BREAKING THE SOUND BARRIER WITH AIR BREATHING JET ENGINE

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ABSTRACT

This paper represents a study on air breathing jet engines. Jet engines are similar to the gas turbine, jet engines produces thrust by jet propulsion according to the newton’s law of motion. Gas turbines are used for aircraft propulsion due to favourable power to weight ratio. In this paper we know about the working, component design, material used for the construction of jet engine. We learn about the factors responsible for the production of noise in the jet engine and solution through which we reduce the level of noise and know about the stress and temperature faced by the jet engine during its working. Materials used for the production of parts of the jet engine such as super alloys, super alloys are those material which can withstand at a very high temperature without deformation of the shape like nickel based super alloy and study about those smart structure or material which possess the ability to change shape during flight and came to its original shape and size. In this paper we widely discuss about turbojet engine and turbofan jet engines and the comparison shown which gives us idea about the difference between the construction and working of rockets and jet engines

Hypersonic speed is the speed above Mach 5. Hypersonic speed will be the key factor for the sixth generation of fighter aircraft. Sixth generation aircraft were able to travel more than Mach 5 and able to reach any point on the earth within 30 minutes. The key factor for fifth generation of aircraft is stealth mode. so, the key factor for sixth generation fighter aircraft will be hypersonic speed using scramjet engine.

Key words: Thrust, Brayton cycle, Chevron nozzle, Heynas 25, Hypersonic speed, jet engine, Scramjet.


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INTRODUCTION

- A jet engine is a machine which produces thrust by jet propulsion according to the newton’s law of motion. A jet engine has many types like turbojet, turbofan, turboprop, ramjet and scramjet. Turbojet engine are air breathing engine jet engine which are widely used in aircrafts. Jets are also referred as an internal combustion air breathing engine or a duct engine. Jet engines works on “Brayton cycle”

- A jet engine contains and a propelling nozzle. The gas turbine consists of an inlet, compressor and a turbine. The air comes from the inlet then compressed by the compressor heated by the fuel combustion in the combustion chamber and then expands through the turbine, then expanded in the propelling nozzle so; it is accelerated at a very high speed and provides the required thrust. Turbojet engines are widely used in aircraft then replaced by turboprop engines because they consume less fuel. Turboprop engines where not proved efficient at high speed so they are replaced by more efficient, less fuel consuming, more quieter turbofan engines but we find that turbojet engines are still used in cruise missile due to their high exhaust velocity and simplicity. A turbojet engine consist of five parts namely inlet, compressor, combustion chamber, turbine, nozzle.

T & S DIADRAM OF JET ENGINE

- **INLET**: An inlet is required for the smooth incoming of air to the compressor blades. A special intake is provided to minimize any flow losses when the compressor is accelerating the air through the intake at zero. The air enter into engine must be subsonic, regardless the speed of air craft itself.

- **COMRESSOR**: The compressor is driven by the turbine; it rotates at high speed adding energy to the airflow. Compressor the air increases its temperature and pressure. The smaller the compressor faster it turns. In case of large engine such as GE-90-115 fan rotates about 2500 RPM where in smaller helicopter engine compressor rotates about 50000 RPM. Early engine has pressure ratio 5:1 improvement such as dividing the compressor into two parts separately, using variable blade angle the pressure ratio improves to 15:1 or more, compressor used are typically axial or centrifugal.

- **COMBUSTION CHAMBER**: The combustion chamber of a turbojet engine is different from a piston engine, for piston engine there is an increase in pressure as the fuel burns. In case of turbojet engine the air and fuel mixture burns in the combustion chamber and pass through the turbine in a continuous flowing process with no increase in the pressure instead there is small loss in pressure. Less than 25% of the air is typically used in combustion as an overall lean mixture is required keeping within the turbine limits.
• **TURBINES:** Hot gases leaving the combustor expand through the turbine. Material used for turbine were able to face high stress and temperature , the blades of the turbine are provide with internal cooling passages air comes from the compressor is passed through these to keep the metal temperature within limits . The turbine is largely an impulse and rotates because of the impact of hot gases stream. Energy is transferred from the turbine to the compressor through shafts, the power is developed by the turbine drives the compressor as well as accessories like fuel, oil and hydraulic pumps.

