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Condition Monitoring and Numerical Simulation of Subsonic Jets using Thermograph Analysis

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ABSTRACT

This research work proposed a new diagnosis method of thermography technique. Condition monitoring is an effective methodology for all machining operations. It's used to detect and correct the operations error in the running condition. This study is focused on the detection and temperature characteristic analysis of tabs and chevrons nozzle in subsonic jets using the non-destructive thermography method. Reduction of jet noise has been a challenge faced by the engineers from the invention of the jet engines. In a subsonic civil aircraft with turbofan engines which experienced noise causes during takeoff which is called broadband noise of turbulent jet. Development in aeroacoustics each and every aircraft undergoes only with tab or chevron methods to reduce the jet noise. In this project tabs and chevrons are placed at the nozzle exit to enhance mixing in jets and consequently reduce noise but with a thrust penalty.

Keywords: Acoustics; Condition Monitoring; CFD; Jet noise; Tabs and Chevrons; Thermography

1. INTRODUCTION

Infrared thermography measure the surface temperature of a nozzle without contact. Condition monitoring of jet engine machinery or any component of a jet engine has become challenging and important task for the identification of different running conditions. An aircraft's overall noise signature can be categorized into three major components: aerodynamics airframe sound, engine noise as well as aircraft systems sound. Sound of jet is a main cause from the aircraft predominantly when take-off as well as landing. Since aircrafts climbs to cruise elevation, the exhaust states may turn out to be under expanded. Although higher bypass relation in turbo fan engines are significantly calm down than turbojets and additional decrease in noise is still attractive also will turn into compulsory in the future. The noise generation is related with sudden changes in air pressure; such situations are commonly found in and around aircraft turbojet engines where changes in pressure and temperature are required for the generation of thrust. Significant components of engine noise are generated by the compressor and turbine. At present two major resources of noise in profitable aircraft engines from fan, compressor in the form of jet noise. Jet noise includes turbulent combination noise also it is extremely complicated to manage, Therefore its containment remains confront. Noise levels from the jet engine have been estimated to be comparatively eighth power of jet exiting speed. Hence a variation in jet noise, through varying jet velocity, will have a greater influence on the overall noise generated by the engine when compared to the compressor or turbine. Based on this comparison, the simplest form of reducing jet noise is through a reduction in jet exhaust velocity and hence aircraft speed. Nowadays the most victorious method for decreasing jet sound starting more bye pass engine entails fixing the tab and chevrons mixer of exhaust nozzles.

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Alajmi [1] found the cutting temperature assessment using infrared thermography is gaining wide technical acceptance by reason of the opening of digital thermal cameras. This infrared thermal camera has been fitted in rotating lathe for recording machining heat when machining rate as well as feed is varying and by using together coated as well as uncoated carbide inserts. Also, temperatures gradient together by SEM micrographs and are investigated on behalf of possible relationship by means of both regular as well as irregular cutting edge deviation. When the cutting speed established with non influential parameter of represent temperatures the feed enhance tends to lesser cutting temperature. Lakhan [2] infrared thermography is one of the newest Condition Monitoring methods which are practicing in Bhilai Steel Plant. Predictive maintenance method is following in Bhilai Steel Plant for monitoring physical condition of the apparatus in addition to recognizing potential difficulties fine in advance also prepare corrective actions for rectifying unnecessary breakdowns. Ashish [3] used this technology in machine condition monitoring such as fault detection, identification as well as for fault diagnose. Karakoulidis [4] **i**nfrared thermography is a powerful non contact method with the ability to fast inspection of abnormal situations in many electrical systems and equipments. With the aim of a high resolution thermal camera a laboratory power transformer was checked under different scenarios.

Karakoulidis [5} established the co-flow retards and the addition of main jet, most important to probable core deplextion. The quality decay of the jet is moreover retarded in the occurrence of co-flow. Rathakrishnan [6] investigated the effectiveness of grooved tabs for encouraging the addition of Mach 1.8 axi symmetric free jet. Vlasenko [7] presented the computational point of view of the troubles of plan as well as mathematical replication of nozzles for recent airplane turbo fan engine. They reviewed recent ideas of noise suppression of the nozzle of civil aircraft. Tide [8] carried out the experimental investigations of chevron nozzle for assessing the significance of chevron restrictions for example number of chevrons as well as chevron diffusion. Jonghoon [9] presented adaptive network creation process to improve declaration of mathematical recreation of turbulent jet exhaust through chevron nozzles.

