EXPERIMENTAL INVESTIGATION OF FLOW THROUGH PERFORATED PLATE IN CONICAL DIFFUSER AND ANALYSIS OF ITS PRESSURE DISTRIBUTION

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Abstract - *A diffuser is a primary component in an air breathing engine that helps in conversion of kinetic energy into increased static pressure rise results in efficient combustion. The report deals with investigation of flow through conical diffuser of 7° attached with perforated plates inside the diffuser to improve the axial flow and to achieve high static pressure rise without total loss in pressure. A supersonic speed wind tunnel was used for analysis. The values of pressure are determined using multitube manometer and mean coefficient of pressure was calculated using required formulas.*

Key Words: Diffuser, Perforated plates, Wind tunnel, Coefficient of pressure, conical diffuser.

1. INTRODUCTION

Diffuser in an aircraft engine finds it application in slowing down the intake air to reduce flow losses in combustor. Slower air is required to help stabilize the combustion flame and higher static pressure in the slower air provides high efficient combustion. Several geometrical models of diffusers are used which vary in their performance and efficiency. The prominent function is to improve the static pressure rise without any loss in the total pressure. The total pressure corresponds to the sum of static pressure and dynamic pressure. The air entering the diffuser possesses high turbulent kinetic energy which is difficult enough to be made to high static pressure rise. For this condition to resolve, two perforated plates are placed at inlet to yield uniform flow that has fewer disturbances in conversion to pressure rise. The pressure rise in conical diffuser is studied separately and mean coefficient of pressure in conical diffuser with perforated plates is analysed and the values are compared.

1.1 Conical Diffusers

Conical diffusers result in a high static pressure rise generation than any other rectangular or un-truncated diffuser. The parameters that govern the pressure rise in any conical diffusers are area of the duct, angle of expansion, length of diffuser and discharge conditions. In 'AN EXPNENTIAL INVESTIGATION OF THE BEHAVIOUR OF CONICAL DIFFUSERS IN TRUBULENT FLOW' by V.K.SHARAN, it is advised that in order to maintain high static pressure rise the angle of conical diffuser should be maintained at 5° to 15°. This angle is generally described as the divergence angle.

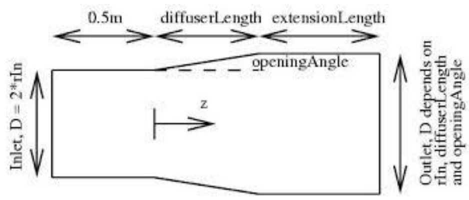

Fig – 1.1.1: A conical diffuser

1.2 Perforated Plates

Perforated sheets, also known as perforated plates or perforated screen is a sheet metal that has been manually or mechanically stamped or punched to create a pattern of holes/slots for various applications. Materials used to manufacture perforated metal sheets include cold rolled steel, galvanized steel, Monel, inconel. The two perforated plates used in the diffuser allows the flow to be axial which results in less disturbance and increased static pressure rise.

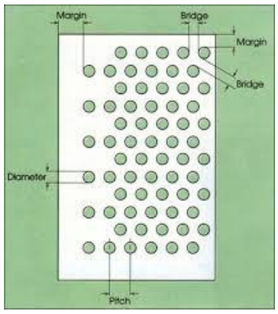

Fig 1.2.1: A typical perforated sheet

2. DESIGN AND EXPERIMENTATION

2.1 Design

The inlet diameter of the diffuser is 100mm and the outlet diameter is 170mm. The diverging portion of the diffuser is at an angle of 7°. There are two plates placed at a distance of 450 mm from the inlet.

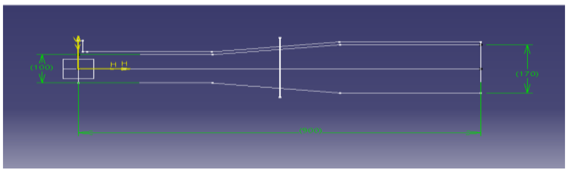

Fig 2.1.1: Diffuser with plates

The perforated plates are designed with the cross section dimensions of 55 x 60 mm with a 2.5 mm multi holes in the section.

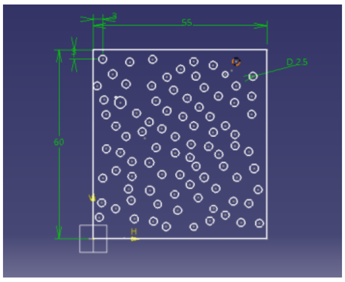

Fig 2.1.2: Perforated holes with dimensions

2.2 Experimental Setup

The experiment was conducted in a supersonic wind tunnel. A pipe of 100 mm internal diameter and a length of 900 mm were fitted at the exit of the wind tunnel to achieve a fully developed flow. The present measurements were carried out using a pressure measuring device. The pressure manometer with Pitot tube is a robust, compact and comprehensive meter to take measurements of pressure, air flow velocity and flow. The velocity of the flow is maintained at 35 m/s. The value of pressure at each port in the structure is noted the pressure ratio values are determined. The graphical representation is provided below.

