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OPTIMIZATION FLOW ANALYSIS OF SUPERSONIC NOZZLE USIING CFD

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1 ABSTRACT

A Nozzle is a device which is used to control the fluid flow and directions. The design is considered based on the pipe cross sectional area & length of the pipe. It is used for converting the pressure energy into kinetic energy. Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape and the pressure of the stream that emerges from them. A convergent divergent nozzle with a variable area and profile through which the relative airflow is supersonic is known as supersonic nozzle. The expansion of supersonic flow causes the static pressure and temperature to decrease from the throat to the exit, so the amount of the expansion also determines the exit pressure and temperature. Computational Fluid Dynamics (CFD) is used for flow analysis of the nozzle. Thermal analysis and flow analysis are done using CFD. Boundary conditions like pressure and temperature are applied on the nozzle. As supersonic nozzle has wide variety of applications it is necessary to optimize the flowthrough a supersonic nozzle with minimum losses. By CFD analysis of supersonic nozzle high concentration of stress, strain and deformation of nozzle is observed. By thermal analysis expansion of high temperature area and deformation due to high temperature is observed. This analysis helps us to improve the nozzle design and to optimize the flow of the fluid through supersonic nozzle. Further, this helps in improvement of efficiency of supersonic nozzle.

Key Words: *SUPERSONIC NOZZLE , CFD ANALYSIS , DESIGN.*

2 INTRODUCTION

A nozzle is a device which is used to control the fluid flow and directions. The design of the nozzle is considered based on the pipe cross sectional area and length of the pipe for controlling the velocity, direction and pressure. It is used for converting the pressure energy into kinetic energy. The primary function of a nozzle is to control flow rate and convert the spray liquid into droplets that are of a suitable size for depositing on the intended target. There are Types of Nozzles:

- Convergent Nozzle
- Divergent Nozzle
- Convergent-Divergent Nozzle

Convergent Nozzle: A typical convergent nozzle is shown in fig. in a convergent nozzle, the cross-sectional area decreases continuously from its entrance to exit. It is used in a case where the backpressure is equal to or greater than the critical pressure ratio.

Divergent Nozzle: The cross-sectional area of the divergent nozzle increases continuously from its entrance to exit. It is used in a case, where the back pressure is less than the critical pressure ratio.

Convergent-Divergent Nozzle: In this case, the cross-sectional area first decreases from its entrance to the throat and then increases from throat to exit. It is widely used in many types of steam turbine.

Mach number: It is the number as the ratio of flow velocity after a certain limit of the sounds speed. In other words, it is the ratio of the speed of some object to the speed of sound in the surrounding medium. So, Mach number is useful to compare the speed of an object with the speed of sound.

Subsonic: It is defined as the Commercial aircraft with aerodynamic features such as the rounded nose and leading edges have Mach number below 0.8 at every flow.

Sonic: It is defined as the inlet flow is equals to the outlet flow of the region. The sonic flow is always equals to 1

Supersonic: The supersonic flow is the speed of an object that is greater than the speed of the sound. It ranges up to 1.3 to 5.0

3 LITERATURE SURVEY

Pathan Khizar Ahmed [1]This paper says that intensity of velocity is found to have an increasing trend with increment in divergent angle thereby obtaining an optimum divergent angle, eliminates instabilities due to shock and satisfies the thrust requirement from the nozzle. CFD analysis is conducted to analyze flow pattern. At different divergent angles velocity magnitude, Static pressure, turbulent intensity and static temperature are analysed using CFD. The author says that oblique shocks are formed during flow through the nozzle, when the divergent angle was low and as the divergent angle is increased the shock is completely eliminated from the nozzle. This could be considered as good design for the nozzle.

Snehil Varghese[2]In this paper the convergent-divergent nozzle with varying cross- section are designed and are investigated by numerical simulations. By keeping all input parameters constant divergent angle is varied, Velocity, pressure and Mach number contours are compared for every nozzle configuration using CFD. It is found that the study says that 9.5degrees nozzle angle is the best suited for the maximization outlet thrust and velocity. Small variation of nozzle angle leads to reverse flow in the divergent section which is not acceptable because high negative pressure was observed in the whole flow region. The limitation of this study is that the flow is taken to be turbulent thus the study is not applicable for certain applications.

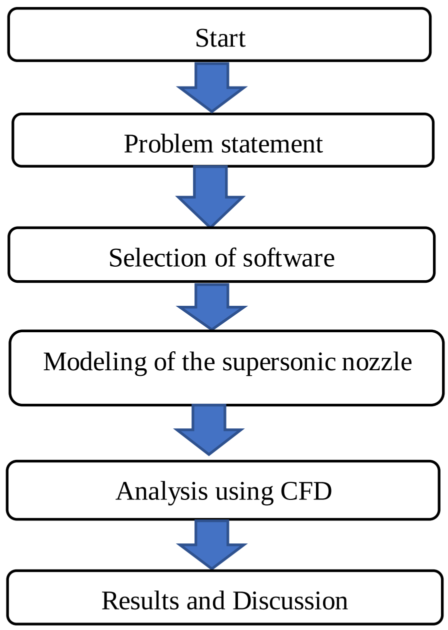
Bovas Herbert Bejaxhin ALPHONSE Mohamed K. Elshebani [3] In this study, the compressed air is used considering it as perfect gas; the desired nozzle is designed and evaluated. The author says that the internal compressible flow along a passage is usually affected by a number of different conditions like shear stress, heat transfer, cross-sectional area change and shock and expansion waves. The performance of aircrafts depends on the improved and properly integrated propulsion systems which rely on the design of the nozzle. This study can be utilized in creating software that is used for the analysis of compressible flow and also utilized for different gases and different operating conditions. This involves reducing the required driving pressure by modifying the geometry of the passage.