Zaman [10] described chevrons by means of new aggressive penetration and deliberated with early days with focus for mixing improvement of jet. Abraham [11] studied on effect of tab geometry on flow characteristics for jet concerning through 2:1 rectangular nozzle by means of two elements hotwire anemometry. Arunkumar [12] made an experimental investigation for getting efficiency of truncated triangular tabs and also presented through corrugations of all boundaries with accomplish of shedding little level vortices of continuous changeable dimensions.

This research study is focusing on the detection and temperature characteristic analysis of tabs and chevrons nozzle in subsonic jets using the non-destructive thermography method and the reduction of jet engine noise.

2. COMPUTATIONAL WORKS

Nozzles are designed and meshed by using ANSYS ICEMCFD software which is flexible one and user friendly.

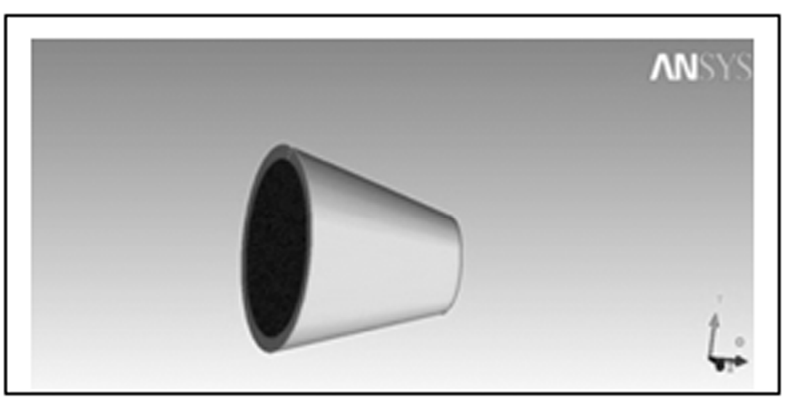

Figure 1: Isometric view of nozzle geometry

Flow analyses of nozzles are carried out with the help of ANSYS-CFX software. The isometric view of nozzle geometry is shown in Figure 1. The structure of the nozzle and Tabs are given Figure 2.a) as well as b).

The specification of the nozzle is given Table 1.

2.1. Preprocessing

The model is meshed by using Ansys ICEMCFD and computation steps are done by using Ansys CFX. The Isometric mesh view of nozzle geometry and nozzle with tabs are given Figure 4 a) as well as b).

The Isometric mesh view of nozzle with chevrons and tabs are shown in Figure 5.

2.2. Boundary conditions

Boundary conditions are implemented to every one of the bounding sections of the domains. The various fluid domains and their conditions are tabulated in Table 2.

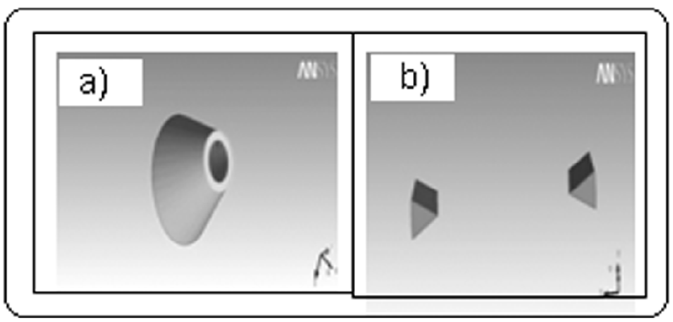

Figure 2: Structure of a) nozzle b) Tabs

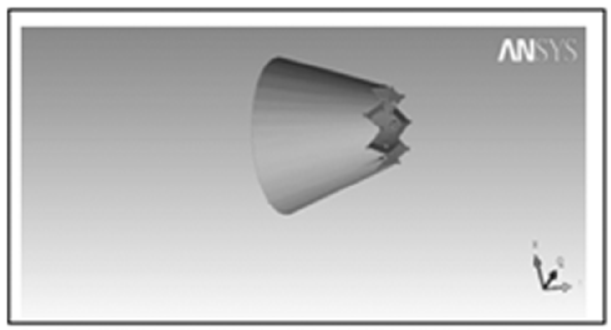

Figure 3: Isometric view of nozzle with chevrons and tabs

Table 1
Specifications of the nozzle

Sl. No.	*Description*	*Dimensions in mm*
1	Inner Diameter	30.4
2	Outer Diameter	11.6
3	Nozzle Length	35.5
4	Chevrons for eight count	4.5
5	Chevron Penetration	0^{o}
6	Tab size	Width: 1.5 mm Height: 2mm