Fig 2.2.1: Photographic view of Conical diffuser of half angle 7°

Two perforated plates were placed in the conical diffusers at a distance of 100mm and the inlet and exit of the conical diffuser is fitted at both ends in a supersonic wind tunnel and is operated at an initial velocity of 35 m/sec.

Fig 2.2.2: Supersonic wind tunnel facility with diffuser

3. NUMERICAL CALCULATIONS

3.1 Pressure Distribution Without Perforated Plates

The conical diffuser of 7° angle was initially placed in the supersonic wind tunnel without the attachment of perforated plates and the values of pressure at each ports in the conical diffuser is displayed in the multitube manometer and the coefficient of pressure is calculated using required formulas.

Pressure Coefficient

- Pressure coefficient : $C_p \equiv \frac{P - P_\infty}{\frac{1}{2}\rho V_\infty^2}$ P = Pressure V = Velocity (3.1.1)

The coefficient of pressure achieved at each port in the conical diffuser is

At A, C_{p1} = 0.0014

At B, C_{p2} =0.0013

At C, C_{p3} =0.00098

At D, C_{p4}=0.00064

At E, C_{p5}=0.00040

At F, C_{p6}=0.00032

At G, C_{p7}=0.00027

At H, C_{p8}=0.00024

The values are noted and finally compared with the mean coefficient pressure values of diffuser with conical diffuser.

3.2 Pressure Distribution with Perforated Plates

CONTINUITY EQUATION

The continuity equation reflects the fact that mass is conserved in any non-nuclear continuum mechanics analysis. The equation is developed by adding up the rate at which mass is flowing in and out of a control volume, and setting the net in-flow equal to the rate of change of mass within it.

$A_1V_1=A_2V_2$ (3.2.1)
Diffuser inlet diameter $D1$ = 100mm
Diffuser outlet diameter $D2$ = 170mm
Area for inlet = $\pi/4*D1^2$

= 7853.98 mm^2
= 78.53 cm^2

Area for outlet = $\pi/4D2^2$

= 22698.00 mm^2
= 229.98 cm^2 .

Velocity, $V1$= 35m/s
$V2$=78.53×35226.98
$V2$ = 12.10 m/sec
Storage pressure P = 10 bar
Dynamic pressure = ½*ρ*$V2$ * $V2$
Velocity $V2$ = 12.10 m/sec, Dynamic pressure = 89.68 Pa

Coefficient of pressure

At velocity = 35 m/s
8 pressure ports,
At velocity = 35 m/s
8 pressure ports,
$CP1$= (10−0.99)/89.86=0.1005

$CP2$ = (10−1.02)/89.68=0.1001
$CP3$= (10−0.99)/89.68=0.10046
$CP4$= (10−1.01)/89.68=0.1002
$CP5$= (10−0.99)/89.68=0.1005
$CP6$= (10−1.03)/89.68=0.1000
$CP7$= (10−1.00)/89.68=0.1004
$CP8$= (10−0.99)/89.68 =0.1005

The general values of coefficient of pressure of conical diffuser without perforated sheets is considered and compared with the above results.

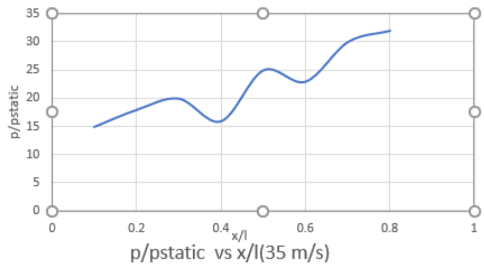

Fig 3.2.1: Pressure ratio vs. x/l of diffuser

4. RESULTS AND DISCUSSION

4.1 Introduction

In this chapter the computational analysis of the diffuser is carried out. There are many Researchers who have studied the flow through diffuser, nozzle and the inlet of the wind tunnel using CFD approach. So we are going to analyze the diffuser using computational fluid dynamics approach to investigate the mean and turbulence characteristics of fluid flow through the model, and to study the effect of pressure distribution through the diverging portion of the diffuser.

4.2 CFD Analysis

The CFD analysis for a flow through a diffuser section is done using the ansys 16 software. The boundary conditions for the inlet of the diffuser is given as 35m/s. The flow variation through the diverging portion of the diffuser section is observed. The flow is considered as laminar flow and the ambient air conditions are taken at the inlet section. The validation has been carried out by comparing the mean and fluctuating quantities obtained using different mesh sizes and topologies and different turbulence models against their data.

