A STUDY ON TURBOFANENGINE FOR KNOWING THE WORKINGPRINCIPLE AND TO RECOGNIZE THE DIFFERENT PARTS.

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CERTIFICATION OF APPROVAL

The thesis title "Study on Turbofan engine for knowing the working principle and to recognize the different parts" Md. Abu Imran, Kamal Pasha Ratin, Kazi Minhazuddin Ahmed, MD. Abbas Siddiq, Md. Sajjat Hossain, Session: September-December, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering on 14 September 2022.

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DECLERATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for this award of any degree or diploma.

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ABSTRACT

The word "turbofan" is a portmanteau of "turbine" and "fan": the *turbo* portion refers to a gas turbine engine which achieves mechanical energy from combustion, and the *fan*, a ducted fan that uses the mechanical energy from the gas turbine to force air rearwards. Most modern airliners use turbofan engines because of their high thrust and good fuel efficiency. Turbofans are the most widely used gas turbine engine for air transport aircraft. The turbofan is a compromise between the good operating efficiency and high thrust capability of a turboprop and the high speed ,high altitude capability of a turbojet. Our goal is to recognize the different part of a turbofan engine and to know working principles of turbofan engine .To achieve our goal, we divided our study in 12 stages. They are Introduction, Classification of Turbofan Engine, Turbofan Engine Components, Working principle of Turbofan Engine , Body Structure, Major Component, Gas Turbine Engine Fuel systems, Air Systems, Starting and Ignition, Power Augmentation Systems, Power Augmentation Systems, Result and Discussion and Conclusion .Before starting our thesis, we have studied different journals and thesis paper and different books and technical documents and we have collected information from it (reference) to determine the parts and working principle of Turbofan Engine. It will be better for us if we have an opportunity to open the total engine.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION:

An engine is a thermal device that converts heat energy into mechanical energy. A gas turbine engine uses turbines to convert heat energy of a gas into torque; the gas is the combustion-product produced by burning fuel in compressed air in its combustion chamber inside the engine.

The turbofan engine has a duct-enclosed fan mounted at the front or rear of the engine and driven either mechanically geared down or at the same speed as the compressor, by an independent turbine located to the rear of the compressor drive turbine.

Turbofan engines are used to propel commercial airliners and military aircraft. Most commercial aviation jet engines in use today are high-bypass, and most modern fighter engines are low-bypass. Afterburners are used on low-bypass turbofans on combat aircraft.

Because the fuel flow rate for the core is changed only a small amount by the addition of the fan, a turbofan generates more thrust for nearly the same amount of fuel used by the core. This means that a turbofan is very fuel efficient. In fact, high bypass ratio turbofans are nearly as fuel efficient as turboprops. Because the fan is enclosed by the inlet and is composed of many blades, it can operate efficiently at higher speeds than a simple propeller. That is why turbofans are found on high speed transports and propellers are used on low speed transports. Low bypass ratio turbofans are still more fuel efficient than basic turbojets. Many modern fighter planes actually use low bypass ratio turbofans equipped with after burns. They can then cruise efficiently but still have high thrust when dog fighting. Even though the fighter plane can fly much faster than the speed of sound, the air going into the engine must travel less than the speed of sound for high efficiency. Therefore, the airplane inlet slows the air down from supersonic speeds.[1]

1.2 OBJECTIVE:

I) TO RECOGNIZE COMPRESSOR,

II) TO RECOGNIZE TURBINE,

III) TO RECOGNIZE COMBUSTION CHAMBER,

Iv) TO RECOGNIZE EXHAUST,

v) TO RECOGNIZE WORKING PRINCIPLES OF TURBOFAN ENGINE.

1.3 SCOPE AND LIMITATION OF STUDY:

We have recognized most of the components of a turbofan engine theoretically and physically but we have learnt working principles of turbofan engine theoretically and watched different videos and animations.

Chapter 2

CLASSIFICATION OF TURBOFAN ENGINE

2.1 INTRODUCTION:

The air that goes through the fan duct are called secondary air and the air that goes through the engine core are called primary air . The bypass ratio is a ratio of the mass of secondary air to the mass of primary air.

According to bypass ratio, turbofan engine are three types:

I) Low bypass engine

II) Medium bypass engine and

III) High bypass engine.

2.2 LOW BYPASS ENGINE:

The bypass ratio of low bypass engine is approximately 1:1 . In a low bypass engine , the fan and compressor section utilize approximately the same mass airflow , but the fan discharge will generally be slightly greater than that of the compressor .The fan discharge air may be ducted directly overboard from a short fan duct or it may pass along the entire length of the engine in what a called a long fan duct .In either case ,the end of the duct has a converging discharge nozzle to produce a velocity increase and reactive thrust .[1]

2.3 MEDIUM BY-PASS ENGINE:

A medium, or intermediate, by-pass engine has an airflow by-pass ratio of between 2:1 and 3:1, and has a thrust ratio that is approximately the same as its by-pass ratio. The fan used on these engines has a larger diameter than that on a low by-pass engine of comparable power and its diameter is determined by both the by-pass ratio and the thrust output of the fan compared with the thrust obtained from the core engine. This later ratio is often called the cold-stream to hot-stream ratio.[1]

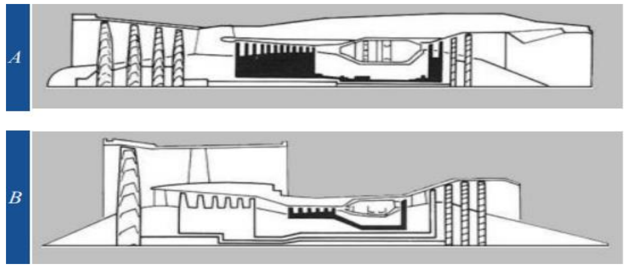

Fig: 2.1 A) Medium by-pass engine, B) High by-pass engine.

2.4 HIGH BY-PASS ENGINE:

A high by-pass turbofan engine has a fan ratio of 4:1 or greater and has an even wider diameter fan in order to move more air. A typical Turbofan engine (GE 90- 115B fitted in B777-300ER aircraft) has a by-pass ratio 9:1 (fan diameter 128 inch or 3.52 meter) produces 115,300lb of Takeoff thrust.[1]

CHAPTER 3

TURBOFAN ENGINE COMPONENTS

3.1 INTRODUCTION:

Turbofan has a core compressor, combustion chamber and a turbine. In addition, they have a fan in front of the core compressor and second power turbine behind the core turbine. Turbofan engine exhibits good efficiency at high subsonic flow and exhibit lower fuel consumption which is preferred in commercial aircraft transportation.

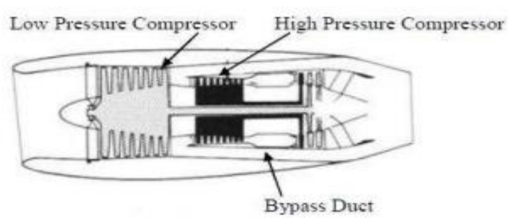

Fig: 3.1 Schematic illustration of turbofan engine

3.2 TURBOFAN ENGINE COMPONENTS:

We have divided the turbofan engine with two categories: -

- BODY STRUCTURE.
- MAJOR COMPONENTS.

3.2.1 BODY STRUCTURE:

We have identified 3 major components in turbo fan engine's body structure. Here the 3 components: -

I) Inlet Cowl,

II) Fan Cowl,

III) Thrust Reverser Cowl,

IV) Nacelle,

V) Pylon,

VI) Spinner.

3.2.2 MAJOR COMPONENTS:

There are 4 major components in turbofan engine, each one of them have different purposes which contribute producing thrust from the engine. Listed below the 4 major components of turbofan engine:

I) Compressor.

II) Combustion Chamber.

III) Turbine

IV) Exhaust.

CHAPTER 4

WORKING PRINCIPLE OF TURBOFAN ENGINE

4.1 INTRODUCTION:

A cycle is a process that begins with certain conditions and ends with those same conditions. The Brayton cycle describes the events that take place in a turbine engine as the fuel release its energy. When energy is added, the air remains at a relatively constant pressure, but its volume is increased which increases the velocity of the air as it leaves the engine. [1]

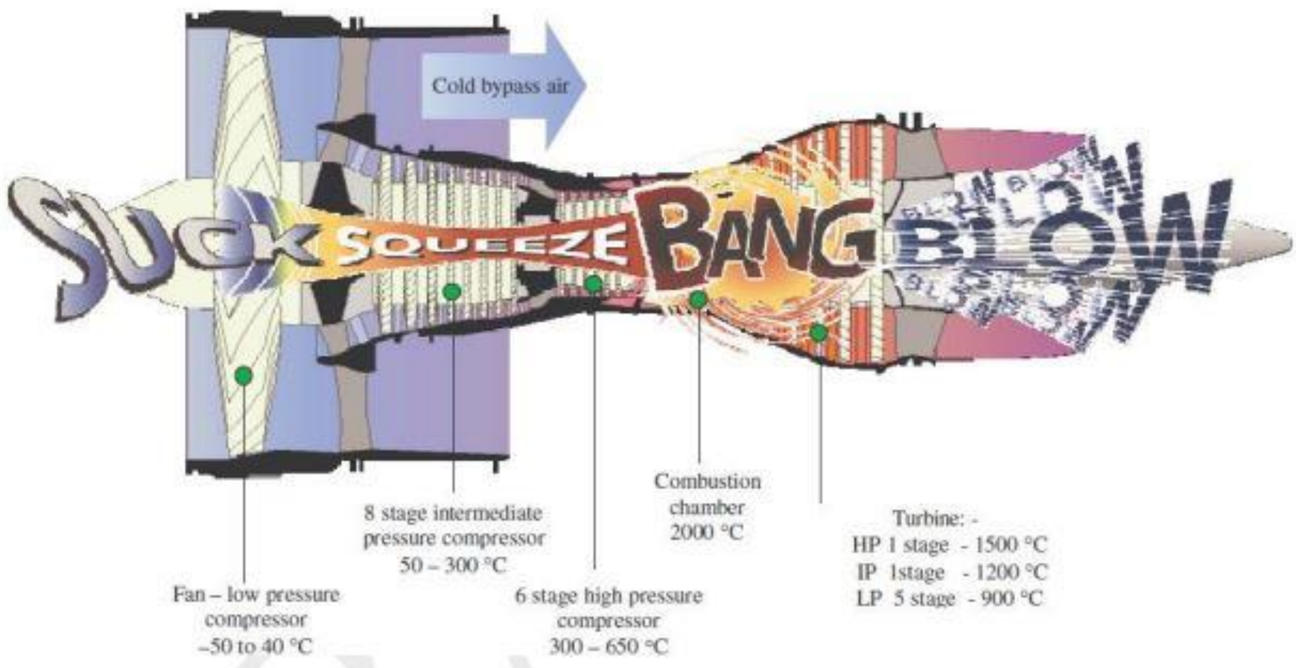

FIG: 4.1 The principle of operation of a GTE- Suck, Squeeze, Bang, and Blow

4.2 IDEALIZED BRAYTON CYCLE:

I. Adiabatic compression (in compressor). Process: 1-2

II. Isobaric (constant pressure) process heat addition (in combustion chamber).Process: 2-3

III. Adiabatic expansion (in turbine).Process: 3-4

VI. Isobaric (constant pressure) heat rejection (exhaust).Process: 4-1 [1]

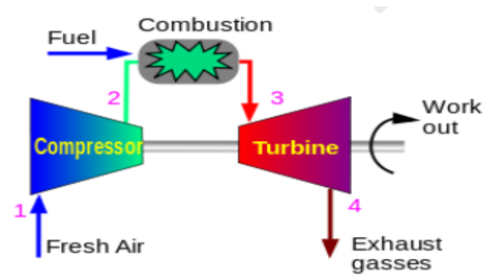

FIG: 4.2.1 IDEALIZED BRAYTON CYCLE

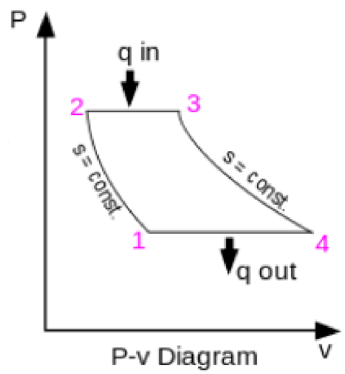

FIG: 4.2.2 IDEALIZED BRAYTON CYCLE P-V DIGRAM

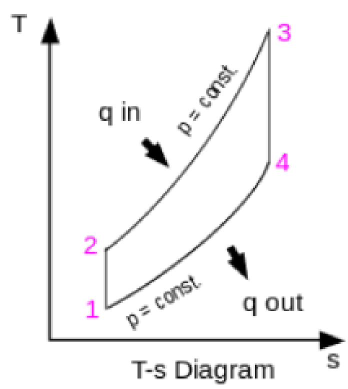

FIG: 4.2.3 IDEALIZED BRAYTON CYCLE P-V DIGRAM

4.3 BRAYTON CYCLE FOR A GAS TURBINE ENGINE:

The four continuous events shown on the pressure volume graph of (fig 15.1.4) are intake, compression, expansion, and exhaust.