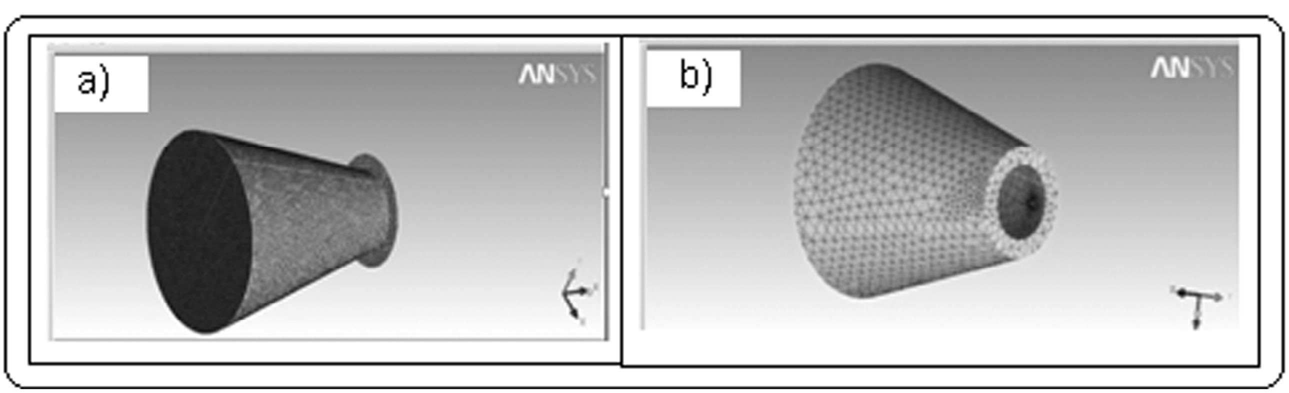

Figure 4: Isometric mesh view of a) nozzle geometry b) nozzle with tabs

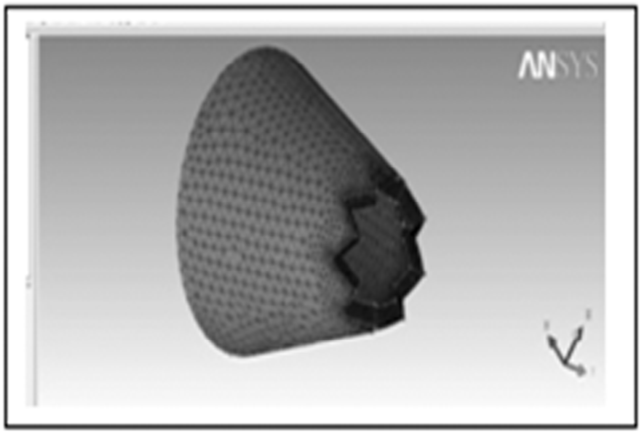

Figure 5: Isometric mesh view of nozzle with chevrons and tabs

Table 2
Various fluid domains and their conditions

Sl. No.	*Domain*	*Fluid Domain*
1	Material	Air ideal gas
2	Turbulence	Shear stress transport
3	Inlet Total	27916 Pa
4	Wall, Tabs, Chevron	No slip wall
5	Pressure far	Opening

Inlets are the condition of boundary and outlets symmetry planes are openings of walls. Indeterminate outside sections be automatically allocated a no slip as well as the condition of adiabatic wall boundary. Such section imagine of name <Domain> Default, where <Domain> related to name domain and indeterminate ignoring the interior boundaries.

2.3. Solver Manager

CFX Solver Manager as act as a graphical user interface which allows to put attributes in the CFD calculation. It organizes CFX Solver interactively. It is also viewing information regarding the emerging solution. The definition file which is stored in CFX will be opened by using the Define Run command. The normal force plot has been monitored for the convergence of the solution. The convergence is in all the case between 150 to 10000 iterations. As soon as the solution converged, the result files are stored for validating result.

2.4. Postprocessor

Post of CFD is the flexible state of the art and post processor. It is planned to permit simple visualization along with quantitative investigation of the outcome of the CFD simulations. The different Mach numbers and its respective pressures are tabulated in Table 3.

The different contours like pressure, velocity were plotted for each and every case.