Dushyant Kalihari [4]In this paper, for two-dimensional study, MATLAB program is developed for scheming minimum length of the supersonic nozzle for the optimum ratio at the nozzle exit with uniform flow at the divergent section of the nozzle. The planning issues square measure targeted at the radiating section. This can be obtained by contacting the growth section and reducing the entire length of the nozzle. The study says that the essential feature needed to realize steady, sustained supersonic flow is that the nozzle contour. The required exit ratio is achieved.

Brijesh Patel [5]This paper consists of Computational Analysis of a Convergent Divergent Nozzle. Ejector mainly uses the principle of fluid dynamics for pumping. Software SED is used for calculations. 3D models are developed using AutoCAD. CFD analysis in ANSYS is done, Mach number, pressure and temperature variations at different fluid positions along the flow is applied. Unlike pressure and Mach number the value of inlet temperature decreases at throat and increases gradually. At the end the convergence is achieved with the designed shape of the CD nozzle to drain out the low-pressure exhaust gases to the ambient. This says that the rate of decrease of temperature is directly proportional to the inlet fluid temperature.

S. A. Khan [6] In this paper has been administered with AN aim to introduce a additional economical and higher activity nozzle. In increasing procedure Fluid Dynamics connected explorations in industries, the implementation of additional economical and better activity nozzles are going to be essential. This project’s objective is to bring nearer to the fact. This includes style of various shapes of nozzles on the idea of reference knowledge that had given a practical impact to the analysis of the nozzle and conjointly evaluated their performance. CFD has given a practical approach of testing of those nozzles by applying normal, constant and ranging conditions to the various parameters module through analysis results are obtained and evaluated which is able to be primary supply for the more exploration within the style and analysis of nozzles. These can kind the bottom for more analysis in style and development of various shapes of nozzle.

4 METHODOLOGY



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5 MODELING

CATIA allows the user to create 3D parts, from 2D Sketches, sheet metal, composites, moulded, forged or tooling parts up to the denotation of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW(Body in white) applications. It not only provides tools to complete product definition, including functional tolerances but also their kinematics. CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault to provide 3D surface modelling and NC functions for the CADAM software they used at that time to develop the Mirage fighter jet. Catia is one amongst CAD Software that was initially developed to help design aviation systems. It is today one of the leading CAD Software in aviation and automobile industry.

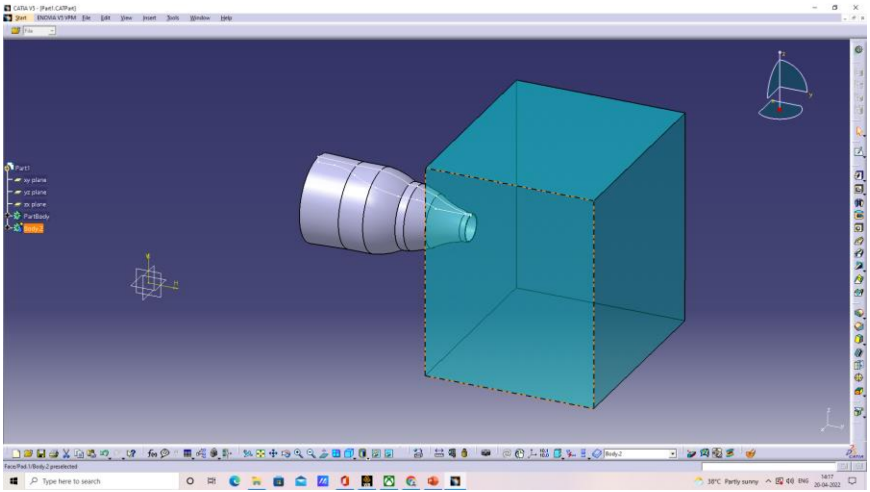

Fig. 5.1 Finished Design of supersonic nozzle.

6 ANALYSIS

ANSYS a product of ANSYS Inc. Is a world's leading, widely distributed and popular commercial CAE package. It is widely used by designers/analysis in industries such as aerospace, automotive, manufacturing, nuclear, electronics, biomedical, and much more. Engineering Data Cell is used to define the material to use in the analysis. To define the materials, double click on the engineering data cell, the workbench corresponding to this the engineering data cell will displayed. You will generate the mesh with default global mesh control settings and find six natural frequencies and their respective mode shapes. Select faces on the model. Next, choose the Apply button in the geometry selection box; the selected faces turn purple indicating that Fixed support is applied.