Intake: The air entering the inlet duct of the engine is at essentially ambient pressure. Ultimate goal of an Air Inlet Duct designer is to recover the total pressure of the air passing thru' it. The static pressure thru' the Air Inlet Duct increases slightly in the process 0-2.[1]

Compression: The thermodynamic (adiabatic compression) process 2-3 shows that the air pressure rises from ambient as the compressor does work (-ve) on the air. Here work is done on the system (air)by the surrounding (compressor). Compressor increases the pressure and decreases volume of the air passing thru' it. [1]

Expansion: When energy is added to the air from the fuel burned in the combustion chamber, the pressure remains relatively constant, but the volume increases greatly in accordance with isobaric process 3-4. It is because of this characteristic that the Brayton cycle is called a constant pressure cycle. But in practice the exit of a combustion chamber is slightly narrow to speed up the flowing gases which cause decrease in pressure. [1]

Exhaust: When the heated air leaves the combustion chamber, it passes through the turbine where the pressure drops, but its volume continues to increase and it is expressed as thermodynamic (adiabatic expansion) process 4-5. The burning gases have heated the air and expanded it greatly, and since there is little opposition to the flow of these expanding gases as they leave the engine, they are accelerated greatly. Here work is done by the system (air) on the surrounding (turbine). So the work done is +ve. Some of the energy is extracted from the exiting gases by the turbine and this is used to drive the accessories and the various engine accessories Because the turbine and compressor are on the same shaft, the work done on the turbine is exactly equal to the work done by the compressor and, ideally, the temperature change is the same. The nozzle (converging exhaust system where the pressure continues to drop to ambient and the velocity continues to increase) then brings the flow isentropically back to free stream pressure from station 5 to station 8. Externally, the flow conditions return to free stream conditions, which complete the cycle. In this cycle, work is accomplished by increasing the velocity of the air as it passes through the engine. The area under the T-s diagram is proportional to the useful work and thrust generated by the engine. After the air leaves the turbine, it passes through a converging exhaust system where the pressure continues to drop to ambient and the velocity continues to increase. In this cycle, work is accomplished by increasing the velocity of the air as it passes through the engine.[1]

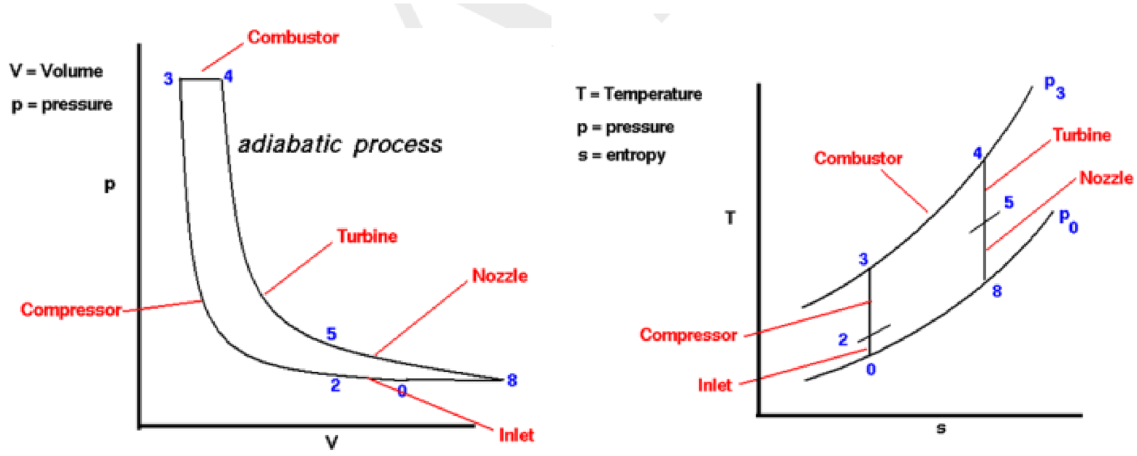

FIG 4.3: BRAYTON CYCLE(INLET DUCT AND EXHAUST PIPE IS INSTALLED)

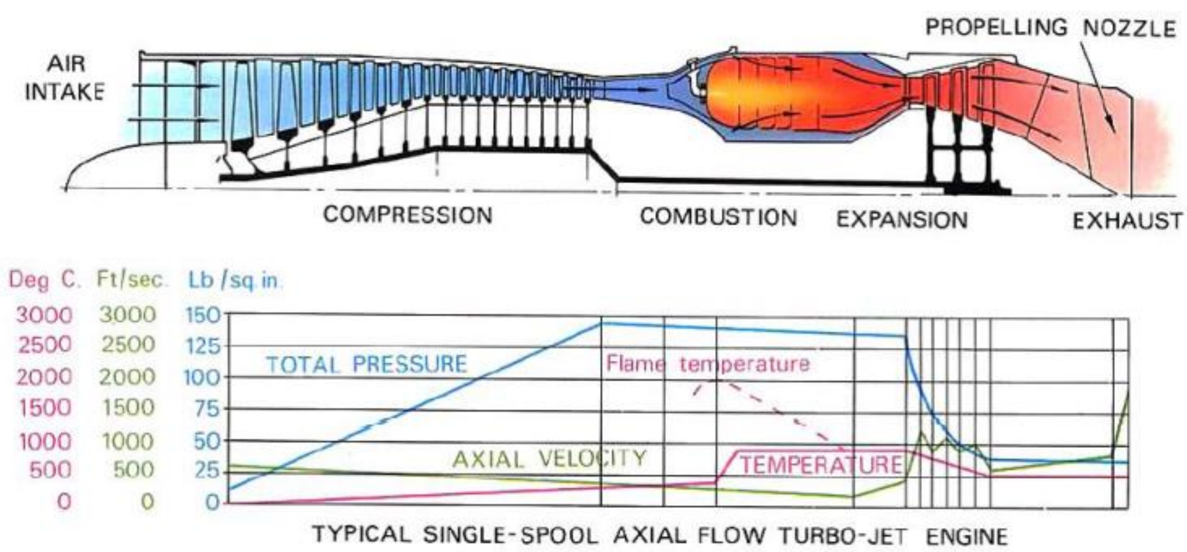

FIG 5.3.1: GAS FLOW DIAGRAM

CHAPTER 5

BODY STRUCTURE

5.1 INLET COWL:

An air intake should deliver air to the engine compressor with a minimum loss of energy and at a uniform pressure under all engine operating conditions. The purpose of the engine inlet duct is to provide the engine compressor with a uniform supply of air in order to prevent the compressor from stalling. Since the inlet is directly exposed to the impacting airflow, it must also create as little drag as possible. It has been found that even the smallest discontinuity of airflow supply can cause major engine problems as well as significant efficiency losses. It is obvious that if the inlet duct is to retain its function of providing sufficient air with a minimum of turbulence.[2]

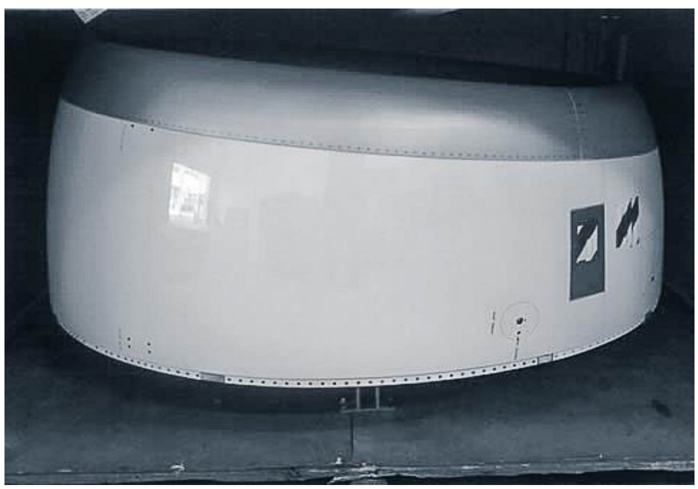

FIG: 5.1 INLET COWL

Inlet duct may be divided into two broad categories:

- sub-sonic ducts
- super-sonic ducts .

SUB-SONIC DUCTS: -The duct must be shaped to deliver the air to the front of the compressor with an even pressure distribution. Poor air pressure and velocity distribution may result in compressor stall. During flight the inlet duct must convert the kinetic energy of the air stream into pressure energy.[2]

SUPER-SONIC DUCTS: **-**The high-speed inlet duct is often a complex construction because, not only must the air be delivered to the face of the compressor at an acceptable mass flow rate, velocity, angle, and pressure distribution, it must do this under wide extremes of aircraft speed, altitude, and attitude, and with as little loss of total pressure as possible.[2]

The supersonic inlet duct must operate in the following three speed zones:

- Subsonic
- Transonic
- Supersonic

5.2 FAN COWL:

Left and right fan cowl doors enclose the engine fan section between the nose cowl and fan reverser. The fan cowl doors provide access to approximately 70 percent of the total line replaceable units. Principal items include the fuel pump and filter, main engine control, pressurizing valve, fuel/oil cooler, oil tank, scavenge oil filter, oil scavenge/pressure pump, hydraulic pumps, hydraulic pump filters, generator, constant speed drive (CSD), starter, starter shutoff valve, fire detectors, throttle control and fuel shutoff push-pull cable linkages, compressor inlet temperature (CIT) sensor, ignition exciters, nose cowl anti-icing valve, fan reverser actuators, oil quantity, fuel pressure, and hydraulic pressure transmitters, fan speed sensors, and core speed sensor.

FIG: 5.2 FAN COWL

5.3 THRUST REVERSER COWL:

A simple and effective way to reduce the aircraft landing run on both dry and slippery runways is to reverse the direction of the exhaust gas stream, thus using engine power as a deceleration force. Thrust reverser has been used to reduce airspeed in flight but it is not commonly used on modern aircraft.

FIG: 5.3 THRUST REVERSER COWL

5.4 NACELLE:

The nacelle is the entirety of the cover or shroud that contains the engine. The nacelle not only streamlines the entire engine assembly, it also protects it and contains the various devices and systems which are attached to the engine.

FIG: 5.4 NACELLE AND PYLON

5.5 PYLON:

Pylons is a rigid structure used to hold the heavy aircraft engine in its place and position under (or over, occasionally) an aircraft's wing, without interfering with the airflow over and under the aircraft wing that is needed for lift and control whereby it between the engine and the wing.
In some fact, this technology is a new type of aircraft pylon design for noise control. A pylon connects the engine to the air-frame of an aircraft. This design uses air passing through the pylon to actively disrupt the jet engine exhaust stream after it exits the engine, disrupting and redistributing the axial and azimuthally distributed sources of jet noise from the aircraft.

5.6 SPINNER:

A spinner is an aircraft component, a streamlined fairing fitted over a propeller hub or at the center of a turbofan engine. Spinners both make the aircraft overall more streamlined, thereby reducing aerodynamic drag, and also smooth the airflow so that it enters the air intakes more efficiently.

Fig: 5.5 SPINNERS

CHAPTER 6

MAJOR COMPONENTS

6.1 COMPRESSOR:

It is an engine component which is directly coupled with turbine (another engine component). Compressor takes energy from turbine and adds this energy to the air passing through it to satisfy the needs of the combustor.[4]

PURPOSE OF COMPRESSION: -

• The primary purpose of the compressor is to increase the pressure of the mass of air by (reducing its volume) entering the engine inlet and then to discharge it into the diffuser and the combustors at the correct velocity, pressure, and temperature.

• The secondary purpose of the compressor is to supply engine bleed air to cool the internal hot section, and supply heated air for inlet anti-icing.

TYPES OF COMPRESSORS: -

All gas turbine engines use one of the following forms of compressor: -

- Centrifugal Flow Compressor
- Axial Flow Compressor

6.1.1 CENTRIFUGAL-FLOW COMPRESSOR:

A centrifugal compressor performs its duties by receiving the air at its center and accelerating it outward by centrifugal force. The air then expands into a divergent duct called a diffuser, and as it spreads out, it slows down and its static pressure increases. Centrifugal compressors consist basically of an impeller (rotor) and a diffuser (stator).[4]

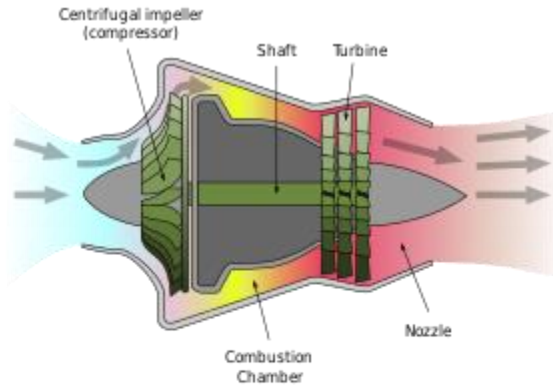

Fig: 6.1 Centrifugal-flow compressor.

CONSTRUCTION: -The construction of the compressor centers around the impeller, diffuser and air intake system.

IMPELLERS: - The impeller consists of a forged (usually forged from aluminum alloy), disc with integral radially disposed vanes on one or both sides forming convergent passages in conjunction with the compressor casing. The vanes may be swept back, but for ease of manufacture straight radial vanes are usually employed.[4]

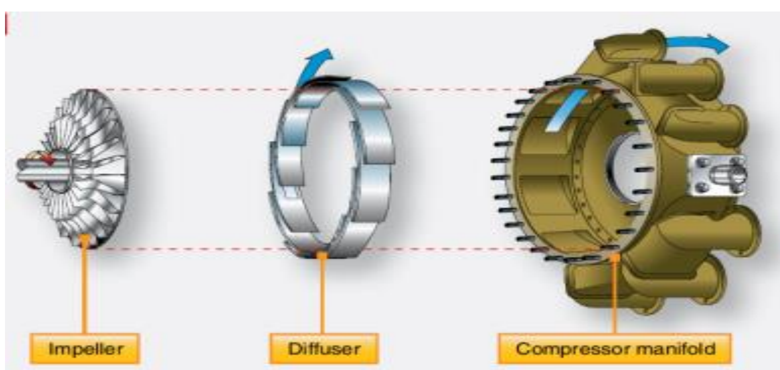

Fig: 6.2 Components of a centrifugal-flow compressor

DIFFUSER:- The diffuser assembly may be an integral part of the compressor casing or a separately attached assembly. In each instance it consists of a number of vanes formed tangential to the impeller. The vane passages are divergent to convert the kinetic energy into pressure energy and the inner edges of the vanes are in line with the direction of the resultant airflow from the impeller[4]

FEATURES OF CENTRIFUGAL COMPRESSOR:- Centrifugal compressors could be manufactured in a variety of design including single-stage, multiple-stage, and double-sided types. On the basis of arrangement of impeller it is divided into following three categories:

- Single-stage compressor
- Two stages, single entry compressor
- Single-stage, double entry compressor

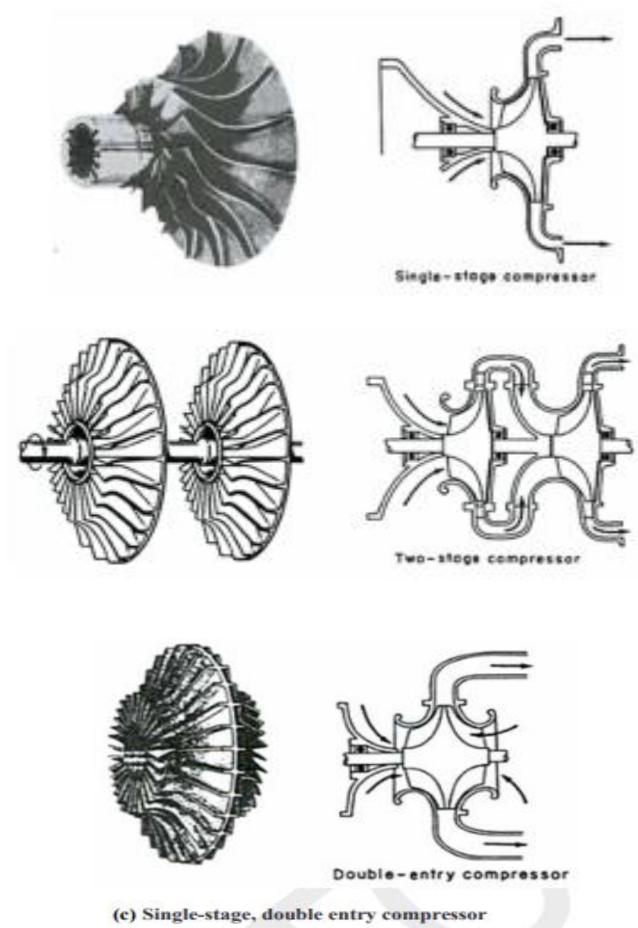

FIG: 6.3 I) SINGLE-STAGE COMPRESSOR, II) TWO-STAGE, SINGLE ENTRY COMPRESSOR, III) SINGLE-STAGE, DOUBLE ENTRY COMPRESSOR.