Table 3
Different Mach numbers and its respective pressures

Sl. No.	*Mach No.*	*Pressure in Pa*
1	0.6	129240.42
2	0.8	154453.75
3	1	191801.05

2.5. Total Pressure

Formula to find the total pressure:

$$\frac{P_o}{P} = \left[1 - \left(\frac{\gamma - 1}{2}\right) M_2\right] \frac{\gamma}{\gamma} - 1$$

At Atmospheric condition (P) = 101325 Pa

Formula to find the sound intensity level:

dB = 20log10 [P/ P0],

P0 = 2*10-5 N/m2, dB = 20log10 [7710/0.00002] = 171.72 dB

3. RESULTS AND DISCUSSION

The absolute results are attained through CFX post. Results are taken for flow jets with nozzle, tab nozzle, and chevron nozzle with tab. The base line geometry for the nozzle are taken from the reference of Pinnam Lovaraju. His work has been tested under various Mach number and by validating there occurs a 5 percent error. Flow analysis of nozzle, nozzle with tabs, nozzle with both chevrons and tabs are done at various Mach number 0.6, 0.8 and 1.0 with the help of Ansys CFX software and the acoustic characteristic are measured. Using Shear Stress Transport (SST) model in CFX we can obtain the turbulence result for the models. Pressure and velocity variation tables for all cases (nozzle, tabs & chevrons wirh tabs) at various Mach number 0.6, 0.8 and 1.0 are compared and finally the sound intensity level is calculated.

The indication of the pressure and velocity plots for nozzle, tab nozzle and chevron and tab nozzle in under expanded condition at various Mach number 0.6, 0.8, 1.0. From these results it is known that by combining chevrons and tabs, noise generated at the exit of the convergent nozzle is reduced when compared with nozzle, tab nozzle. As the velocity of flow increases, the sound intensity level also increases but by using chevrons and tabs the velocity is not affected and the sound intensity level is reduced.

3.1. Computational results and observations

3.1.1. Flow through nozzle

In the flow through nozzle Pressure and Velocity Contour for nozzle with M = 0.6 given Figure 6 a) as well as b). The Pressure along with Velocity Contour for nozzle with M = 0.8 given Figure 7 a) as well as b). Pressure along with Velocity Contour for nozzle with M = 1.0 given Figure 8 a) as well as b).

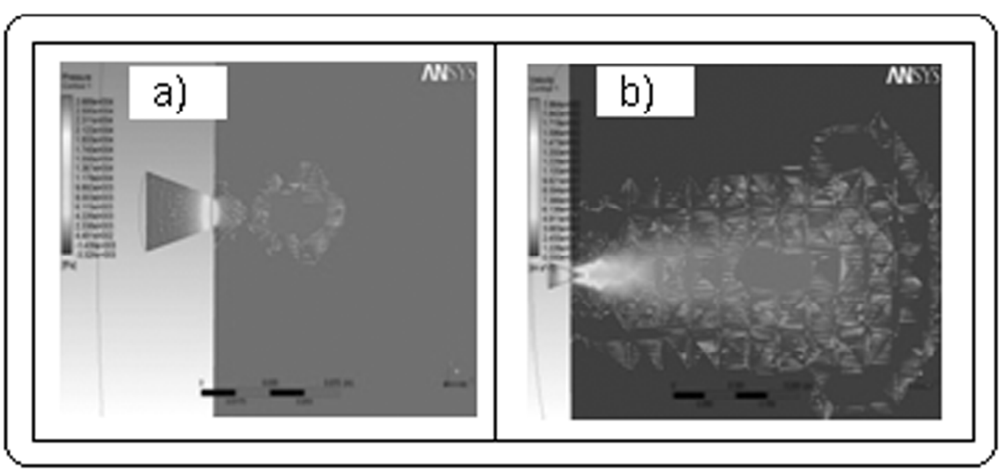

Figure 6: Pressure along with Velocity Contour for nozzle with M = 0.6

3.1.2. Flow through nozzle with tabs

The Pressure and Velocity Contour for tab nozzle with M = 0.6 given Figure 9 a) as well as b). Pressure along with Velocity Contour for tab nozzle with M = 0.8 given Figure 10 a) as well as b). Pressure along with Velocity Contour for tab nozzle with M = 1.0 given Figure 11 a) as well as b).

3.1.3. Flow through nozzle with chevrons and tabs

Pressure and Velocity Contour for chevron and tab nozzle with M=0.6 given Figure 12 a) as well as b). Pressure along with Velocity Contour for chevron and tab nozzle with M=0.8 given Figure 13 a) as well as b). Pressure along with Velocity Contour for chevron and tab nozzle with M=1.0 given Figure 14 a) as well as b).