• **NOZZLE:** After the turbine the gas expands through the exhaust nozzle producing a high velocity jet. In a convergent nozzle the ducting narrows progressively to the throat. The nozzle pressure on a turbojet id high enough at higher thrust setting to cause the nozzle choke , if a convergent –divergent nozzle is fitted the divergent (increasing flow area) section allows the gases to reach supersonic speed within the divergent section , additional thrust is generated by the higher resulting exhaust velocity.

**JET ENGINE PERFORMANCE**
The net thrust (Fn) of a turbojet is given by:-

\[ Fn = (M_{\text{air}} + M_{\text{fuel}}) V_e - M_{\text{air}} V \]

Where,

- \( M_{\text{air}} \) = the mass rate air flow through the engine.
- \( M_{\text{fuel}} \) = the mass rate of fuel flow entering the engine.
- \( V_e \) = Velocity of the jet (less than sonic)
- \( V \) = Velocity of the aircraft.

\( (M_{\text{air}} + M_{\text{fuel}}) V_e \) = the nozzle gross thrust (\( F_g \))
\( M_{\text{air}} V \) = the ram drag of the intake air.

The above equation applies only for air breathing jet engine if the velocity of the jet from a jet engine is equal to sonic velocity the engine's nozzle is said to be chocked . If the nozzle is chocked the pressure at the nozzle exit is greater than atmospheric pressure. The velocity of the jet (\( V_e \)) must exceeds the true airspeed of the aircraft (\( V \)) if there is to be a net forward thrust on the aircraft, the (\( V_e \)) can be calculated thermodynamically based on a adiabatic expansion. Jet thrust can be increased by injecting additional fluids and it is then called wet thrust. Early engines and some current non afterburning engine use water to increase thrust .Water is injected at the compressing air which permits an increase in pressure for higher burning, a 10% to 30% additional thrust can be gained. There is improvement is done in the turbojet engine , turbojet engine are provided with an additional fan then it becomes turbofan jet engine due to this fan the air intake increases by 75% and the engine becomes more fuel efficient and produce less noise , pressure ratio in combustion reaches to chamber 44:1 .
T & S DIAGRAM OF JET ENGINE USING AFTERBURNER

Afterburner are used to burn the left fuel in the combustion chamber, afterburner are similar to the reheat device it increases the velocity and efficiency.

OBJECTIVE

The main objective of this paper is to represent the methods through which we increase the performance and efficiency of a turbojet engine and study about the structure and materials used in the turbojet engine to withstand with such high temperature and pressure without deformation of parts.

The key feature of the fifth generation fighter aircraft is stealth technology so, the key feature for the sixth generation fighter aircraft and missiles will be hypersonic speed and the fighter aircraft are able to fly more than Mach 5. Using the scramjet we are to achieve hypersonic speed with some modification.

LITERATURE REVIEW

First jet propulsion system device was developed in Egypt name aeolipile this device directed steam power through two nozzles to cause a sphere to spin. Dr Hans von ohain and sir frank whittle are both recognized as being co-inventor of jet engine, each worked separately and knew nothing about other’s work. Hans von ohain is considered the designer of the first operational turbojet engine. Frank whittle was the first to register a patent for the turbojet engine in 1930. Hans von ohain was granted patent for engine in 1936. Hans von ohain patented a jet propulsion engine similar in concept that of sir frank whittle but different in internal arrangement in 1934. However Hans von ohain’s jet was the first to fly in 1939 but frank whittle jet flew in 1941. Hans von ohain joined Ernst Heinkel in 1936 and continued with the development of his concept of jet propulsion and proposed a new propulsion system called the Heinkel He178. Now, days the world’s largest aircraft jet engine is GE 90-115B produced the maximum thrust of 569 KN.