PRINCIPLES OF OPERATION AND APPLICATION:- The impeller is rotated at high speed by the turbine and air is continuously induced into the center of the impeller. Centrifugal action causes it to flow radially outwards along the vanes to the impeller tip, thus accelerating the air and also causing a rise in pressure to occur. The engine intake duct may contain vanes that provide an initial swirl to the air entering the compressor. The air, on leaving the impeller, passes into the diffuser section where the passages form divergent nozzles that convert most of the kinetic energy into pressure energy, In practice, it is usual to design the compressor so that about half of the pressure rise occurs in the impeller and half in the diffuser.

6.1.2 AXIAL FLOW COMPRESSOR:

The axial-flow compressor is made up of a series of rotating airfoils called rotor blades and a stationary set of airfoils called stator vanes. As the name implies, the air is being compressed in a direction parallel to the axis of the engine

A stage consists of a row of rotating blades followed by a row of stator vanes. The entire compressor is made up of a series of alternating rotor and stator vane stages, with each stage constructed of blades shaped to provide the most lift for the least drag[3]

There are 2 types of Axial Flow Compressor:

- Single Spool Axial Flow Compressor
- Double Spool Axial Flow Compressor

SINGLE SPOOL AXIAL FLOW COMPRESSOR:- In case of single spool axial flow compressor, compressor, shaft, and turbine all rotate together as a single unit.

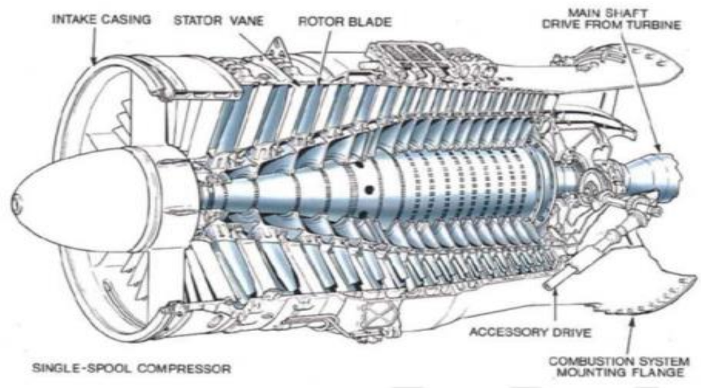

Fig: 6.4 Single Spool Axial Flow Compressor

DOUBLE SPOOL AXIAL FLOW COMPRESSOR: -In case of multi-spool engine, the turbine shafts attach to their respective compressors by fitting coaxially, one within the other and the different spool rotate at different RPM.

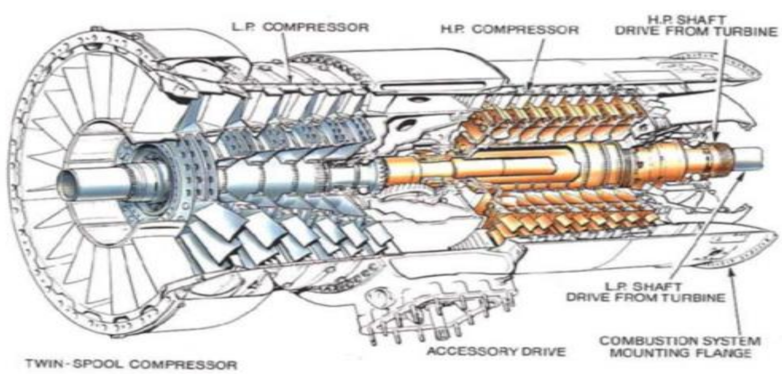

FIG: 6.5 DOUBLE SPOOL AXIAL FLOW COMPRESSOR

CONSTRUCTION: -The construction of the compressor centers around the rotor assembly and casings. The rotor shaft is supported in ball and roller bearings and coupled to the turbine shaft in a manner that allows for any slight variation of alignment. The cylindrical casing assembly may consist of a number of cylindrical casings with a bolted axial joint between each stage or the casing may be in two halves with a bolted center line joint [2]

An axial-flow compressor has two main elements: -

- the rotor blades (made up of a series of rotating airfoils)
- Stator vanes (made up of a stationary set of airfoils).

ROTOR BLADES: - The rotor blades force air rearward through each stage which consists of one set of rotor blades and the following set of stator vanes. The speed of the rotor determines the air velocity in each stage. As the velocity increases, kinetic energy is added to the air. The stator vanes are placed to the rear of the rotor blades to receive the high velocity air and act as diffusers, changing the kinetic energy into potential energy of pressure. The stators also serve a secondary function of directing the airflow into the next stage of compression.[2]

STATOR VANES: - The stator vanes are again of airfoil section and are secured into the compressor casing or into stator vane retaining rings, which are themselves secured to the casing. The vanes are often assembled in segments in the front stages and may be shrouded at their inner ends to minimize the vibrational effect of flow variations on the longer vanes. It is also necessary to lock the stator vanes in such a manner that they will not rotate around the casing.[2]

INLET GUIDE VANES (IGV):- The Inlet Guide Vanes (IGV) which is the vanes immediately in front of the first stage rotor blades may also be stationary or variable. The function of the Inlet Guide Vanes (IGV) is to direct the airflow into the compressor at the most desirable angle. The width of passage at inlet and outlet section of an IGV is same. Exit Guide Vanes are placed at the compressor discharge to remove the rotational moment imparted to the air by the compressor.[3]

PRINCIPLE OF OPERATION OF AXIAL FLOW COMPRESSOR: -During operation the rotor is turned at high speed by the turbine so that air is continuously induced into the compressor, which is then accelerated by the rotating blades and swept rearwards onto the adjacent row of stator vanes. The pressure rise results from the energy imparted to the air in the rotor which increases the air velocity. The air is then decelerated (diffused) in the following stator passage and the kinetic energy translated into pressure. Stator vanes also serve to correct the deflection given to the air by the rotor blades and to present the air at the correct angle to the next stage of rotor blades. The last row of stator vanes usually act as air straighteners to remove swirl from the air prior to entry into the combustion system at a reasonably uniform axial velocity.

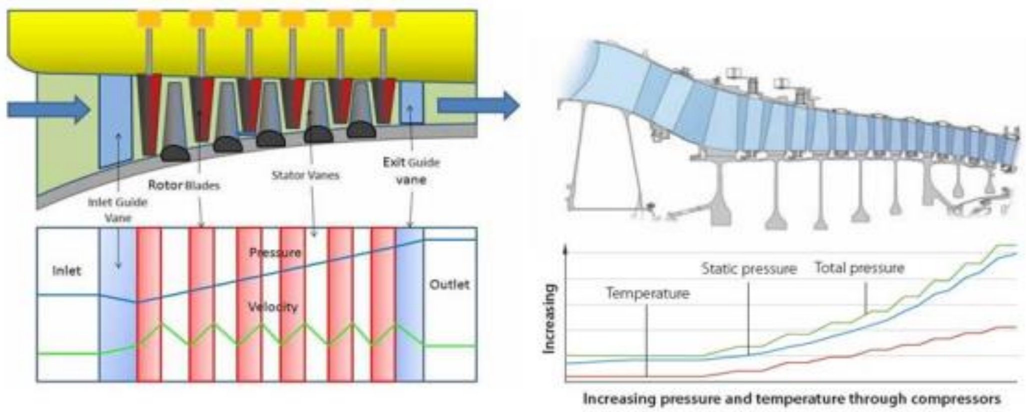

FIG: 6.6 PRESSURE, VELOCITY AND TEMPERATURE CHANGE THROUGH THE AXIAL FLOW COMPRESSOR

Changes in pressure and velocity that occur in the airflow through the compressor are shown diagrammatically in Figure. The changes are accompanied by a progressive increase in air temperature as the pressure increases.[2]

CHOKE, STALL AND SURGE OF COMPRESSOR: -

CHOCK: - Choke is an unexpected condition of airflow through the compressor due to low angle of attack (AOA) [5]

Conditions of low AOA are:

• If velocity of airflow increases at a constant (normal) engine RPM.

• If engine RPM decreases at a constant (normal) velocity of airflow.[5]

STALL: - A compressor stall is a condition of airflow when the angle of attack becomes excessive so that the compressor blades can no longer exert its lifting effect and the airflow through it becomes unstable. [5]

Conditions of high AOA are:

• If velocity of airflow decreases at a constant (normal) engine RPM.

• If engine RPM increases at a constant (normal) velocity of airflow.[5]

SURGE: - When complete flow breakdown occurs throughout the entire compressor stages is called surge. [5]

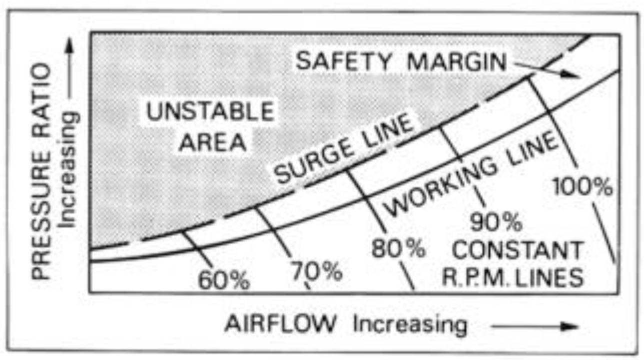

FIG: 6.7 LIMITS OF STABLE AIRFLOW

PREVENTION OF COMPRESSOR STALL AND SURGE: -There are number of methods by which we can prevent the compressor from stall and surge, those methods are: -

- Employing Engine Bleed (BVB) systems
- Employing Variable Incidence Guide Vanes (Axial compressor)
- Employing increased number of stages (Axial compressor)
- Employing Multiple-Spool Design

DIFFUSER: - The diffuser is the divergent section of the engine after the compressor and before the combustion section. It is in the form of a divergent duct, and is usually a separate section, bolted to the compressor case. It has the all-important function of reducing high-velocity compressor discharge air to increased pressure at a slower velocity. The pressure in the diffuser is the highest in the engine [2]

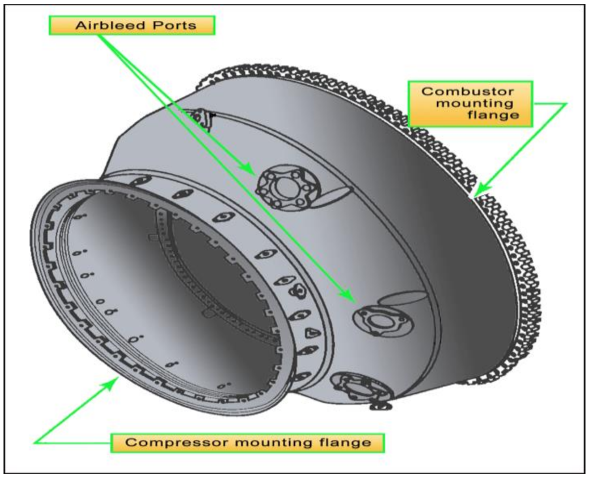

FIG: 6.8 DIFFUSER.

6.2 COMBUSTION CHAMBER

INTRODUCTION: - The function of the combustion chamber is to add heat at constant pressure to increase the energy of fluid before it is expanded over the turbine and the propelling nozzle. To do this, it burns injected fuel to liberate heat. No burning should occur after the gases leave the chamber outlet, which means that complete combustion must take place entirely within the chamber. The gases must have satisfactory temperature distribution and acceptable maximum temperature as they enter the turbine.[6]

CONSTRUCTION: All combustion chambers contain the same basic elements:

- A casing.
- A perforated inner liner.
- A fuel injection system.
- Some means for initial ignition.

- A fuel drainage system to drain off unburned own

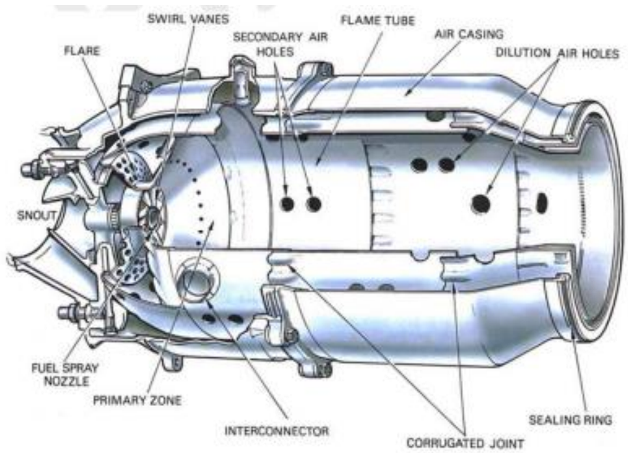

FIG: 6.9 A TYPICAL COMBUSTION CHAMBER

Chamber has different zones e.g. primary, secondary and tertiary zones.

In modern combustion chambers, two zones are classified:

- Combustion Zone or primary burning zone and
- Dilution zone

6.2.1 COMBUSTION PROCESS:

AIRFLOW:-To function properly, the combustors must mix the air and the fuel for efficient combustion. Then it must lower the temperature of the hot combustion products enough that they will not overheat the turbine components. To do this, the airflow through the combustor is divided into some air paths.[7]

PRIMARY AIR: This is the main combustion air. It is highly compressed air from the high pressure compressor (often decelerated via the diffuser) that is fed through the main channels in the dome of the combustor and the first set of liner holes. Approximately 25 to 35 percent of the air is routed to the area around the fuel nozzle as primary air. This air is mixed with fuel, and then combusted. [7]

INTERMEDIATE AIR: Intermediate air is the air injected into the combustion zone through the second set of liner holes (primary air goes through the first set). This air completes the reaction processes, cooling the air down and diluting the high concentrations of carbon monoxide (CO) and hydrogen (H_2). [7]

DILUTION AIR: Dilution air is airflow injected through holes in the liner at the end of the combustion chamber to help cool the air to before it reaches the turbine stages. The air is carefully used to produce the uniform temperature profile desired in the combustor [7]

COOLING AIR: Cooling air is airflow that is injected through small holes in the liner to generate a layer (film) of cool air to protect the liner from the combustion temperatures [7]

6.2.2 FUNCTION OF COMBUSTION CHAMBER:

The combustion chamber is the element of the gas turbine arranged between the compressor and the turbine, inside which is performed the mixture of the fuel fed by the injectors, with the air fed by the compressor and the combustion of said air and fuel mixture. The combustion leads to an important increase in temperature of said air, which increases its energy, the fraction of which may be recovered through expansion is used on the one hand for driving the above-mentioned compressor and, on the other hand, for supplying propelling power in the case of a jet engine or of the mechanical power in the case of a turbine engine.

