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Reduction of Jet Noise in the Aircraft Nozzle

Saurabh Shriwas[1], Sachin Shah[2] Prashant Singh[3], Kalpit P. Kaurase[4]

[1,2]Student, B.E. (Aeronautical), MATS University, Raipur saurabhshriwas1994@gmail.com
[3]Student, M. Tech. (Turbo machinery), MATS University, Raipur
[4]Assistant Professor, Dept. of Aeronautical Engg. MATS University, Raipur

Abstract

In this paper, the reduction of jet noise in exhaust nozzle of aircraft engines is discussed. This is due to the high turbulence structure created in the jet shear. These turbulence structures are generally caused by the flow instability due to pressure fluctuation created in nozzle. Here the effort is to study the way of noise reduction methods in the exhaust nozzle, and this can be done by using various methods such as the chevron nozzle, nano materials, extending the engine nacelle, increasing the bypass ratio in turbofans and acoustic lines of the main engine. Chevron nozzle are provided with the sharp saw tooth structure at its aft, which is responsible for the smooth mixing of hot and bypass stream hence the energy of the turbulence structure is reduced. Nano materials with very high density are able to absorb the noise within the nozzle. Increasing the bypass ratio is also a good option in turbofan engines; it reduces the energy of main stream by mixing cold stream into hot stream. Acoustic lines can also be the solution for the noise reduction; it converts the energy of turbulence structure into the form of heat. By increasing the size of the engine housing, noise can also be reduced. At this condition the hot jet will not directly expose to the atmosphere but passes through the nacelle first which can absorb the noise by some amount.

Keywords*:* Jet shear, Exhaust nozzle, Turbulence, Jet noise.

1. INTRODUCTION

As the cruise speed increases the noise of the jet also increases and due to the flow instability the turbulence is created which lead to the noise in the exhaust nozzle of the aircraft, but the problem is not associated with the time of cruising, the main problem occurs at the time of ground run, climbing and descent of the aircraft when it is more close to the population. Now the suppression has become the one of the most challenging research topic in the aviation industry in order to minimize its effects on people around the airport and the important breakthrough is the use of modern aircraft with various experimental designs like saw tooth pattern and other method described below. In this review paper our work is to study and analyze the method of noise reduction in aircraft nozzle and we will be dealing with the chevron nozzle and other available ideas. Here the problem is associated with the nozzle so it is mandatory to know about nozzle [1]. The exhaust nozzle is one of most essential part of an aircraft engine .basically the work of the nozzle is to collect the hot flow coming from the turbine and straightening or it increases the kinetic energy of the flow. For the higher value of the thrust the kinetic energy of the flow must be very high which can be done by very high exhaust velocity. The expansion of flow occur in the nozzle is due to the pressure ratio [2].

Some important functions of nozzle are described below:-

1. With minimum total pressure loss it accelerates the flow with very high velocity.
2. It can be used in thrust vectoring, by changing the direction of exhaust.
3. Use to suppress infrared radiation.
4. It allows the application of the thrust reversal; generally clamshell and cascade types are used. This arrangement allows the flow in reverse direction.
5. In turbofan engine it mixes the main stream and the bypass air.
6. One of the most important function of the nozzle is to match exit and the atmosphere pressure that is denoted by $P_e=P_a$, which is an optimum condition for the flow expansion from the nozzle [3].
7. It use also used for wall cooling.
8. Thrust augmentation can be performed by the use of nozzle, especially in afterburner when additional fuel is burn in the tail pipe then the mass flow rate of the hot jet increases and for the expansion of this addition hot jet variable area nozzle is required.

Generally for subsonic flow, subsonic nozzles (convergent type) and for supersonic flow, De Laval nozzle are used this selection is generally based upon the Area-Mach number relationship.