METALLURGY

Turbine compressor blades in aircraft jet engine works in extreme conditions under large temperature gradient and high mechanical forces, it must have to satisfy the safety factors during its operational life and fulfil correctness of shape in order to satisfy the requirement of engine efficiency. The number of blades in the modern aircraft jet engines is in many pieces and simultaneously the blades are responsible for the correct running of jet engine, failure of one blade. Basic factor which assure the required operational properties of blade are shape and high precision of blades and also proper material used for the production. Only nickel based super alloy are unusual class of metallic material with an exceptional combination of high
temperature strength, toughness and resistance to degradation in corrosive and oxidizing environment they can tolerate an average temperature of 1050 Celsius with occasional hot spot near air foils tips to the temperature as high as 1200 Celsius. At such temperature most of the metals starts melting but nickel based super alloy maintain its mechanical and physical properties , nickel based super alloy typically constitute of 40%-50% of the total weight of the aircraft jet engine.

Nickel based super alloy have high yield and ultimate tensile strength , with yield strength often in the range of 900 – 1300 mpa and ultimate tensile strength of 1200 – 1600 mpa at room temperature. Exceptional combination of strength of strength, toughness and crack growth resistance can be achieved in these materials through multiple stages of wrought processing. Face cantered cubic structure (FCC) nickel is the major super alloy constituent many alloy contains up to 40% of weight of the combination of five to ten elements, the elements typically alloyed with nickel to form super alloy, the nickel aluminium system is the binary basis of super alloy composition.

**TYPICAL PHYSICAL PROPERTIES OF SUPER ALLOY**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>7.7 – 9.0 g/cm³</td>
</tr>
<tr>
<td>Melting Temperature</td>
<td>1320 – 1450 Celsius</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>Room temperature: 210 GPA, 800 Celsius: 160GPA</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>8 - 18 x 10⁻⁶ /°C</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>Room temperature: 11 W/mk, 800 Celsius: 22 W/mk</td>
</tr>
</tbody>
</table>

**NOISE REDUCTION TECHINEQUES**

Engine noise is one of the major contributors to the overall sound. The noise reduction mainly comes from the combination of changes to the engine cycle parameters and low noise design features. Turbofans are commonly used due to its high efficiency and low noise. Noise reduction can be achieved through two methods such as fan noise reduction and jet noise reduction.

**FAN NOISE REDUCTION:** Fan noise is closely associated with the rotational tip speed and fan pressure ratio, the easiest way to reduce the fan noise is to reduce the tip speed and pressure ratio, which causes increase in engine diameter, the rotational tip speed is just under Mach 1 to reduce shock associated noise, advantage of reducing fan tip speed and pressure ratio is the number of noise sources are reduced. A scarf inlet can be used to reduced inlet fan noise by redirecting the forward radiated sound away from the people, one main reason for noise production is unsteady aero dynamical forces forward swept fans help to reduce noise related shocks by delaying the onset of multiple pure tones fan sweep design near the tip to reduce aerodynamic losses related with shocks, additional mass flow can be achieved through the fan. Swept stators are found to reduce noise by Increasing the phase change from hub to tip of the unsteady aerodynamic producing the sound and by increasing the effective distance from the fan to stator. Variable area nozzle have used as a way to reduce jet noise by lowering the jet exit velocity and also by controlling the incidence angle of flow near the rotor and stator.
Another technique is to be used to increase the acoustic treatment area over the tip of the rotor. A honey comb material with porous or felt metal sheets to provide maximum insertion losses around the desired target frequency, it is known that bulk material provide better noise reduction over a range of frequencies but bulk or porous material is not for the harsh environment of the engine. So, metal foam named “Heynas 25” is invented which provide favourable bulk linear properties and it can withstand with the range of temperature for either the core or fan ducts.