The walls of the combustion chamber define two inner communicating areas: the combustion area which is termed the primary chamber and the dilution area termed secondary chamber. Inside the primary chamber are arranged the fuel injectors and the sparking plugs. In order that the combustion be possible and stable, it is necessary to form, in the primary chamber, a hot gaseous core with the gases produced through combustion which is essential for the upkeep of the latter combustion. Said core can exist only if there is a local slowing down and a turbulence in the mixture of air and fuel, which mixture should approximate stoichiometric proportions.

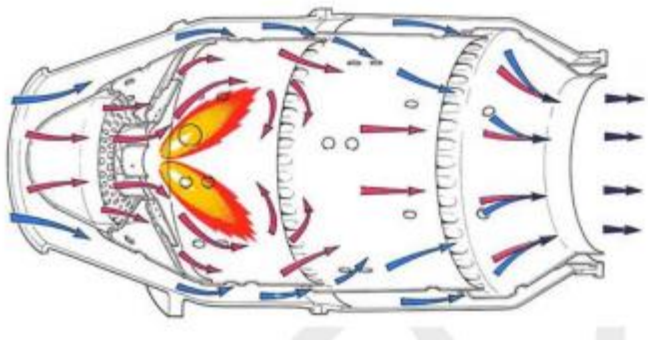

FIG: 6.10 FLAME STABILIZING AND GENERAL AIRFLOW PATTERN.

The combustion of such a mixture leads to a temperature of the gases approximately 2000 C., the application of which to the turbine, would lead to its destruction. In order to return the gases to a temperature consistent with the resistance of the material, one fraction of the air fed by the compressor, termed secondary flux, is distributed into the secondary chamber where it is mixed with the gases fed by the primary chamber. The introduction of the secondary flux must be such that it leads to a gradient in temperature increasing from the root of the blades to the periphery of the turbine blades [2]

6.2.3 FUEL SUPPLY:

Fuel is supplied to the airstream by one of two distinct methods. The most common is the injection of a fine atomized spray into the recirculating airstream through spray nozzles. The second method is based on the pre-vaporization of the fuel before it enters the combustion zone.[7]

6.2.4 TYPES OF COMBUSTION CHAMBER: -

There are three main types of combustion chamber used for gas turbine engines. They are

- Multiple Can
- Can-annular
- Annular type

MULTIPLE CAN TYPE COMBUSTION CHAMBER:

CONSTRUCTION: This type of combustion chamber consists of a series of outer housings, each with its own perforated inner liner, fuel injector, igniter, and casing. Each of the multiple combustion can is actually a separate burner unit interconnected with small flame propagation tube

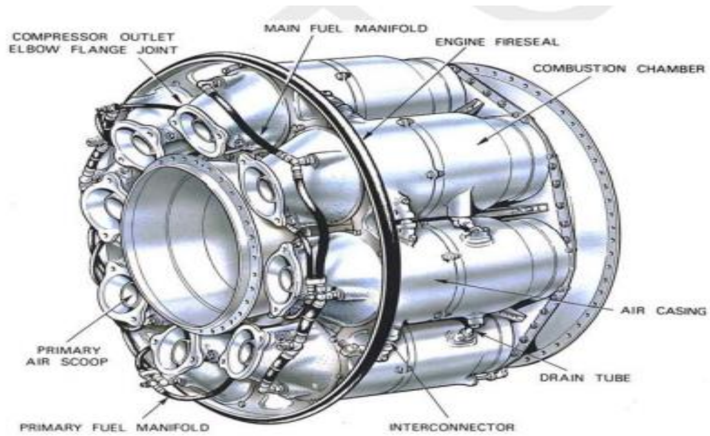

FIG: 6.11 MULTIPLE CAN TYPE COMBUSTION CHAMBER

OPERATION:- The primary air from the compressor is guided into each individual can, where it is decelerated, mixed with fuel, and then ignited. The secondary air also comes from the compressor, where it is fed outside of the liner (inside of which is where the combustion is taking place). The secondary air is then fed, usually through slits in the liner, into the combustion zone to cool the liner via thin film cooling. All of the combustion products of the cans are discharged into the open area at the turbine nozzle inlet.[2]

CAN- ANNULAR:

CONSTRUCTION: Like the can type combustor, can annular combustors have discrete combustion zones contained in separate liners with their own fuel injectors. Unlike the can combustor, all the combustion zones share a common ring (annulus) casing.[2]

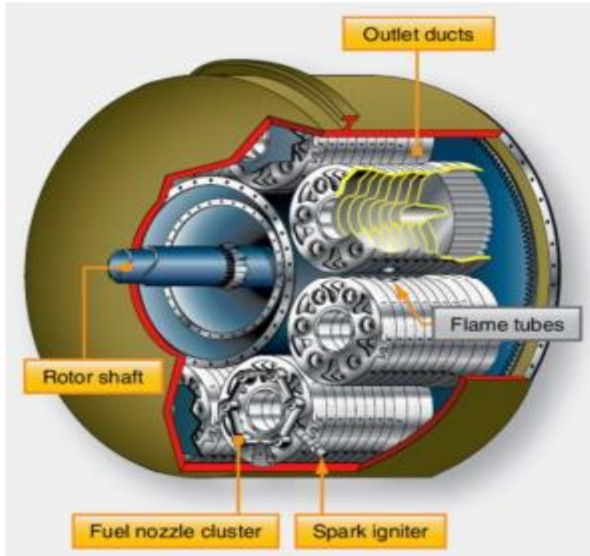

FIG: 6.12 TURBO-ANNULAR COMBUSTION CHAMBER

OPERATION: Each combustion zones no longer has to serve as a pressure vessel. The combustion zones can also "communicate" with each other via liner holes or connecting tubes that allow some air to flow circumferentially. The exit flow from the can-annular combustor generally has a more uniform temperature profile, which is better for the turbine section. [2]

ANNULAR TYPE COMBUSTION CHAMBER: -

CONSTRUCTION: - This type of combustion chamber consists of a single flame tube, completely annular in form, which is contained in an inner and outer casing. Annular combustion chamber may be reverse flow type.[2]

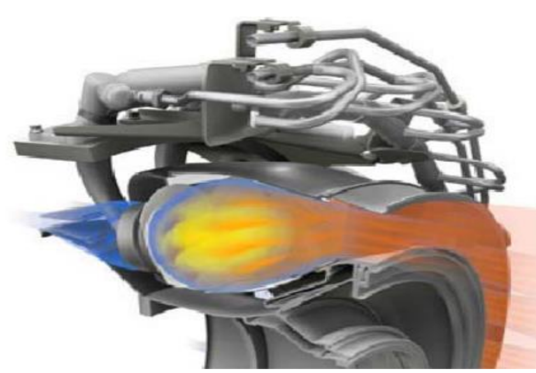

FIG: 6.13 A ANNULAR COMBUSTION CHAMBER

OPERATION: The airflow through the flame tube is similar to that already described, the chamber being open at the front to the compressor and at the rear to the turbine nozzles.[2]

6.2.5 MATERIALS OF COMBUSTION CHAMBER:

The containing walls and internal parts of the combustion chamber must be capable of resisting the very high gas temperature in the primary zone. In practice, this is achieved by using the best heat resisting materials available, the use of high heat resistant coatings and by cooling the inner wall of the flame tube as insulation from the flame. The combustion chamber must also withstand corrosion due to the products of the combustion, creep failure due to temperature gradients and fatigue due to vibrational stresses.[2]

6.3 TURBINE

INTRODUCTION: - The turbine has the task of providing the power to drive the compressor and accessories and, in the case of engines which do not make use solely of a jet for propulsion, of providing shaft power for a propeller or rotor. It does this by extracting energy from the hot gases released from the combustion system and expanding them to a lower pressure and temperature. High stresses are involved in this process, and for efficient operation,

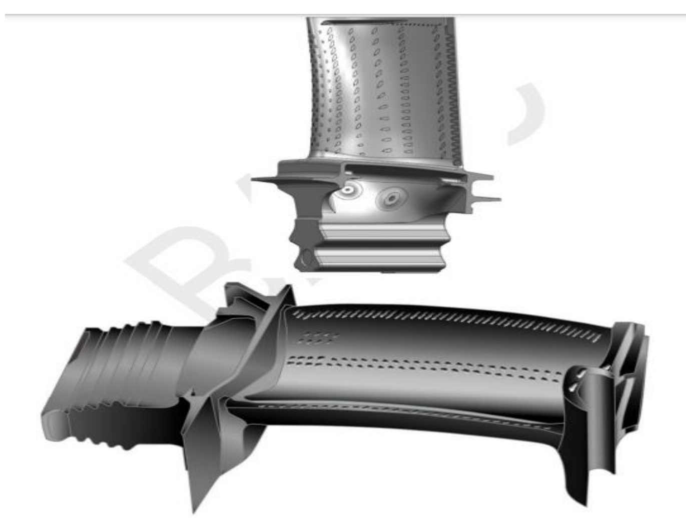

FIG: 6.14 A SINGLE TURBINE BLADE

Types of turbine with a few exceptions, gas turbine manufacturers have concentrated on the axial-flow turbine (Figure 15.6.1), although some manufacturers are building engines with a radial- inflow turbine (Figure 15.6.2). The radial-inflow turbine has the advantage of ruggedness and simplicity and is relatively inexpensive and easy to manufacture when compared with the axial-flow type.[8]

There is type of turbine write down below:

I) Axial flow Turbine,
II) Radial-inflow turbine,
III) Impulse turbine,
IV) The Reaction turbine,
V) Reaction-Impulse turbine.

6.3.1 AXIAL FLOW TURBINE:

The axial-flow turbine comprises two main elements consisting of a set of stationary vanes and one or more turbine rotors. The turbine blades themselves are of two basic types, the impulse and the reaction. The modem aircraft gas turbine engine utilizes blades that have both impulse and reaction sections. [9]

FIG: 6.15 A SINGLE STAGE, AXIAL-FLOW TURBINE WHEEL

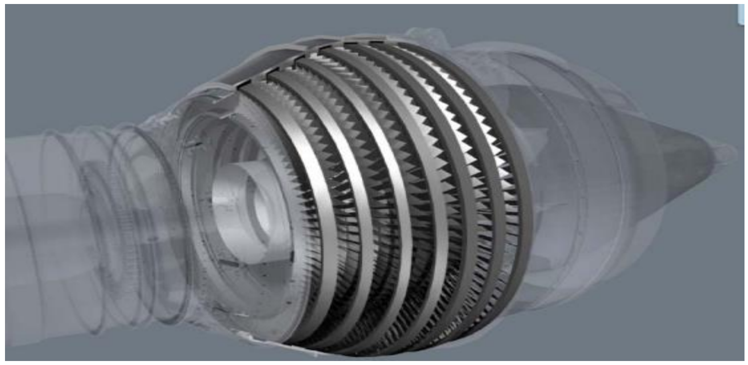

FIG:-6.16 A MULTI-STAGE, AXIAL FLOW TURBINE WITH TURBINE NOZZLE

6.3.2 RADIAL-INFLOW TURBINE:

The radial-inflow turbine has the advantage of ruggedness and simplicity and is relatively inexpensive and easy to manufacture when compared with the axial-flow type. On this type of turbine, inlet gas flows through peripheral nozzles to enter the wheel passages in an inward radial direction.[9]

FIG: 6.17 AIRFLOW THROUGH A RADIAL-INFLOW TURBINE

Depending on the pressure expansion through turbine, turbine is further classified as

- Impulse turbine,
- Reaction turbine
- Impulse reaction turbine

6.3.3 IMPULSE TURBINE:

A characteristic of an impulse turbine and the nozzle used with it is that gases entering tile nozzle diaphragm are expanded to atmospheric pressure. In the ideal impulse turbine, all pressure energy of the gas has been converted into kinetic energy; hence, no further pressure drop can occur across the blades.[2]

6.3.4 THE REACTION TURBINE:

As the gases from the combustion chamber enter the first row of nozzle vanes, they experience a drop in pressure and an increase in velocity through the nozzle, but to a lesser degree than through the nozzle used with the impulse turbine.[2]

6.3.5 REACTION-IMPULSE TURBINE:

The turbine balding is a blending of the impulse type at the roots and the reaction type at the tips. The blade "impulse" at the root and "reaction" at the tip, the blade exit pressure can be held relatively constant. The changing height between the two pressure lines indicates the pressure differential across the blade. From previous discussion it can be seen that the required pressure drops for "reaction" is present at the tip and gradually changes to the "no pressure loss" condition required for "impulse" at the root.[2]

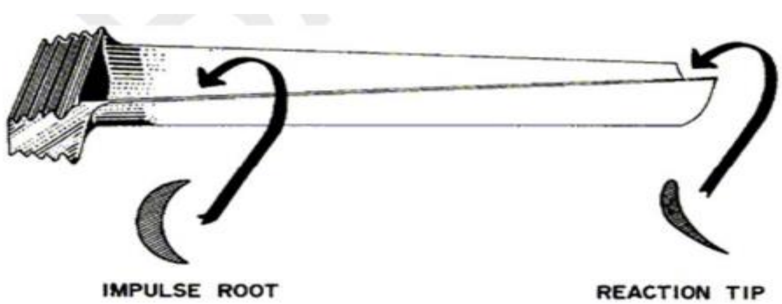

FIG: 6.18 AN IMPULSE-REACTION BLADE

6.3.6 NOZZLE GUIDE VANES:

The basic components of the turbine are the combustion discharge nozzles, the nozzle guide vanes, the turbine discs and the turbine blades. The rotating assembly is carried on bearings mounted in the turbine casing and the turbine shaft may be common to the compressor shaft or connected to it by a self-aligning coupling. The nozzle guide vanes are of an aero foil shape with the passage between adjacent vanes forming a convergent duct. The vanes are located in the turbine casing in a manner that allows for expansion. The nozzle guide vanes are usually of hollow form and may be cooled by passing compressor delivery air through them to reduce the effects of high thermal stresses and gas loads.

The nozzle guide vanes (NGV) form convergent to convert the pressure energy in the gas stream into kinetic energy ensuring that the flow is fast enough to impinge on the rotor blades. They must also change the direction of the gas stream so that the turbine blades can maximize the energy passing through them.

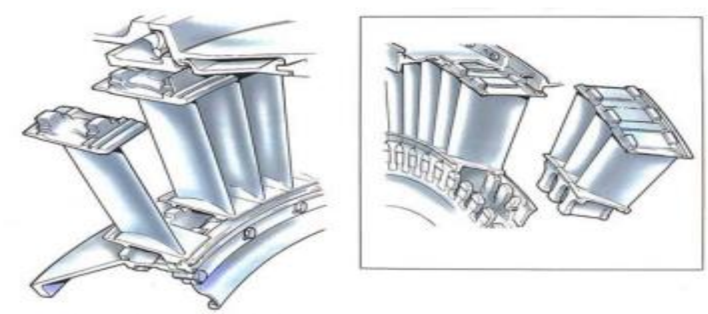

FIG: 6.19 TYPICAL NOZZLE GUIDE VANES SHOWING THEIR SHAPE AND LOCATION

Turbine blades the turbine blades are of an airfoil shape, designed to provide passages between adjacent blades that give a steady acceleration of the flow up to the 'throat', where the area is smallest and the velocity reaches that required at exit to produce the required degree of reaction. The actual area of each blade cross-section is fixed by the permitted stress in the material used and by the size of any holes which may be required for cooling purposes.