An appropriate turbulence model must be selected to simulate the flow. Recently, Aziz et al. (2008) have compared the accuracy of the k–ε standard and RNG models for the simulation of turbulent jets and found that the standard scheme performs as well as the RNG scheme. However, the internal nozzle flow exhibits features which are quite different from the jet and therefore one cannot assume that the k–ε standard model will accurately predict the nozzle flow. To assess the capability of different turbulence models to accurately capture the main turbulence features of the flow in the nozzle, we have implemented a one-equation model (Spalart-Allmaras), two equation models (k-ε standard, RNG and Realizable; k-ω standard and SST) and the Reynolds Stress Model (RSM) (Wilcox, 1994). In general, there are three mesh types available for discretization of the physical domain, structured, unstructured and hybrid, and each mesh type has its own advantages and disadvantages. It is well-known that a 2D quadrilateral mesh is generally of higher quality than an unstructured or hybrid mesh and the mesh quantity can be significantly reduced. The number of cells in the mesh can significantly affect the results, so repeated refinement should be carried out until the desired solution accuracy is achieved. In order to determine the appropriate mesh for the present problem and, in particular, to ensure that the final simulation results are not dependent on the mesh, the physical domain was discretized with the three mesh topologies described above and with several levels of refinement.

The analysis of the diffuser is done using the cfd software, fluent is used for the fluid flow analysis is the test section and the necessary flow parameters are obtained. The geometry of the diffuser with the plates are designed in the module and the meshing of the modal is done. The meshing is don with fine refinement and the quadrilateral type meshing is done for high degree of accuracy.

The solution is initialized for hybrid initialization and the solution is run. The diffuser is analysed for various values of the velocity and the corresponding flow parameters in the surface is obtained as plots, graphs and contours.

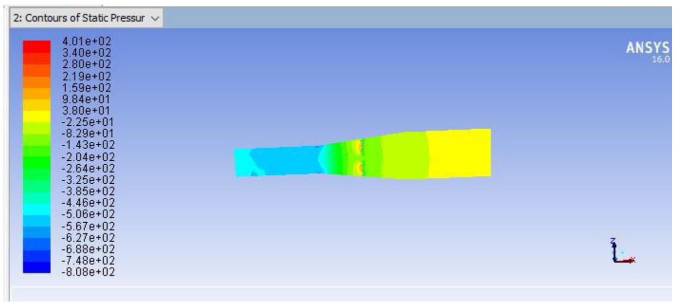

Fig 4.2.1: Flow analysis contour of static pressure (35 m/s)

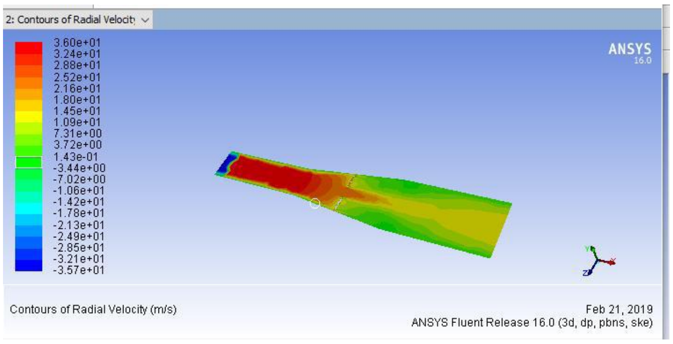

Fig 4.2.2: Flow analysis contour of radial velocity(35m/s)

Thus the analysis of the diffuser for various values of the velocities is done and the corresponding values of the pressure are obtained. The flow of the velocity over the diffuser section is done and the corresponding variations the pressure in the diffuser section is obtained using the software. The graphs are obtained for various values of the velocity and the corresponding pressure calculations are done using the formulas.

5. CONCLUSIONS

The values are compared and thus the values of mean coefficient of pressure from conical diffusers with perforated sheets are relatively high when compared to any non conical or any conical diffusers without perforated sheets. This denotes that 'higher the flow of uniform flow with slower speed generated by perforated plates results in an increased static pressure rise in diffuser without the loss in diffuser.'

This can be induced in any subsonic engines with further fabrication in the structure that may result in high pressure air entering the compressor whose pressure can be further improvised via compressor and thus may provide a higher efficiency in combustion resulting in greater thrust production.

In future, the slots or holes in the perforated plates can be made in copper plates of high thickness i.e. the holes must be made as a passage with certain length with change in inlet and exit area of the hole which may serve as separate small diffusers and contribute as a whole.

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