3.2. Comparison

The above characteristics indicates the pressure and velocity variations for nozzle, nozzle with tabs and nozzle with both chevrons and tabs in under expanded condition at various Mach number 0.6, 0.8, 1.0. The

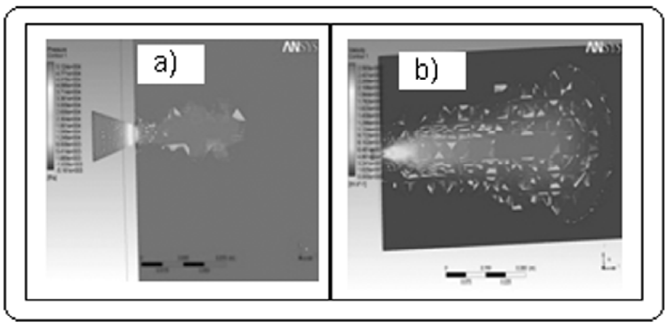

Figure 7: Pressure along with Velocity Contour of nozzle with M = 0.8

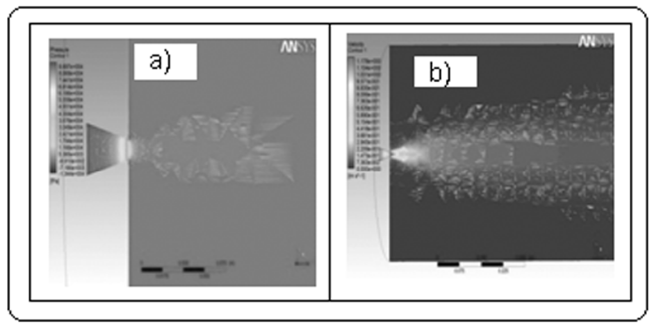

Figure 8: Pressure along with Velocity Contour of nozzle with M = 1.0

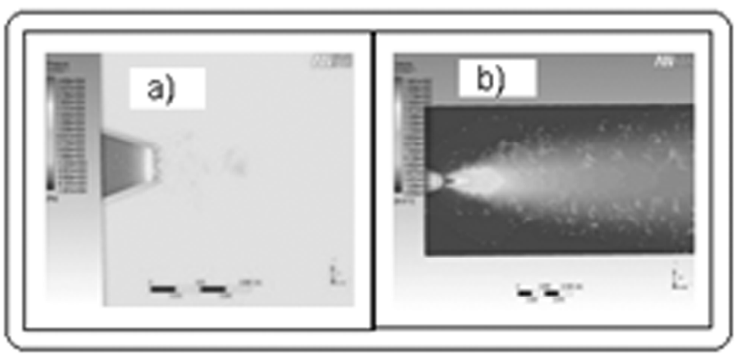

Figure 9: Pressure along with Velocity Contour for tab nozzle with M = 0.6

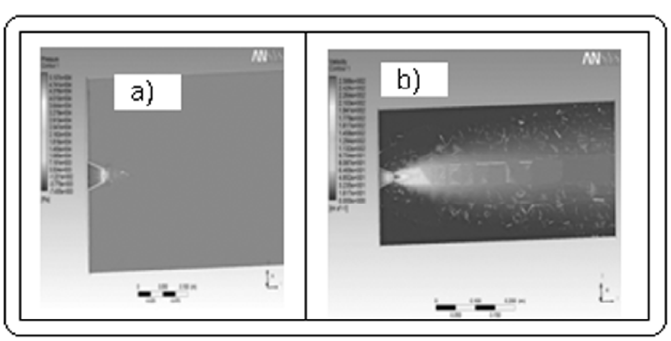

Figure 10: Pressure along with Velocity Contour of tab nozzle with M = 0.8

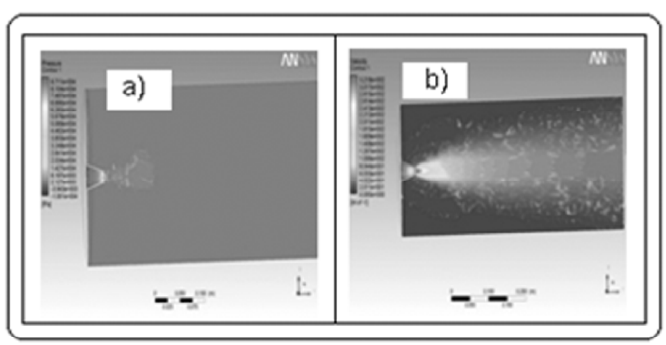

Figure 11: Pressure and Velocity Contour for tab nozzle with M = 1.0

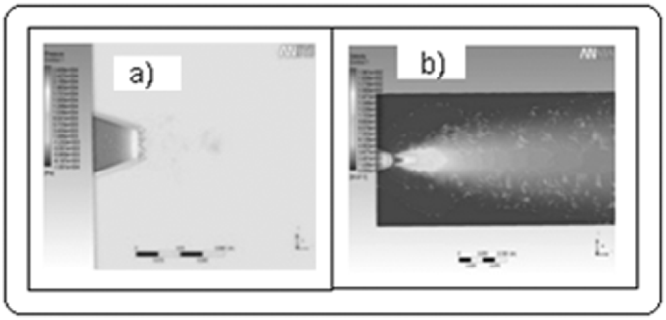

Figure 12: Pressure along with Velocity Contour for chevron and tab nozzle with M = 0.6

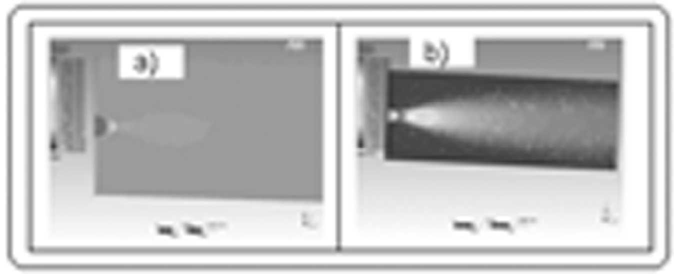

Figure 13: Pressure and Velocity Contour for chevron and tab nozzle with M = 0.8

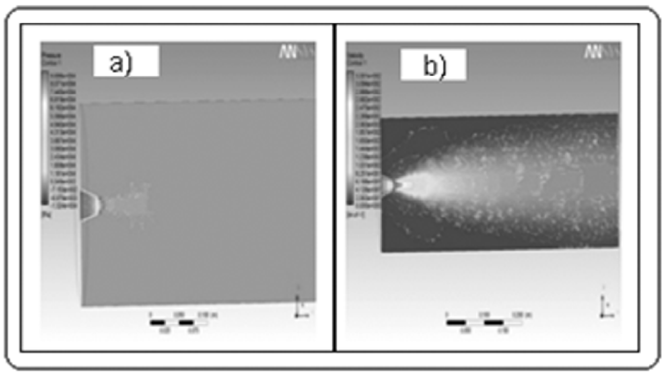

Figure 14: Pressure and Velocity Contour for chevron and tab nozzle with M = 1.0

Table 4
Pressure Variations

Mach No.	*Nozzle (Pa) × 103*	*Nozzle with Tabs (Pa) × 103*	*Nozzle with Chevrons and Tabs (Pa) × 103*
0.6	7.71	6.67	2,82
0.8	0.164	0.137	4.4
1	0.233	0.272	8.43

Table 5
Velocity Variations