Importance of the correct choice of blade material:- The blades, while glowing red-hot, must be strong enough to carry the centrifugal loads due to rotation at high speed. A small turbine blade weighing only two ounces may exert a load of over two tons at top speed and it must withstand the high bending loads applied by the gas to produce the many thousands of turbine horsepower necessary to drive the compressor. Turbine blades must also be resistant to fatigue and thermal shock, so that they will not fail under the influence of high frequency fluctuations in the gas conditions, and they must also be resistant to corrosion and oxidization.[10]

6.3.7 TURBINE ACTIVE CLEARANCE CONTROL:

The turbine engines operate with different gas temperatures that change with the power setting and the outside air temperature (OAT). The energy for the heating of the turbine rotor and the turbine case comes from the gas flow with its variable temperatures. Due to the different thermal expansion characteristics of the turbine rotor and the turbine case the clearance between the turbine blade tips and the turbine case (tip clearance) changes during the engine operation. A larger tip clearance decreases the efficiency of the turbine with the result of a higher thrust specific fuel consumption (TSFC) and higher gas temperatures because the lack in efficiency is compensated for by the fuel control system with more fuel. A too small tip clearance can lead to rubbing of the turbine blades on the case. To prevent these undesirable effects a control of the thermal expansion of the turbine case is necessary. This is ensured by a cooling system that has a changeable cooling effect, the active clearance control system (ACC system). [10]

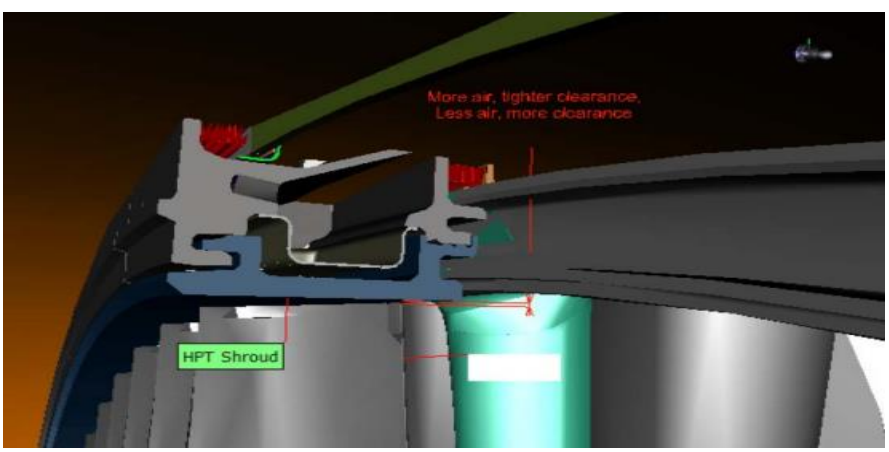

Fig: 6.20 Principle of turbine clearance control

6.4 EXHAUST

6.4.1 CONSTRUCTIONAL FEATURES:

A basic exhaust system is consisting of the use of a thrust reverser, noise suppressor and a two-position propelling nozzle entails a more complicated system. The low by-pass engine may also include a mixer unit to encourage a thorough mixing of the hot and cold gas streams

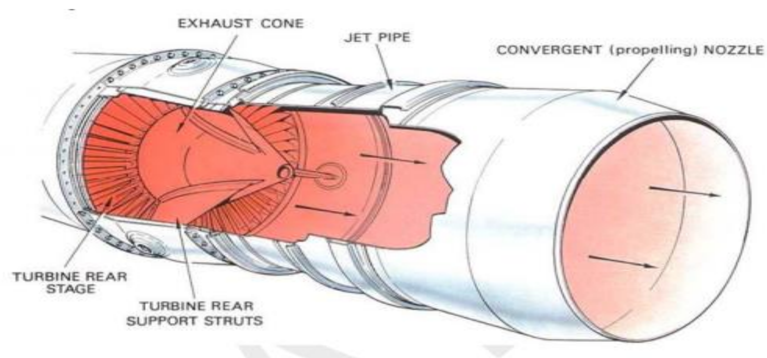

FIG: 6.21 A BASIC EXHAUST SYSTEM

The exhaust system must be capable of withstanding the high gas temperatures and is therefore manufactured from nickel or titanium. It is also necessary to prevent any heat being transferred to the surrounding aircraft structure. This is achieved by passing ventilating air around the jet pipe, or by lagging the section of the exhaust system with an insulating. Each blanket has an inner layer of fibrous insulating material contained by an outer skin of thin stainless steel, which is dimpled to increase its strength. In addition, acoustically absorbent materials are sometimes applied to the exhaust system to reduce engine noise.

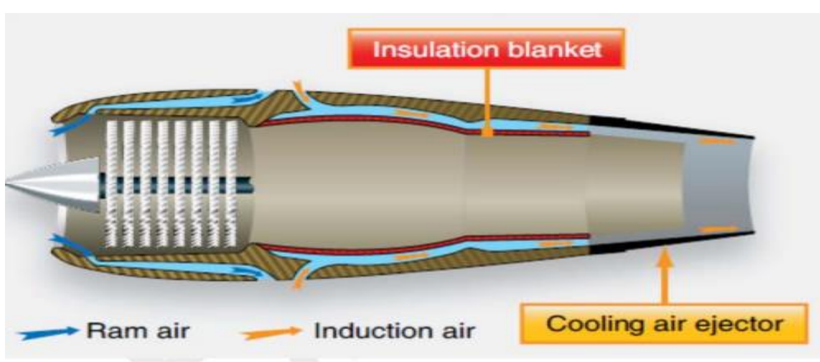

FIG: 6.22 AN INSULATING BLANKET

When the gas temperature is very high (for example, when afterburning is employed), the complete jet pipe is usually of double-wall construction with an annular space between the two walls. The hot gases leaving the propelling nozzle induce, by ejector action, a flow of air through the annular space of the engine nacelle. This flow of air cools the inner wall of the jet pipe and acts as an insulating blanket by reducing the transfer of heat from the inner to the outer wall.[2]

6.4.2 PRINCIPLES OF OPERATION:

Aero gas turbine engines have an exhaust system which passes the turbine discharge gases to atmosphere at a velocity, and in the required direction, to provide the resultant thrust. The velocity and pressure of the exhaust gases create the thrust in the turbo-jet engine but in the turbo propeller engine only a small amount of thrust is contributed by the exhaust gases, because most of the energy has been absorbed by the turbine for driving the propeller. The design of the exhaust system therefore, exerts a considerable influence on the performance of the engine. The areas of the jet pipe and propelling or outlet nozzle affect the turbine entry temperature, the mass airflow and the velocity and pressure of the exhaust jet.[2]

6.4.3 CONVERGENT, DIVERGENT AND VARIABLE AREA NOZZLES:

That the convergent section exit now becomes the throat, with the exit proper now being at the end of the flared divergent section. When the gas enters the convergent section of the nozzle, the gas velocity increases with a corresponding fall in static pressure. The gas velocity at the throat corresponds to the local sonic velocity. As the gas leaves the restriction of the throat and flows into the divergent section, it progressively increases in velocity towards the exit. The reaction to this further increase in momentum is pressure force acting on the inner wall of the nozzle. A component of this force acting parallel to the longitudinal axis of the nozzle produces the further increase in thrust.[2]

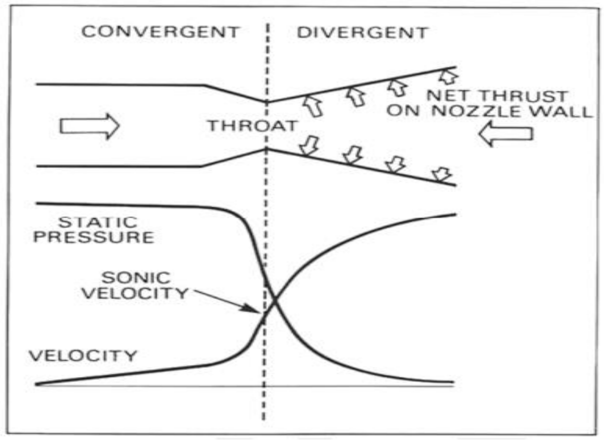

FIG: 6.23 GAS FLOW THROUGH A CONVERGENT-DIVERGENT NOZZLE

6.4.4 EXHAUST NOISE:

Jet exhaust noise is caused by the violent and hence extremely turbulent mixing of the exhaust gases with the atmosphere and is influenced by the shearing action caused by the relative speed between the exhaust jet and the atmosphere. The small eddies created near the exhaust duct cause high frequency noise but downstream of the exhaust jet the larger eddies create low frequency noise.

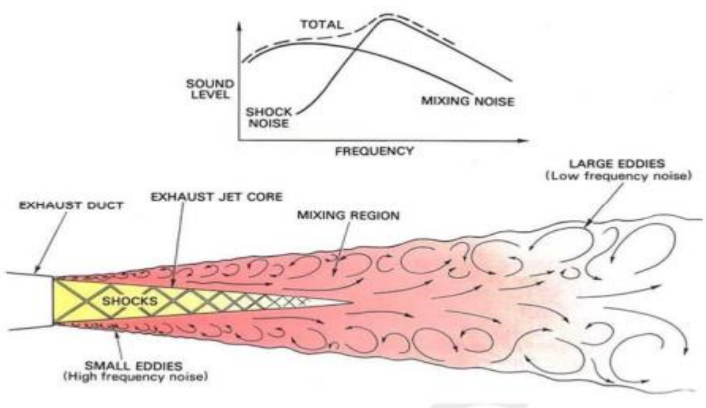

FIG: 6.24 EXHAUST MIXING AND SHOCK STRUCTURE

Additionally, when the exhaust jet velocity exceeds the local speed of sound, a regular shock pattern is formed within the exhaust jet core. This produces a discrete (single frequency) tone and selective amplification of the mixing noise, With the pure jet engine the exhaust jet noise is of such a high level that the turbine and compressor noise is insignificant at all operating conditions [2]

6.4.5 METHODS OF SUPPRESSING NOISE:

Noise suppression of internal sources is approached in two ways; by basic design to minimize noise originating within or propagating from the engine, and by the use of acoustically absorbent linings. Noise can be minimized by reducing airflow disruption which causes turbulence. This is achieved by using minimal rotational and airflow velocities and reducing the wake intensity by appropriate spacing between the blades and vanes.

The major source of noise on the pure jet engine and low by-pass engine is the exhaust jet, and this can be reduced by inducing a rapid or shorter mixing region. This reduces the low frequency noise but may increase the high frequency level. Fortunately, high frequencies are quickly absorbed in the atmosphere and some of the noise which does propagate to the listener is beyond the audible range, thus giving the perception of a quieter engine. This is achieved by increasing the contact area of the atmosphere with the exhaust gas stream by using a propelling nozzle incorporating a corrugated or lobe-type noise suppressor.

FIG: 6.25 TYPES OF NOISE SUPPRESSOR.

Noise absorbing 'lining' material converts acoustic energy into heat. The absorbent linings normally consist of a porous skin supported by a honeycomb backing, to provide the required separation between the face sheet and the solid engine duct. The acoustic properties of the skin and the liner depth are carefully matched to the character of the noise, for optimum suppression.[2]

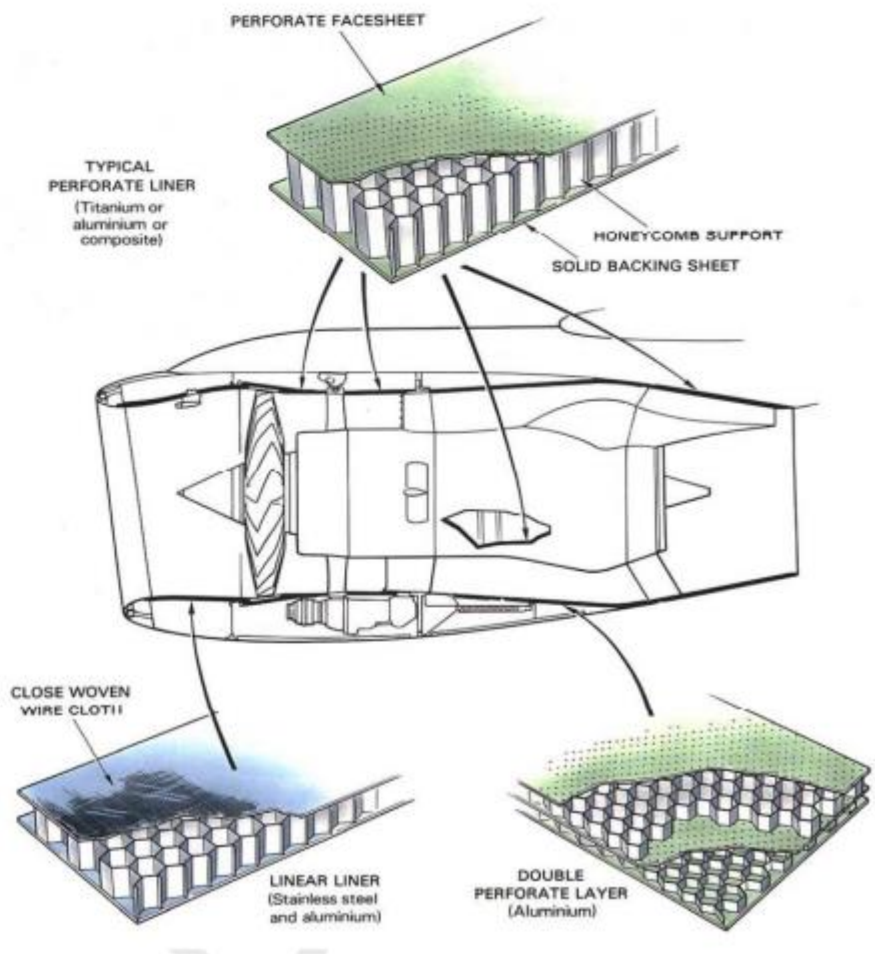

FIG: 6.26 NOISE ABSORBING MATERIALS AND LOCATION.

