal efficiency (iii) Propulsive efficiency (iv) Overall efficiency **(May / June 2016)**

2. A ramjet is traveling at Mach 3 at an altitude of 4572m, the external static temperature is 258.4 K and the external static pressure is 57.1 kPa. The heating value of the fuel is 46520 kJ/kg. Air flows through the engine at 45.35 kg/s. The burner exit total temperature is 1944 K. Find the thrust, fuel ratio and TSFC. The specific heat ratio can be assumed to be 1.4 **(Nov / Dec 2015)**

3. Explain the different modes of ramjet engine operation with neat sketch **(May / June 2016)**

4. Describe the various critical inlet operation modes of ramjet **(Nov / Dec 2015)**

5. Explain the working principle of ramjet engine with neat sketch. **(May / June 2016)**

6. A ramjet is to propel an aircraft at Mach 3 at an altitude where the ambient conditions are pressure and temperature is 8.5KPa and 220K respectively. If the maximum permissible temperature is 2540K and under ideal conditions, determine
   (i) The thermal efficiency
   (ii) The Propulsive efficiency
   (iii) The overall efficiency **(Nov / Dec 2016)**

7. Discuss the effect of shock waves in supersonic inlets and describe the working principle of internal compression and external **(MAY 2018)**

8. Discuss the problem associated with supersonic combustion **(Nov / Dec 2016)**

9. Explain the detail the effect of mach number on TSFC and specific thrust of an ideal ramjet **(Nov / Dec 2016)**

10. A ramjet is being flown at a velocity of 2000 ft/s (610 m/s) and is burning a hydrocarbon fuel with a heating value of 44,200 kJ/kg. The uninstalled specific thrust F/m is 736 N.s/kg and the SFC is 62.3 g/Kn.s. Determine the following engine performance
    (a) Thrust
    (b) Specific impulse
    (c) Overall efficiency
    (d) Propulsive efficiency
    (e) Thermal efficiency **(Nov / Dec 2017)**