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NOISE CONTROL METHODS IN TURBOFAN ENGINES

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ABSTRACT

Noise pollution is one of the major issues currently being considered in the aero-acoustic researches. In this paper, we reviewed about noise reduction in jet engines. The main sources of sound in aircraft are aerodynamic noises, noise from aircraft engine and mechanical noises. But, engine noise is what which causes maximum noise pollution. There are various technologies used in noise reduction like chevron nozzle, use of acoustic liners, larger bypass ratio, forward swept fan blades and injecting air through the trailing edge of blades. The noise production in jet engines is due to large turbulences of the exhaust gases and additional fan noises in case a turbofan engine. These methods thereby used for the sound depletion in aircraft engines which causes for better performance with less noise emissions.

INTRODUCTION

The aviation industry is fast growing due to its time efficiency and increasing affordability. For the proper growth of aircraft industry and improved quality of lives of humans, there needs to be proper work on reduction of noise. The well known effects of prolonged exposure to aircraft noises can lead to hypertension, sleep deprivation, stress and annoyance. With an increase in the industry, the problems of noise are only going to worsen and more stringent laws would be applied by ICAO. There has been reduction of about 23dB in the past five decades, but 1985 onwards, there has been a stall in any significant reduction.
the aircraft engine noise can be broadly classified into following main parameters.

- Propeller noise- This noise is mainly present in propeller aircrafts. It is basically tonal noise and the frequency depends upon the blade passing frequency.

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- Turbomachinery Noise- The rotor noise is due to unsteady flow fluctuations exiting the rotor which interact with the stator. There is formation of vortices at the tip of rotors, wakes just behind the rotor blades and turbulence which causes the unsteady fluctuations. The noise is both tonal as well as broadband. The turbine noise is very high frequency noise as the turbine rotates at very high frequency.
- Jet Noise- The subsonic and supersonic jet exiting the nozzle are a main cause of noise in aircraft engines. There is flow instability due to turbulence caused by mixing of the hot nozzle air with the cooler surrounding air. This causes low frequency broadband noise.

From the graph of noise levels of various parts in aircraft, it is evident that more noise is produced while approach than takeoff. Apart from the jet noise, all other engine parts produce more noise while approach.