6.4.6 THRUST REVERSER:

Modern aircraft brakes are very efficient but on wet, icy or snow-covered runways this efficiency may be reduced by the loss of adhesion between the aircraft tire and the runway thus creating a need for an additional method of bringing the aircraft to rest within the required distance. A simple and effective way to reduce the aircraft landing run on both dry and slippery runways is to reverse the direction of the exhaust gas stream, thus using engine power as a deceleration force. Thrust reverser has been used to reduce airspeed in flight but it is not commonly used on modern aircraft. The difference in landing distances between an aircraft without reverse thrust and one using reverse thrust is illustrated in fig. [2]

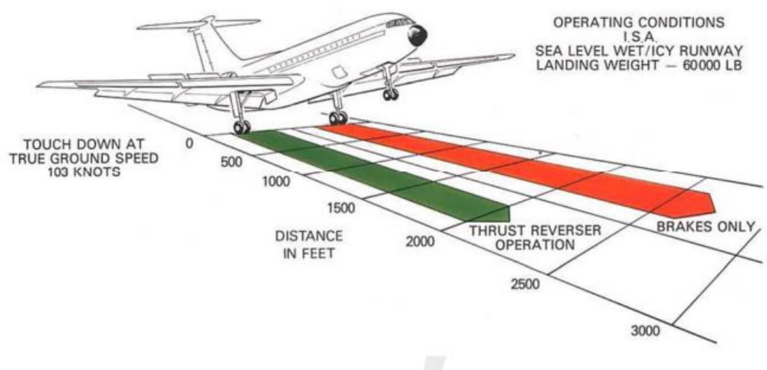

FIG: 6.27 COMPARATIVE LANDING RUNS WITH AND WITHOUT THRUST REVERSER.

6.4.7 PRINCIPLES OF OPERATION OF THRUST REVERSER:

There are several methods of obtaining reverse thrust on turbo-jet engines. One method uses clamshell-type deflector doors to reverse the exhaust gas stream and a second uses a target system with external type doors to do the same thing. The third method used on fan engines utilizes blocker doors to reverse the cold stream airflow. [2]

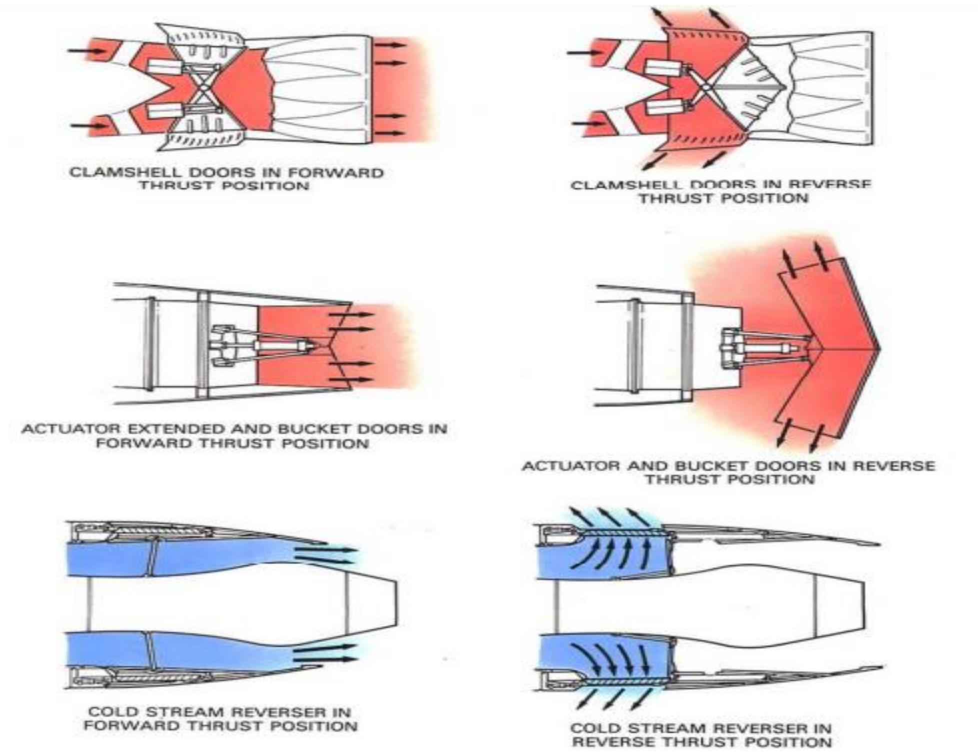

FIG: 6.28 METHOD OF THRUST REVERSER

CHAPTER 7

GAS TURBINE ENGINE FUEL SYSTEMS

7.1 INTRODUCTION:

The main task of the gas turbine engine and fuel control system:

01. Provides clean and vapor-free fuel.

02. Schedules fuel flow to the engine combustor in a chemically correct ratio of "Air to Fuel" for efficient combustion under the operating conditions of:

- steady state
- acceleration
- deceleration

03. Keeps the engine on the thrust level demanded by the pilot.

04. Prevents the expedience of the operating limits to enable maximum engine performance within the bounds imposed by stall margin, rotor speed, compressor discharge pressure (CDP), and turbine temperature limits.

05. Controls the functions of the other engine sub-systems:

(A) Air flow control thru' VSV & VBV scheduling.

(B) Starting & Ignition control and TACC in case of a FADEC Engine. [11]

7.2 ENGINE FUEL SYSTEM COMPONENTS:

Main Fuel Pumps (Engine Driven) Main fuel pumps deliver a continuous supply of fuel at the proper pressure and at all times during operation of the aircraft engine. The engine-driven fuel pump must be capable of delivering the maximum needed flow at appropriate pressure to obtain satisfactory nozzle spray and accurate fuel regulation. These engines driven fuel pumps may be divided into two distinct system categories:

1. Constant displacement

2. non-constant displacement

Their use depends on where in the engine fuel system they are used. Generally, a non-positive displacement (centrifugal pump) is used at the inlet of the engine-driven pump to provide positive flow to the second stage of the pump. The output of a centrifugal pump can be varied as needed and is sometimes referred to as a boost stage of the engine-driven pump.[11]

7.2.1 PLUNGER-TYPE FUEL PUMP:

The pump is of the single- unit, variable-stroke, plunger-type, variable displacement pump; similar pumps may be used as double units depending upon the engine fuel flow requirements. [11]

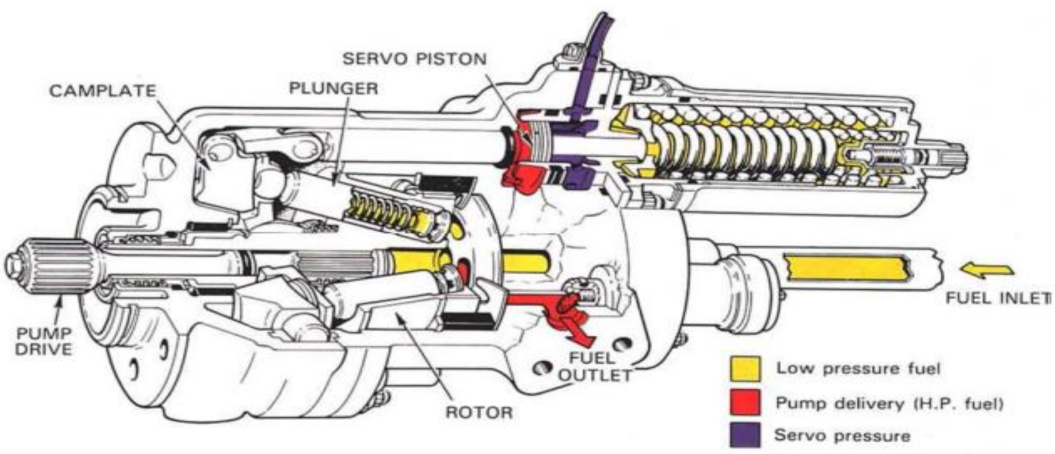

FIG: 7.1 A PLUNGER-TYPE FUEL PUMP

7.2.2 GEAR TYPE CONSTANT DISPLACEMENT:

The gear-type fuel pump is driven from the engine and its output is directly proportional to its speed. [11]

7.2.3 FUEL SPRAY NOZZLES:

The final components of the fuel system are the fuel spray nozzles, which have as their essential function the task of atomizing or vaporizing the fuel to ensure its rapid burning. [11]

7.2.4 FUEL HEATER: Gas turbine engine fuel systems are very susceptible to the formation of ice in the fuel filters. When the fuel in the aircraft fuel tanks cools to 32 °F or below, residual water in the fuel tends to freeze, forming ice crystals. When these ice crystals in the fuel become trapped in the filter, they block fuel flow to the engine, which causes a very serious problem. To prevent this problem, the fuel is kept at a temperature above freezing. Warmer fuel also can improve combustion, so some means of regulating the fuel temperature is needed. One method of regulating fuel temperature is to use a fuel heater which operates as a heat exchanger to warm the fuel. The heater can use engine bleed air or engine lubricating oil as a source of heat.[11]

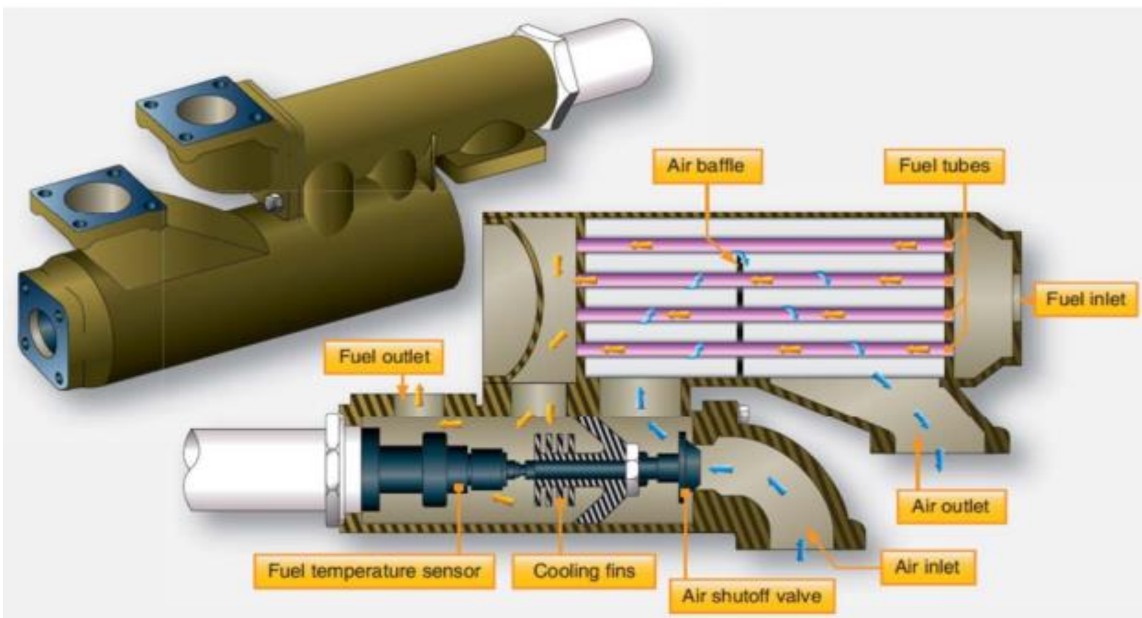

FIG: 7.2 FUEL HEATER.

7.2.5 FUEL FILTERS:

A low-pressure filter is installed between the supply tanks and the engine fuel system to protect the engine-driven fuel pump and various control devices. An additional high-pressure fuel filter is installed between the fuel pump and the fuel control to protect the fuel control from contaminants that could come from the low-pressure pump.[11]

The three most common types of filters in use are the micron filter, the wafer screen filter, and the plain screen mesh filter

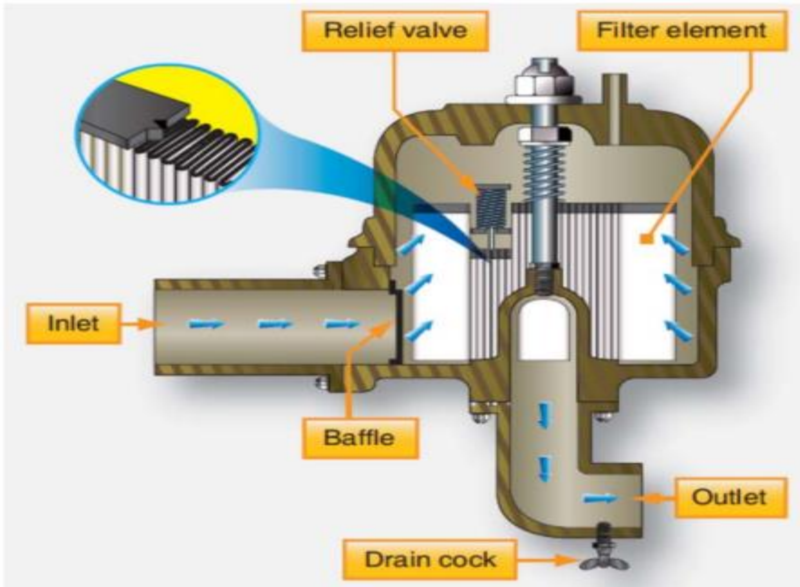

FIG: 7.3 AIRCRAFT FUEL FILTER.

7.2.6 FLOW DIVIDER:

A flow divider creates primary and secondary fuel supplies that are discharged through separate manifolds, providing two separate fuel flows.[11]

FIG: 7.4 FLOW DIVIDER

7.2.7 FUEL PRESSURIZING VALVE:

The fuel pressurizing valve is usually required on engines incorporating duplex fuel nozzles to divide the flow into primary and secondary manifolds. At the fuel flows required for starting and altitude idling, all the fuel passes through the primary line. As the fuel flow increases, the valve begins to open the main line until at maximum flow the secondary line is passing approximately 90 percent of the fuel. [11]

7.2.8 COMBUSTION DRAIN VALVES:

The drain valves are units used for draining fuel from the various components of the engine where accumulated fuel is most likely to present operating problems.

7.3 ENGINE FUEL SYSTEM:

The fuel system must deliver fuel to the combustion chambers not only in the right quantity, but also in the right condition for satisfactory combustion. The fuel nozzles form part of the fuel system and atomize or vaporize the fuel so that it ignites and burns efficiently. The fuel system must also supply fuel so that the engine can be easily started on the ground and in the air. This means that the fuel must be injected into the combustion chambers in a combustible condition during engine starting, and that combustion must be sustained while the engine is accelerating to its normal idling speed. Another critical condition to which the fuel system must respond occurs during a rapid acceleration. When the engine is accelerated, energy must be furnished to the turbine in excess of that necessary to maintain a constant rpm. However, if the fuel flow increases too rapidly, an over rich mixture can be produced, with the possibility of a rich blowout or compressor stall.[11]

7.3.1 FUEL DISTRIBUTION:

The purpose of the fuel distribution system is: - To deliver clean fuel to the engine combustion chamber. - To supply clean and ice-free fuel to various servomechanisms of the fuel system. - To cool down engine oil and Integrated Drive Generator (IDG) oil.[11]

- The fuel distribution components consist of: -
- Fuel supply and return lines (not shown).
- A fuel pump and filter assembly.
- An IDG oil cooler.
- A main oil/fuel heat exchanger.
- A servo fuel heater.
- A Hydro-Mechanical Unit (HMU).
- A fuel flow transmitter.
- A fuel nozzle filter.
- Fuel manifold.
- Fuel nozzles.