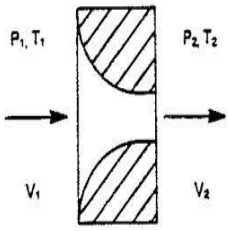

Figure 1: Flow through convergent nozzle

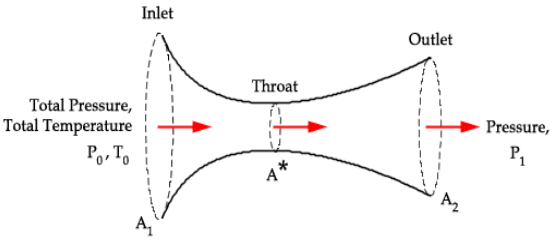

Figure 2: Flow through C-D nozzle

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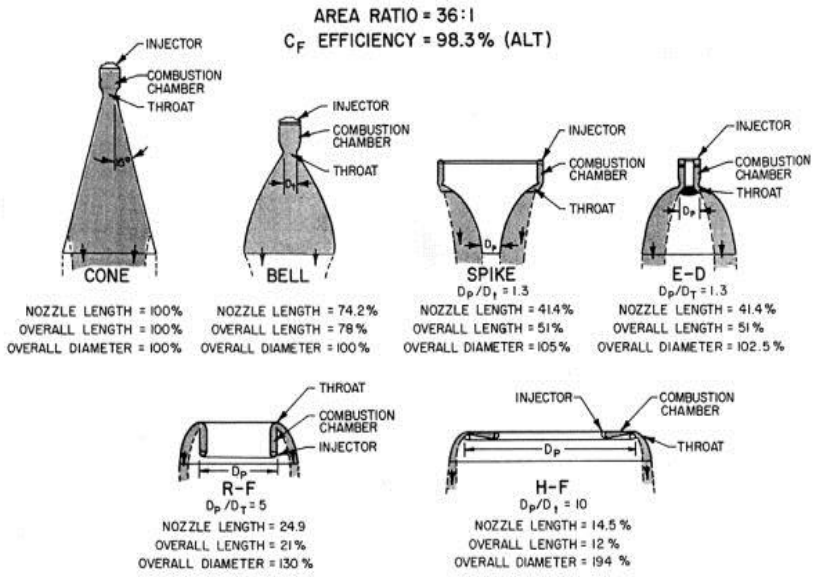

Figure 3: Different shapes of nozzle

2. Cause of jet noise in exhaust nozzle

In the field of aeronautics and aerospace the jet noise is a particular branch which deals with the generation of noise. In early aircrafts piston engine were used. These aircrafts usually produces very high noises which further reduced by the use of silencers. After that during Second World War jet engines used frequently which is also a noise producing engine. The initiative to decrease the noise in the jet engine was taken by the NASA, and they developed chevron nozzles but now here are several possible methods which can be used to reduce noise of the jet aircraft.

The generation of noise is caused by the velocity of jets and the turbulent eddies, developed from the shearing flow. This noise is also known as broadband noise and its frequency is around 100 kHz so it is well beyond the hearing of human. Jet noise sometimes produces the loudest sound ever produced by the humans [3].

In an exhaust nozzle when jet velocity reaches around 100 m/s it becomes the source for the jet noise and in supersonic flow the noise is associated with shocks along with this at the low speed some acoustic source in the tail pipe is responsible for the generation of the jet noise including combustion noise, turbine-compressor system and mixing of free stream with the fans.

When the ambient fluid is mixed with jet by turbulent mixing then the jet noise is created. The mixing initially occurs in the annular shear layer with enhances along with the length of the nozzle. The region of mixing usually fills the complete jet at four or five diameter from the nozzle. Most of the high frequency noises are close to the nozzle because here the dimension of turbulent eddies is very small. When we analyze further down the jet lower frequency starts because eddy size is similar to the diameter [3].

In supersonic jets the flow expands and contracts through the several cells these cells are generally known as the "shock cells". These cells can be seen extending up to 10 times of the jet diameter from the nozzle and it is responsible for the two types of jet noises "screech tones" and other is broadband "shock associated noise". Screech

is produced by a feedback mechanism in which a disturbance convicting in the shear layer generates sound as it traverses the standing system of shock waves in the jet. Even though screech is a side effect of the jet's flight, it can be suppressed by an appropriate design for a nozzle [4].

Aircraft noise is also sometimes known as the “jet noise" when generates from jet powered aircraft regardless of the mechanism of noise production.

Possible methods to reduce jet noise

1. Chevron nozzles

Chevron nozzles are those nozzles having the saw tooth pattern in the trailing edge of the aircraft exhaust nozzle. Working of chevron nozzle is quite simple, the hot jet is mixed with the main cold air stream coming directly from the engine fan. The chevrons are generally triangular shaped structure having a base ,apex and a trailing edges in such a way that they converges there between and radially opposite first and second surface bounded there by. Each of the chevrons is triangular in configuration, with a base, apex, side trailing edges converging there between, and radially opposite first and second surfaces bounded thereby. The trailing edges of adjacent chevrons are spaced laterally apart to define respective diverging slots disposed in flow communication with the duct. The chevrons have a concave contour axially between the bases and apexes which promotes jet mixing through the slots. Shaped edges of the nozzle play an important part in smooth mixing of the flow which significantly reduces turbulence (pressure fluctuation), a cause of noise creation. Chevron nozzle was developed by the NASA. Some examples for the application of Chevron nozzles are GEnx, ROLLS-ROYCE Trent 1000 [5].

2. Nano-Technology

It is a one of the strongest innovation and it has made dramatic change in all kind of industry. Nano material is also used in different sectors of aviation industry because of its multi-functioning such as low weight, availability, eco-friendly and consumption of less fuel. Nano material also has various properties like highly responsive communication system, minimum requirement of repair.