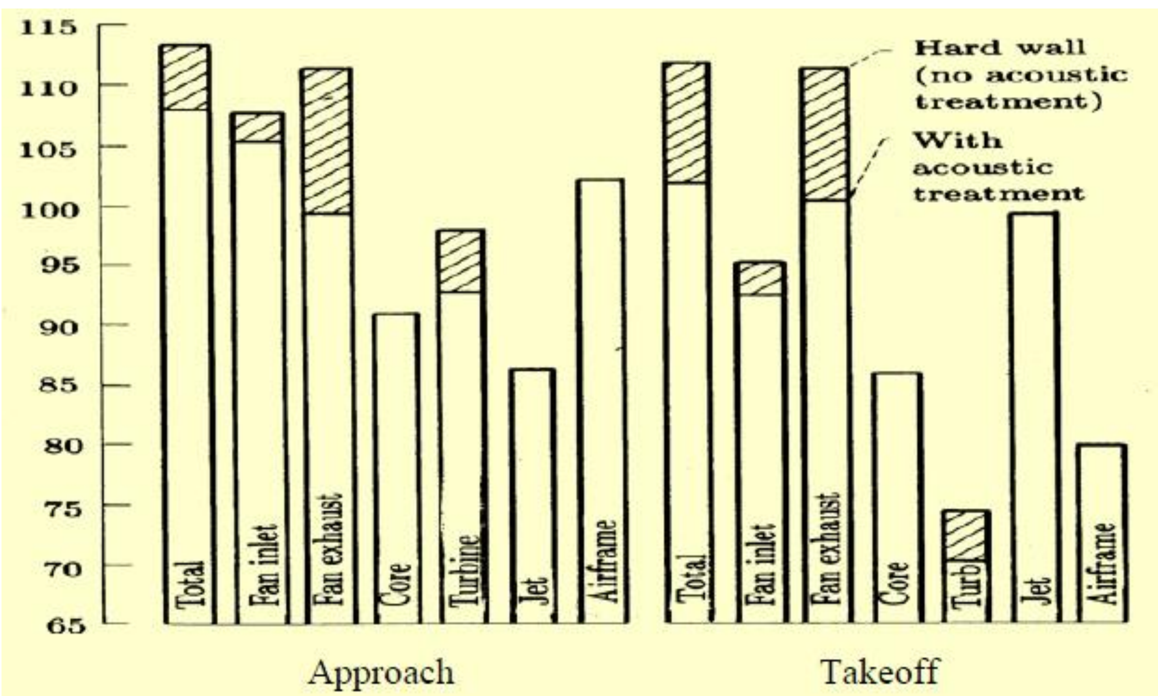

Figure 1. NOISE DISTRIBUTION IN HIGH BYPASS RATIO AIRCRAFT

The first generation of commercial subsonic jetliners was very noisy. The very first improvement that was brought about in the engines was increasing the bypass ratio. It significantly reduced the engine noise by about 20dB. Even though increasing bypass ratio was the first step towards quieter aircrafts, it is something that is still a n area of research and now ultra high bypass ratio with further improvements are under process.

Since fan inlet, exhaust and jet are the areas where most of the noise is produced, most works are concentrated on them. The major cause of noise generation in these regions is flow unsteadiness and there interaction with other components or surrounding air. To reduce the compressor noise in high bypass ratio fans, there are innovative concept like swept blades and injecting air through holes at the end of the blades to stabilize the flow. Damping methods to reduce the noise in critical areas is already in use. But better sound absorbing materials which are effective over a wide range of frequencies are the main thrust areas. To reduce the turbulent mixing of the core, bypass and surrounding air designs like chevrons are used. The smoothen the mixing and reduce the turbulence hence considerably reducing jet noise.

CHEVRON NOZZLE

Exhaust nozzle is an essential part of the jet engines, but they produce the maximum noise than any other part. The turbulent mixing of shear layers at the engine's exhaust is the main source of these sounds. The instability of shear layers leads to high turbulent vorticities producing pressure fluctuations causing sound. These noises can be reduced by disrupting shear layer turbulence and hence chevron nozzles were designed.

Chevrons are saw tooth patterns on the trailing edges of jet engine nozzles. Chevron nozzle increases the mixing rate of turbulent shear layer. The cold air from the engine fan and hot air from the inner part of engine are directed to chevron. This reduces the pressure fluctuations and thereby reducing jet noise. In regular nozzles, the motion of air flow is uniform on the entire surface of nozzle leading to noise, while in chevrons the airflow converges to the center of apex which leads to a gap between each adjacent saw tooth. Hot air occupies these gaps opposing inappropriate mixing of air flows. By this, the turbulence in mixing of hot and cold air is reduced at exit of engine.

Chevron nozzles are mostly used in modern aircrafts such Boeing-787, Boeing747-8. These nozzles may not be the best method to reduce noise, but partial reduction in turbulence of mixing did reduce the jet noises. Drawback of this method is that it reduces engine efficiency by a small amount.

Figure 2. INCLUSION OF CHEVRONS IN COMMERCIAL AERO ENGINE.

INCREASED BYPASS RATIO

In turbofan jets, some amount of air is bypassed from around the core through an annular region. The exhaust from the core consists of the high velocity hot jet which is surrounded by ring of much lower velocity cold air expelled by the fan. The fan air acts as a cushion to the exhaust stream from the core and hence reduces the overall shearing. The velocity of the fan exhaust is considerably less than the exhaust velocity of from the core. Hence the net exhaust velocity also reduces and reduces shearing which reduces noise. Further the exhaust temperature from the nozzle also reduces. There has been a sturdy increase in the bypass ratio of turbofans in the past three decades. Many modern aircraft engines use ultrahigh bypass ratios like Rolls-Royce Trent engines with Bypass ratio of 10:1 and Pratt Whitney PW1000G with Bypass Ratio of 12:1.

INJECTING AIR FROM THE TRAILING EDGES OF THE ROTORS

The noises in compressor region of the turbofan are mainly generated by leading edge shocks, wake and vortices formation and turbulence behind the blades. The wake regions cause differences in velocities and pressure and their interaction with the stator produces both broadband and tonal noise. Most of the present techniques of reducing fan noises try to suppress the noise after it is produced by using acoustic linings or damping materials. Other techniques focus on optimizing the number of blades or the distance between the rotor and stator to reduce the noise. But the concept of injecting air from trailing edges focuses on reducing the generation of noise itself between the blade. Small streams of air are injected from trailing edges, the volume of injected air being about 2% of the total volume flow. The expelled air mixes with the surrounding air and make the flow more steady reducing high unsteady pressure fluctuations. This reduces the noise levels by upto 10dB and mainly acts upon the tonal noises. This technique is made possible by the trend towards large fan blades used in the engines. The air can be injected without much changes to the blade dimensions.