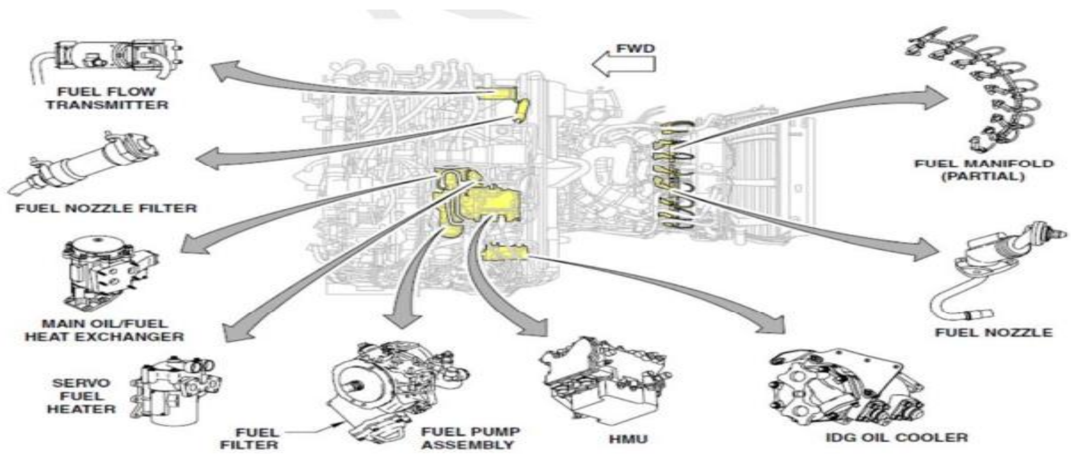

FIG: 7.5 FUEL DISTRIBUTION

CHAPTER 8

AIR SYSTEMS

8.1 INTRODUCTION:

The engine internal air system is defined as those airflows which do not directly contribute to the engine thrust. The system has several important functions to perform for the safe and efficient operation of the engine. These functions include internal engine and accessory unit cooling, bearing chamber sealing prevention of hot gas ingestion into the turbine disc cavities, control of bearing axial loads, control of turbine blade tip clearances and engine anti-icing. The system also supplies air for the aircraft services. Up to one fifth of the total engine core mass airflow may be used for these various functions. [2]

8.2 OPERATION OF ENGINE AIR DISTRIBUTION:

Cooling An important consideration at the design stage of a gas turbine engine is the need to ensure that certain parts of the engine, and in some instances certain accessories, do not absorb heat to the extent that is detrimental to their safe operation. The principal areas which require air cooling are the combustor and turbine.[2]

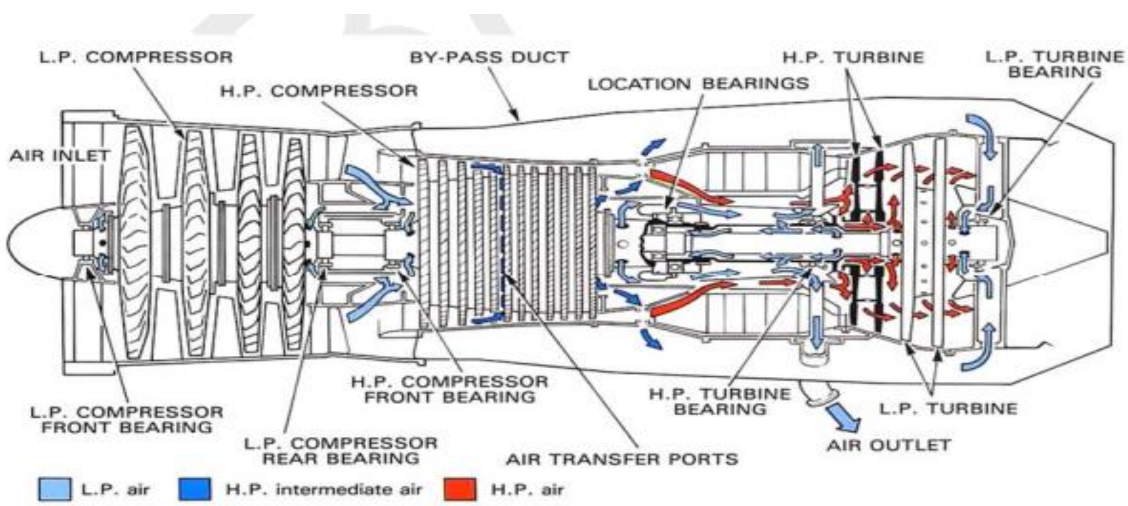

FIG: 8.1 INTERNAL AIR COOLING AND SEALING

Turbine cooling High thermal efficiency is dependent upon high turbine entry temperature, which is limited by the turbine blade and nozzle guide vane materials. Continuous cooling of these components allows their environmental operating temperature to exceed the material's melting point without affecting the blade and vane integrity. [2]

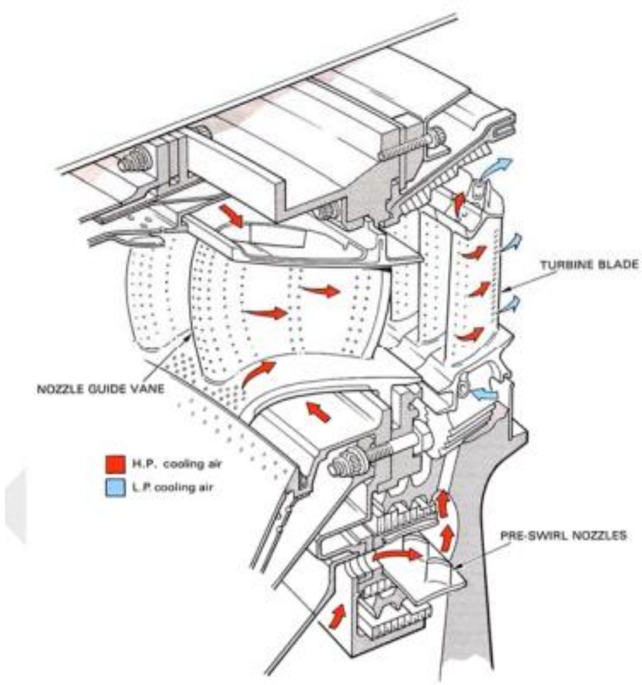

FIG: 8.7 NOZZLE GUIDE VANE AND TURBINE BLADE COOLING ARRANGEMENT.

8.3 ANTI-ICE CONTROL SYSTEM:

Icing of the engine and the leading edges of the intake duct can occur during flight through clouds containing super-cooled water droplets or during ground operation in freezing fog. Protection against ice formation may be required since icing of these regions can considerably restrict the airflow through the engine, causing a loss in performance and possible malfunction of the engine. Additionally, damage may result from ice breaking away and being ingested into the engine or hitting the acoustic material lining the intake duct. An ice protection system must effectively prevent ice formation within the operational requirements of the particular aircraft. The system must be reliable, easy to maintain, present no excessive weight penalty and cause no serious loss in engine performance when in operation [2]

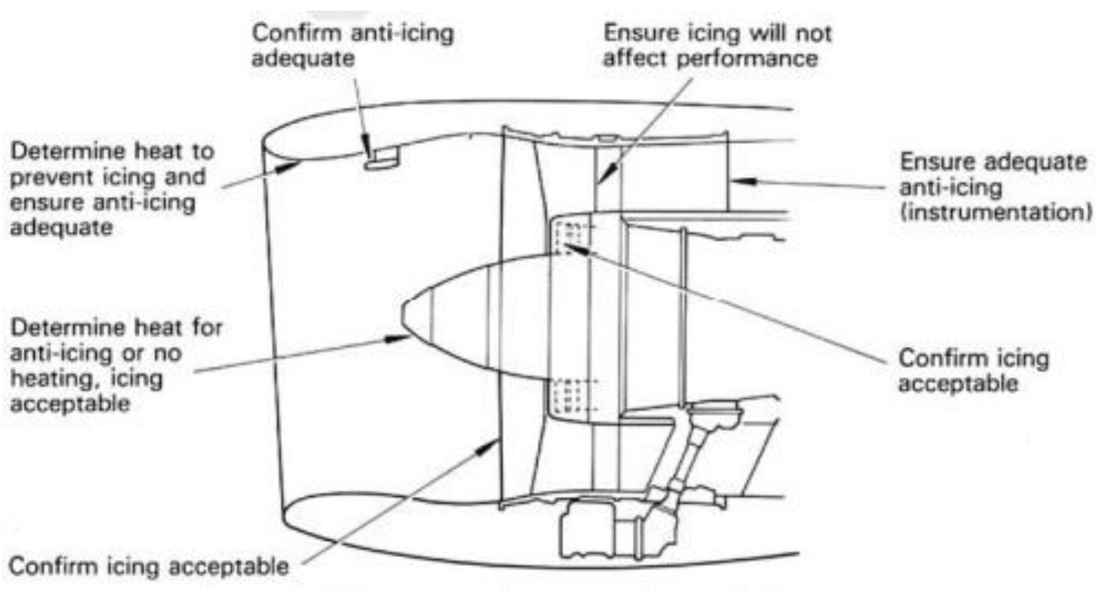

FIG: 8.3 AREAS TYPICALLY CONSIDERED FOR ICE PROTECTION.

CHAPTER 9

STARTING AND IGNITION

9.1 INTRODUCTION: To make the start of an engine possible, two systems are installed for this purpose on a turbine engine. These are the start system and the ignition system. These two systems are always used together for an engine start on ground

Ignition System Components each ignition system on an engine consists of the following components:

- Ignition exciter with electrical power supply
- Ignition lead (high tension cable)

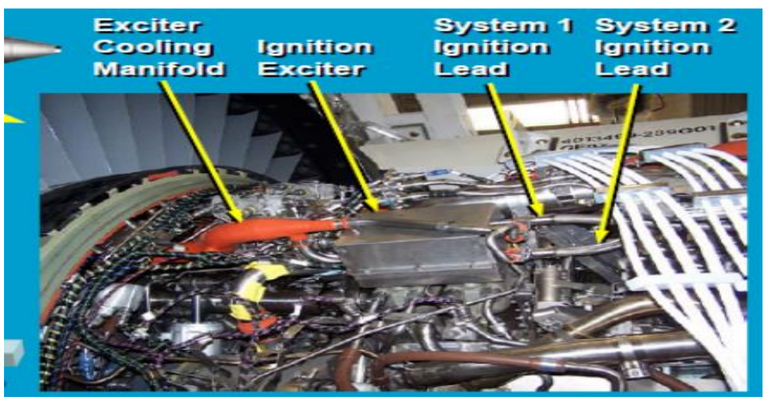

FIG: 9.1THE IGNITION SYSTEM COMPONENTS

9.2 THE IGNITION EXCITER:

The ignition exciters are installed on the engine fan case or on the core engine. If the ignition exciters are installed on the fan case, the air temperatures around the exciters are lower and no exciter cooling is necessary When this installation location is used, the ignition leads are longer compared to the core engine installation. These long ignition leads are usually cooled in the core engine area only. The ignition exciters are supplied with 115 VACS from the aircraft. They contain capacitors, the primary and secondary coil and a spark gap. The charging of the capacitors lasts approximately 1 second. Then they discharge across the spark gap to the igniter plug and the charging starts again. Due to the charge of the capacitors this discharge releases a high level of energy. The current level to the igniter plug is around 1500 A. Thus it is strictly prohibited to work on a powered ignition system. This would be extremely dangerous. [2]

The data of a typical ignition exciter:

- Energy rating 2 to 20 Joule
- Output voltage 2000 V
- Output current 1500 A
- Spark rate 1 per second
- Power supply 115 VAC

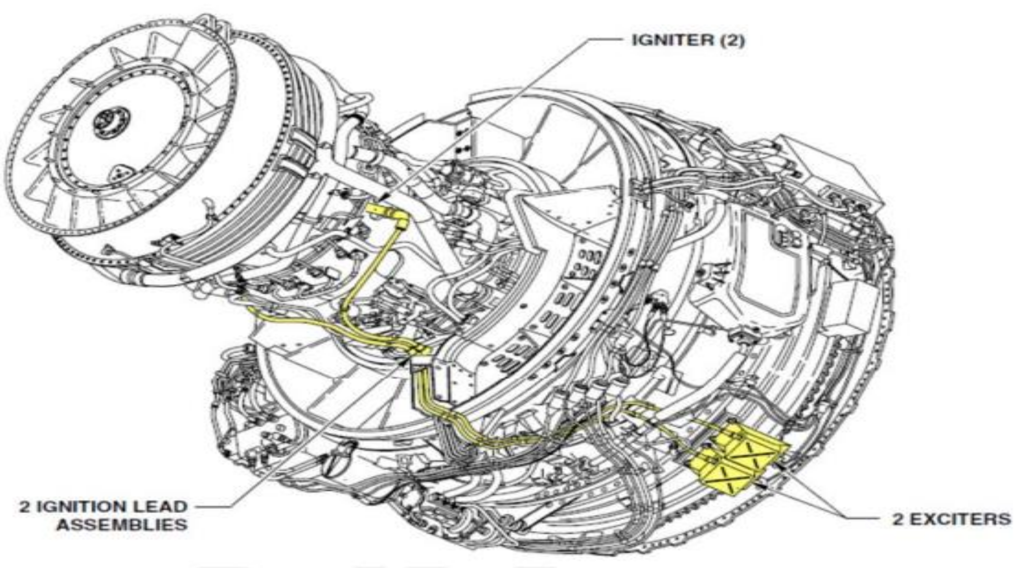

FIG: 9.2 THE IGNITION EXCITERS ON THE FAN CASE OF A CFM56-7B ENGINE

9.3 THE IGNITION LEAD:

The ignition lead conducts a very high current from the ignition exciter to the plug over a distance of up to several meters. All electrical connections must always be in good condition to keep the resistance at the connectors low. Lost energy results in sparks with decreased energy. The ignition lead has an internal copper wire that is connected to the center contacts in the connectors at both ends. On the outside the lead has a flexible steel conduit as a mechanical protection. It also operates as an electromagnetic shielding.