Despite all above properties Nano material are quite useful in reduction of noise in exhaust nozzle of an aircraft. Nano materials has a property of high density (high strength) along with the very less weight, since if the exhaust nozzle of an aircraft is made of with the Nano material, so there is a chance of the absorption of maximum noise within the aircraft nozzle.

3. Aircraft Engine Configuration

In the engine of an aircraft after the nozzle portion if we further increase the length of the tail pipe longitudinally then the exhaust jet will not directly exposed to the atmosphere but it pass through the extended portion. While passing through this portion the most of the noise will be suppressed by the density of the extended part.

4. Acoustic Liner

In order to reduce the jet noise in exhaust nozzle the acoustic lines are used in various modern aircraft. Acoustic lines convert the energy of the jet particle into the form of the heat so that the reduction in heat of the particle leads to the suppression of noise in the exhaust nozzle.

5. Configuration of Nozzle

If the housing of the nozzle (nacelle) is further increased in the axis of the engine then the et will not directly exposed to the atmosphere and at the same instant the atmospheric air is allowed to mixed with the main jet stream with the use of the ports provided on the extended part of nozzle. In this way we will able to reduce the energy of the exhaust jet in the nozzle.

Figure 4: Saw tooth pattern improves noise profile of the Lufthansa 747-8

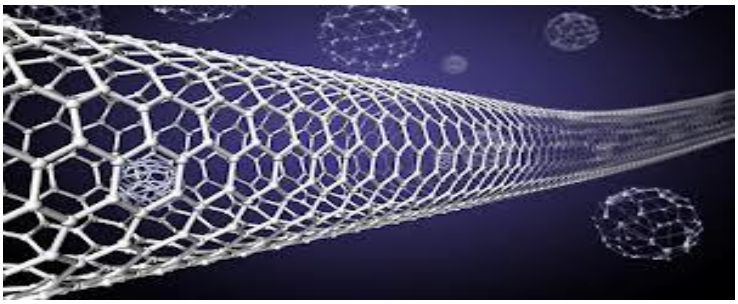

Figure 5: Structure of Nano material

Figure 6: Engine nacelle configuration

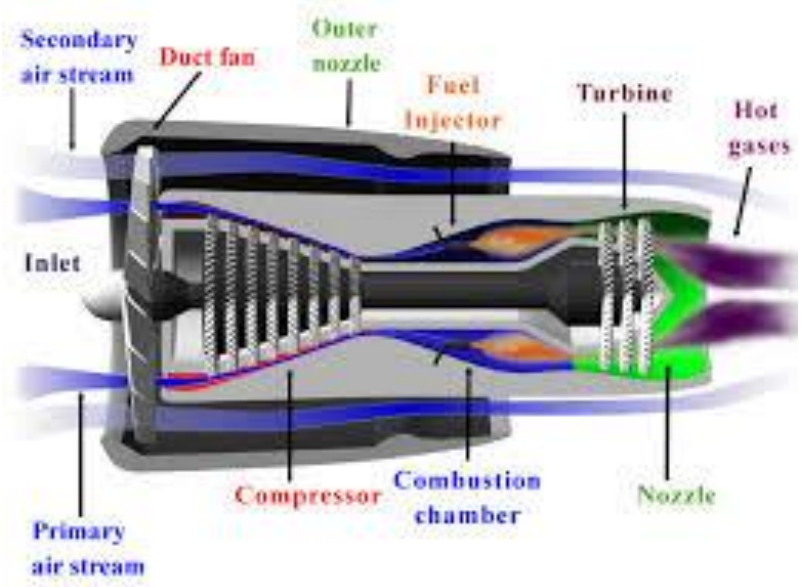

Figure 7: Schematic of turbofan engine

5. Increasing the bypass ratio in turbo fans

In turbofans the thrust is obtain by the hot jets as well as bypass air. Hot jet passes through the conventional jet engine and the cold stream through annular nozzle. If the bypass ratio ($\beta=\dot{m}_c/\dot{m}_h$) is increased with a certain amount and mixed with the hot stream that is obtain from the turbine, then the overall energy of exhaust gas can be reduced by some amount so that the jet noise of the aircraft can be reduce.

3. Conclusion

It is concluded that the paper describes the methods of prevention of noise in the exhaust nozzle of the aircraft, which is one of most interesting topic in aviation field. It is observed that noise arising from the exhaust jet can be reduced by using various techniques such as Chevron nozzles, nano materials, making changes in engine configurations, using acoustic liners, modifying nozzle configuration and in case of turbofan engines by increasing bypass ratio. These methods are easy to implement and can significantly reduce the noise in exhaust nozzle of the aircraft engine.

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