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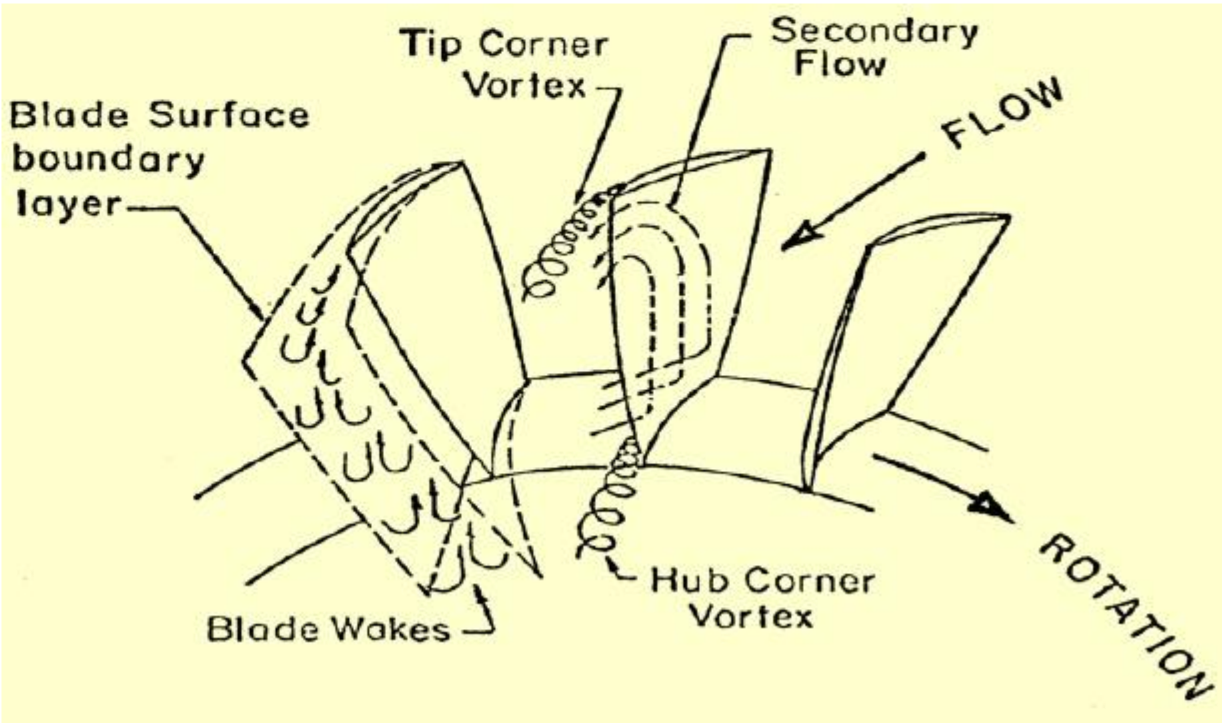

Figure 3. TRAILING EDGE NOISE GENERATORS

ACOUSTIC LINER

A method of supplementary reduction of noise when methods like high bypass ratio are already in used is by suppressing the engine noise in the engine by absorbing materials. It is a passive method of reducing noise wherein the liners absorb the acoustic radiation thereby reducing noise. Liners are mostly placed in the interior of the engine at the inlet lip, bypass duct and core duct. There are mainly two types of liners- Single Degree of Freedom Liner and Multiple Degree of Freedom Liners. The SDOF consists of a porous sheet which rests on honeycomb like structure cells which are mounted on solid backing plate which is attached to the engine . The MDOF liners are multiple chamber liners where the top and intermediate sheets are perforated while the bottom sheet is solid. The liner are mainly based on Helmholtz Resonator principle. The SDOF liners are able to damp only limited noise over a narrow band and their damping capacity

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depends upon the depth of the honeycomb cells. While MDOF liners are able to attenuate broader bandwidth and hence are more effective.

Some of the major constraints of acoustic liners are that they occupy space and add on weight. Most acoustic lining are limited by dimensional constraints and hence there is constraint on usage of MDOF liners and increasing the depth of SDOF liners. Further they should be heavy enough to affect the performance of the engine. Good liners are operable in a wide range of temperature and large bandwidth. Work needs to be done on the impedance of the liners, the material used and dimensions.