**JET NOISE REDUCTION:** Jet noise reduction can be achieved by lowering the jet exhaust velocity. Newer engines using engine cycle to extract energy from the core and reduce the mixed velocity of the core and fan. It is highly desirable to reduce noise without changing the engine cycle, Chevron nozzles that are used or noise reduction, their principal of operation is that as the hot air from the engine core mixes with cooler air blowing through the engine fan the shaped edges serve to smooth the mixing, which reduce the noise creating turbulence, Chevron nozzles have shown reduction in jet noise about 2.5 EPN dB without changing the engine cycle the thrust loss was shown to be less than 0.50%.

**COMPARISION WITH ROCKETS**
Rocket and jet engines both are reaction engines, both produce thrust for their movement, according to the newton’s law of motion. Jet engine is Air Breathing Engine (ABE) and rockets are Non Air Breathing Engine (NABE), this gives ability to the rockets to work in atmosphere as well as in vacuum rockets carry their own oxygen for combustion, jet engines are limited to the atmosphere because they uses atmospheric oxygen for their combustion. Jet engines uses liquid fuel and having a very high endurance as rockets uses liquid and solid both s fuel but they have low endurance. Jet engines are having very complex structure they require many parts and they are very high efficient but rockets having simple structure and low efficiency.

**IMPROVEMENT**
- Employs active cooling so parts of the engine should not melt or deformed.
- Designing of better material and super alloys which withstand at very high temperature and maintain its strength.
- Smart structure and materials where used which changes their shape and properties during flight

**HYPERSONIC SPEED**
In aero dynamics hypersonic speed is refer to the speed of Mach 5 and above, “High” hypersonic speed refers to the any number from Mach 10 to 25 and re-entry speed as anything greater than 25. To achieve hypersonic speed we have to make an engine which is able to reach the speed of more than Mach 5. Scramjet is the only engine which having the design and properties to do so, Scramjet (Supersonic Combustion ramjet) is a variant of ramjet in which combustion take place at supersonic airflow. This allows scramjet to operate efficiently at extremely high speed, theoretically the top speed of the scramjet is between Mach 12(8400 mph, 1400km/hr.) and Mach 24(1600 mph, 25000km/hr.), Scramjet engine is a type of jet engine relies on combustion of fuel and oxidizer to produce thrust. Scramjet are designed to operate at high speed were turbojet is no longer useful, around Mach 3 or Mach 4 turbojet machinery is no longer useful and ram style compression is more preferred, ramjet fill the gap between turbojet engine and scramjet engine. Scramjet are having very simple
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design and having no rotating parts scramjet are very similar to ramjet the difference between both is, in scramjet the combustion take place at supersonic but in ramjet combustion take place at subsonic speed, very few scramjet have ever been built such as X-15 in 2010.

Initial propulsion required is important a scramjet cannot produce efficient thrust unless boosted to high speed around Mach 5, turbojet engines are heavy and cannot exceed the limit of Mach 2 to 5 so another propulsion system is required, which having its own structure, system and fuel supply such as rockets. We can use first stage of droppable solid rocket booster which having very simple structure. Fuel is the another factor for hypersonic vehicle, an important advantage of air breathing engine its does not have to carry oxidizer like rockets so it require only one fuel tank and capacity of payload increases. scramjet needed more fuel to deal with aero dynamical drag, liquid hydrogen as fuel has much low density it require bigger fuel tank and give even more that drag so we have to find a fuel which having higher density, the scramjet engine require active cooling we can use low temperature fuel for its cooling as used in rocket engine for cooling of nozzles.

CONCLUSION
Through these techniques we can make our jet engine more efficient and quieter, these techniques we can improve the metallurgy of jet engine which give them the ability and strength to such high temperature and pressure. Hypersonic speed will be the key feature for sixth generation of fighter aircraft through this speed the aircraft can able to reach any point one the earth in less than half an hour. Hypersonic technology is today’s burning topic so there is a great requirement of research to make reliable, efficient scramjet and Hypersonic vehicle.

REFERENCES