Mach No.	*Nozzle (Pa) × 103*	*Nozzle with Tabs (Pa) × 103*	*Nozzle with Chevrons and Tabs (Pa) × 103*
0.6	170	174	191
0.8	215	224	253
1	255	261	307

Table 6
Variations of sound intensity level

Mach No.	*Nozzle (Pa) × 103*	*Nozzle with Tabs (Pa) × 103*	*Nozzle with Chevrons and Tabs (Pa) × 103*
0.6	171.72	170.46	162.98
0.8	178. 27	176.71	166.84
1	181.32	182.67	172.49

pressure variations, Variations of sound intensity level and Variations of sound intensity level are tabulated in Table 4, 5 and 6 respectively.

The sound intensity level variations are calculated using formula as in and the results are tabulated. From these results, nozzle with chevrons and tabs has minimum pressure, maximum velocity and reduced sound intensity level.

4. CONCLUSION

From the condition monitoring based computational analysis it is clear that nozzle with chevrons and tabs placed at the exit of the convergent nozzle has minimum sound intensity level compared to other cases (nozzle, nozzle with tabs) and the thrust of the aircraft is not affected. The analysis is carried out in under expanded condition for various Mach number 0.6, 0.8, 1.0 and the pressure, velocity and sound intensity level variations are tabulated. From these results as the velocity of flow increases, the sound intensity level also increases but by using nozzle with chevrons and tabs the velocity is not affected and the sound intensity level is reduced.

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