Between the flexible conduit and the internal copper wire a silicon rubber insulation embeds the center wire. When the plug connector is attached to the plug with the coupling nut, the center contact touches the contact cap of the plug to close an electrical connection. A ceramic insulator keeps the contact centered. Ignition leads are cooled where they can become very warm.[2]

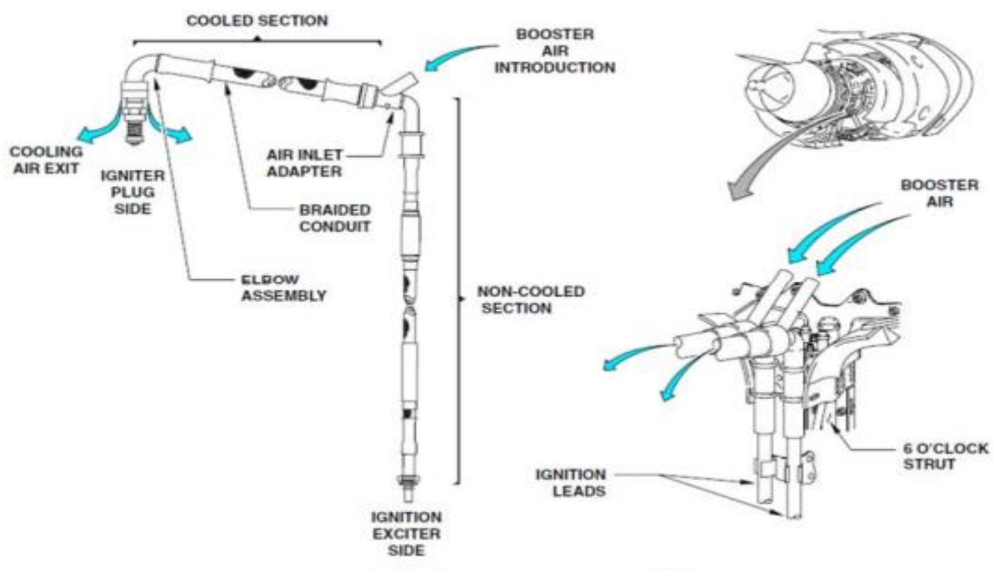

FIG: 9.3 A TYPICAL IGNITION LEAD

9.4 IGNITER PLUGS:

For the location of the two igniter plugs of an engine two different configurations are in use. They are installed on one side of the combustion chamber or symmetrically left and right of the engine centerline. In both configurations the igniter plugs are installed below the horizontal centerline of the engine in the combustion case. The plugs are screwed into a boss in the combustion case and its inner end immerses a few millimeters into the combustion chamber

Operation of Engine Start Systems and Components: -The engines are started with the two generators on each engine. They are designed as starter generators. The large generators are necessary for the supply of the aircraft and are no additional weight for the engine start system. The proliferation of gas turbine starter types seems to indicate that no one starter shows a definite superiority, for all situations, over other types. The choice of a starting system depends on several factors Following is list of various forms of gas turbine starters:

- Electric motor starter
- Electric motor-generator
- Air turbine starter
- Cartridge or solid-propellant starter
- Fuel-air combustion starter
- Hydraulic motor starter
- Liquid monopropellant starter
- Air-impingement starter

On most engines the accessory gearbox is driven by the HP spool via a drive shaft. Thus, a starter motor (or in short starter) mounted on the accessory gearbox is able to drive the HP spool. The start sequence of an engine, begins with the acceleration of the HP spool to a speed high enough to generate airflow through the combustion chamber that allows the build-up of an inflammable fuel/air mixture. This is safely possible at relatively low rotor speeds of approximately 20%. After the shaft speed for safe light-off is reached, the high-pressure shutoff valve is opened and the fuel flows to the fuel nozzles. Some percent of HP spool speed earlier or simultaneously, the ignition is activated and light-off occurs as the fuel reaches the combustion chamber. At this low rotor speed the torque of the HPT is too low for the further acceleration of the spool. Thus, the starter remains on after the combustion has begun. The acceleration with the combined torque of the starter and the HPT continues to a rotor speed from which the engine can accelerate without any further starter assistance. This starter cutout speed is 5 to 10% (approx.) above the self-sustaining speed of the engine. At the starter cutout speed the starter and the ignition are switched off automatically or by the EEC and the engine accelerates to idle. After the beginning of the combustion the EGT starts to rise. It reaches its peak before the HP spool speed reaches the starter cutout speed. [2]

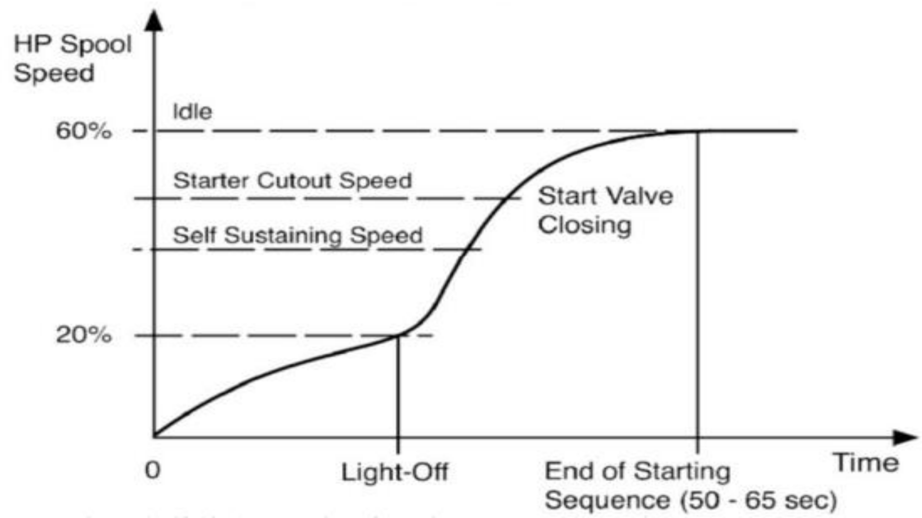

FIG: 9.4 ACCELERATION OF THE HIGH-PRESSURE SPOOL DURING THE START SEQUENCE.

CHAPTER 10

Power Augmentation Systems

10.1 OPERATION AND APPLICATIONS OF WATER INJECTION, WATER METHANOL:

Power can be augmented in three different ways such as water or water-methanol injection and after burner system. The maximum power output of a gas turbine engine depends to a large extent upon the density or weight of the airflow passing through the engine. There is, therefore, a reduction in thrust or shaft horsepower as the atmospheric pressure decreases with altitude, and/or the ambient air temperature increases. Under these conditions, the power output can be restored or, in some instances, boosted for take-off by cooling the airflow with water or water/methanol mixture (coolant). When methanol is added to the water it gives anti-freezing properties and also provides an additional source of fuel.

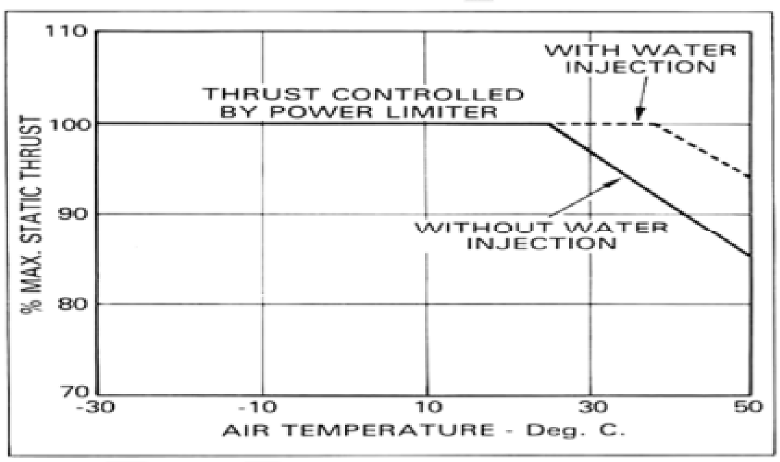

FIG: 10.1 TURBO-JET THRUST RESTORATION.

There are two basic methods of injecting the coolant into the airflow. Some engines have the coolant sprayed directly into the compressor inlet, but the injection of coolant into the combustion chamber inlet is usually more suitable for axial flow compressor engines. This is because a more even distribution can be obtained and a greater quantity of coolant can be satisfactorily injected.[2]

When water/methanol mixture is sprayed into the compressor inlet, the temperature of the compressor inlet air is reduced and consequently the air density and thrust are increased. If water only was injected, it would reduce the turbine inlet temperature, but with the addition of methanol the turbine inlet temperature is restored by the burning of methanol in the combustion chamber. Thus, the power is restored without having to adjust the fuel flow.

The injection of coolant into the combustion chamber inlet increases the mass flow through the turbine, relative to that through the compressor. The pressure and temperature drop across the turbine is thus reduced, and this results in an increased jet pipe pressure, which in turn gives additional thrust [2]

10.2 OPERATION AND APPLICATIONS OF AFTER BURNER SYSTEM:

Afterburning (or reheat) is a method of augmenting the basic thrust of an engine to improve the aircraft take-off, climb and (for military aircraft) combat performance. The increased power could be obtained by the use of a larger engine, but as this would increase the weight, frontal area and overall fuel consumption, afterburning provides the best method of thrust augmentation for short periods. Afterburning consists of the introduction and burning of fuel between the engine turbine and the jet pipe propelling nozzle, utilizing the unburned oxygen in the exhaust gas to support combustion. The resultant increase in the temperature of the exhaust gas gives an increased velocity of the jet leaving the propelling nozzle and therefore increases the engine thrust.[2]

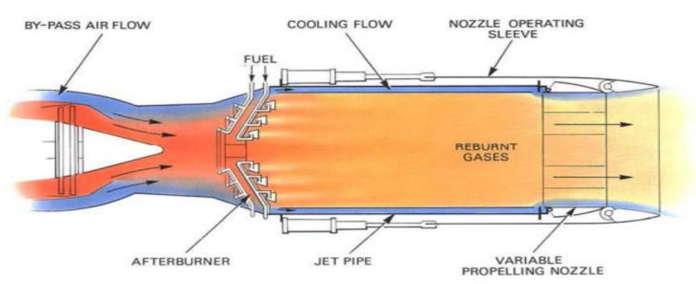

FIG: 10.2 PRINCIPLE OF AFTERBURNING

As the temperature of the afterburner flame can be in excess of 1,700 deg. C., the burners are usually arranged so that the flame is concentrated around the axis of the jet pipe. This allows a proportion of the turbine discharge gas to flow along the wall of the jet pipe and thus maintain the wall temperature at a safe value.[2]

10.3 OPERATION OF AFTERBURNER:

An atomized fuel spray is fed into the jet pipe through a number of burners, which are so arranged as to distribute the fuel evenly over the flame area. Combustion is then initiated by a catalytic igniter, which creates a flame as a result of the chemical reaction of the fuel/air mixture being sprayed on to a platinum-based element, by an igniter plug adjacent to the burner, or by a hot streak of flame that originates in the engine combustion chamber (fig. 15.15.7): this latter method is known as 'hot-shot' ignition. Once combustion is initiated, the gas temperature increases and the expanding gases accelerate through the enlarged area propelling nozzle to provide the additional thrust.[2]

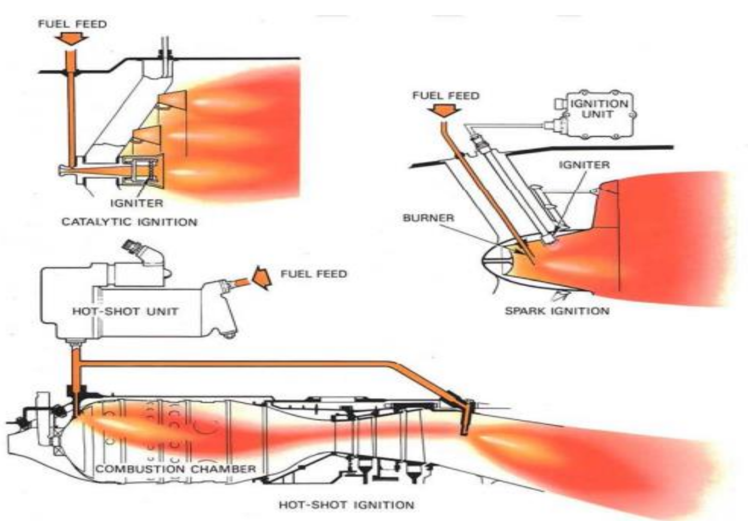

FIG: 10.3 METHODS OF AFTERBURNING IGNITION.

10.4 THRUST INCREASE FROM AFTERBURNER:

The increase in thrust due to afterburning depends solely upon the ratio of the absolute jet pipe temperatures before and after the extra fuel is burnt. For example, neglecting small losses due to the afterburner equipment and gas flow momentum changes, the thrust increase may be calculated as follows. Assuming a gas temperature before afterburning of 640 deg. C. (913 deg. K.) and with afterburning of 1,269 deg. C. (1,542 deg. K.) then the temperature ratio =

(1,542/913= 1.69). The velocity of the jet stream increases as the square root of the temperature ratio. Therefore, the jet velocity = square root of 1.69 = 1.3. Thus, the jet stream velocity is increased by 30 per cent, and the increase in static thrust, in this instance, is also 30 per cent.[2]

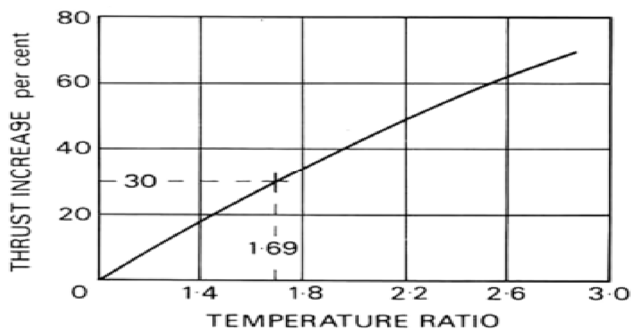

FIG: 10.4THRUST INCREASE AND TEMPERATURE RATIO.

CHAPTER 11

RESULT AND DISCUSSION

11.1 RESULT:

I) we have been studying about knowing the parts of a turbofan engine and to recognize its working principles.

II) We have been able to understand classification of Turbofan engine.

III) We have recognized inlet cowl, fan cowl, thrust Reverser cowl, compressor, combustion chamber, turbine and exhaust of a turbofan engine.

IV) We have been able to understand working principle of turbofan engine and its parts.

11.2 DISCUSSION:

During study time, we face some problems to fulfil our goal like lack of books related to turbofan engine, shortage of technical documentation etc. We can't open total engine for recognizing parts. After all, we did not complete our study smoothly and because of team work, we complete our study successfully.

11.3 LIMITATION:

We have faced some limitations during fulfilling our goal. We can't open an engine to recognize everything which are inside it.

CHAPTER 12

CONCLUSION

12.1 CONCLUSION:

Turbofan engine is one of the most innovative inventions of this generation; Detail analysis of this innovation shows not only the components also how every little components work. Because of this invention many things become possible which was out of our reach.

In future there will be more upgrade of turbofan engine and our journey through the sky will be much safer and easier.

12.2 FUTURE SCOPE:

Our study will be more effective if we can open a turbofan engine and to recognize working principle by running a turbofan engine. Some suggestions' are below :

I) We can visit hangar of different commercial airlines who operate aircraft equipped with turbofan engine.

I) We can open fan cowl, thrust reverser cowl of an turbofan engine.

II) We can run a turbofan engine and know it's working principles.

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