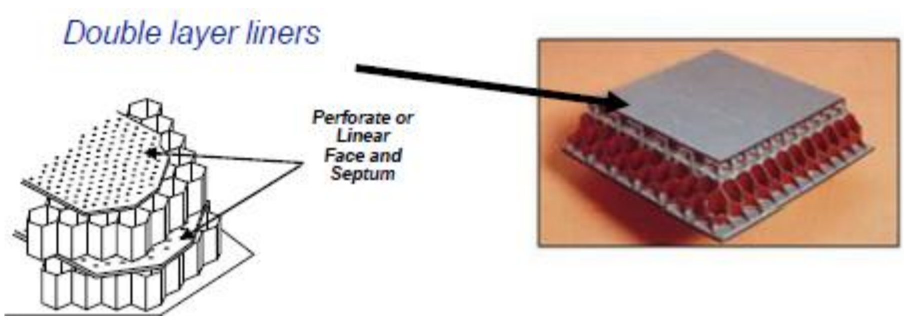

Figure 4. DOUBLE LAYER LINERS

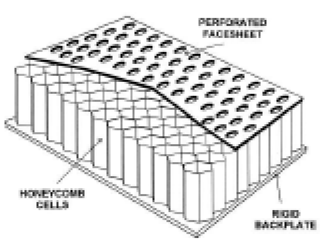

Figure 5. SINGLE LAYER LINER

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FORWARD SWEPT FAN BLADES

Fan noise in an aircraft depends on the fan rotational speed. The difference in the tip speeds of the blades during low and high speeds generates shockwaves. During takeoff, the tip speed of blade is supersonic which causes multiple tone noises called buzz-saw noises. At subsonic tip speed, blade passing tone noises are emitted due to rotor-stator blade interactions. This happens during the approach or landing of the aircraft. Another factor for fan noise is pressure ratio which causes broadband noise (for wide range of frequencies). This occurs due to disruption in interaction of fan blade wakes and stators leading to unsteady pressure field producing acoustic waves.

Forward swept fans, namely Quiet High Speed fans were designed for noise reduction. The purpose of designing these fans is to reduce noise which is studied by Effective Perceived Noise Level during takeoff. It was made for reduction of both buzz-saw noises by forward sweep of fan rotors and blade passing noises by leaned stators. By detaining multiple tone noises, the sound due to shocks decreases. This helps in controlling the stalling of blade and decreases aerodynamic losses due to shocks and thereby increases the effectiveness of fans.

It was observed by previous researches that reduction in blade passing tone was more than multiple tone noise reduction. The reason could be either due to change in design of fan blades or leaned stators. But proper causes could not be identified by this experiment. Another disadvantage, aircraft experienced a fluttering speed problem when forward swept fans were used.

CONCLUSION

Noise pollution is one of the major concerns of aerospace industry. This paper concludes that by using these methods noise at exhaust nozzle of the jet engine can be reduced. Different techniques are mentioned in the paper like chevron nozzles, acoustic liners, increasing of bypass ratio and using forward swept fan blades in turbofan engine. All these were implemented by the industry and so far, the outcome has been good. But people have faced lots problems due to sound making aircrafts. There are many disadvantages of these techniques though. Yet there are researches going on for controlling noise pollution from aircrafts.

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REFERENCES

1. Saurabh Shriwas1,Sachin Shah, Prashant Singh,Kalpit P. Kaurase,(2015) "International Journal of Research in Aeronautical and Mechanical Engineering",Vol.3,Issue.3,ISSN 2321-3051
2. Alagu sundaram.A,Ezhilmaran.G, (2015), "Numerical Investigation of Jet Noise Prediction in Exhaust Nozzle by Passive Control Techniques",Int. Journal of Engineering Research and Applications,ISSN:2248-9622, Vol. 5, Issue 5,(Part -6), pp.96-102
3. Mohammadreza Azimi, Fathollah Ommi, Naghmeh Jamshidi Alashti, (2014), "Using Acoustic Liner for Fan Noise Reduction in Modern Turbofan Engines", Int'l J. of Aeronautical & Space Sci. 15(1), 97–101 (2014), DOI:10.5139/IJASS.2014.15.1.97
4. J. M. Brookfield and I.A. Waitz, (2000), "Trailing Edge Blowing For reduction Of Turbomachinery Fan Noise", Journal of Propulsion and Power, Vol.16, No.1
5. Ulf Michel, "Noise Reductions by Aircraft Innovations", Die Fracht braucht die Nacht (Freight needs night) 24 June 2010, Frankfurt Airport
6. Andrew Kempton, Acoustic liners for modern aero-engines, Chief Noise Specialist, Rolls-Royce, Visiting Professor, University of Southampton