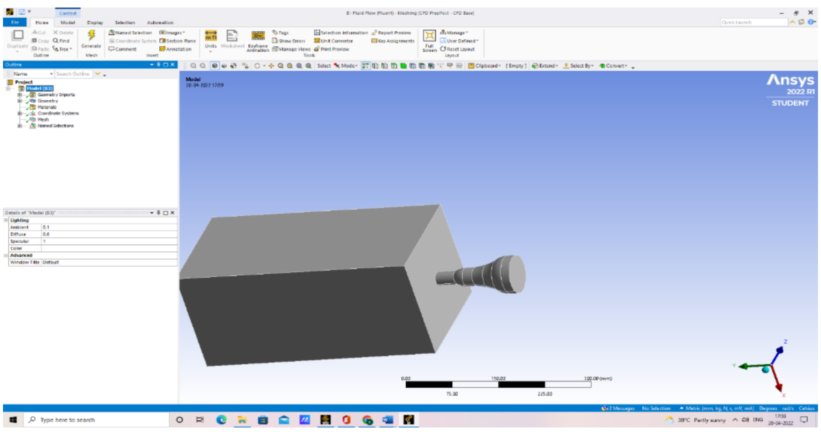

Fig. 6.1 Generating the Model

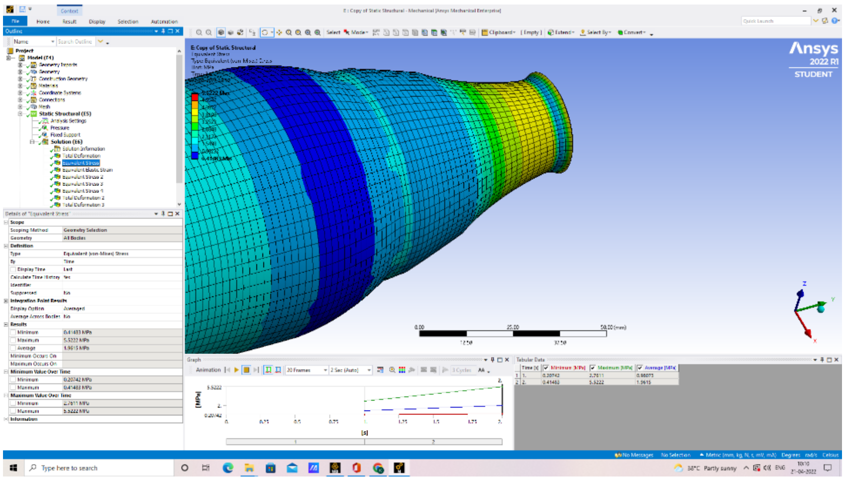

Fig. 6.2 The Values of Equivalent Stress Can Obtained.

7 PROBLEM STATEMENT

Supersonic nozzles are used widely in many areas to get high velocity. There are many losses in the nozzle during flow through the nozzle which leads to the reduction of efficiency of the nozzle which also leads to the overall efficiency reduction of the machine where the nozzle is used. For a steady state turbulent flow, analyze the internal flow in a supersonic jet nozzle model. Use CFD to analyze the supersonic nozzle considering boundary conditions. Comparing theoretical and analytical results of stress, strain and deformation obtained by analysis of supersonic nozzle.

8 OBJECTIVES

- To select the nozzle
- Supersonic nozzle is selected to do flow analysis using CFD
- To design the selected nozzle using catia in 2D and it is converted into 3D model
- To analyze the designed nozzle using CFD
- Supersonic nozzle model is analyzed using CFD in ansys by considering boundary conditions of the nozzle
- To select suitable material for the nozzle to optimize the flow in the nozzle
- To do flow analysis of supersonic nozzle model using ansys software
- To do structural analysis of supersonic nozzle model using ansys software
- To do thermal analysis of supersonic nozzle model using ansys software
- To compare the obtained results.

9 RESULTS

The forces applied to a body can produce a change in shape or size or both the shape and size of the body. By CFD analysis the deformation of the supersonic nozzle due to the forces of fluid is observed. Stress is the resistance offered by the nozzle to the loads applied by the fluid flowing in the nozzle. Here the Equivalent stress is maximum at the very end of outlet of the nozzle. The graph shows Variation of the equivalent stress along the time. It shows that the maximum Equivalent stress is increasing gradually along with the time from inlet to outlet of the nozzle along with the flow.

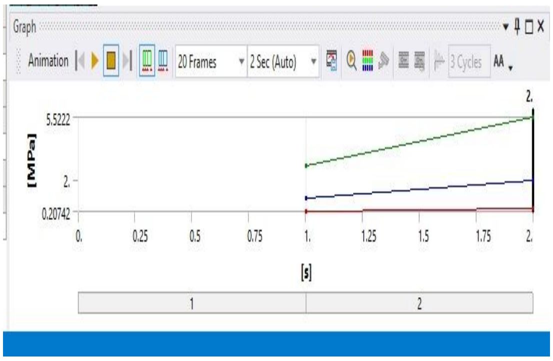

Fig. 9.1 Equivalent Stress and time graph

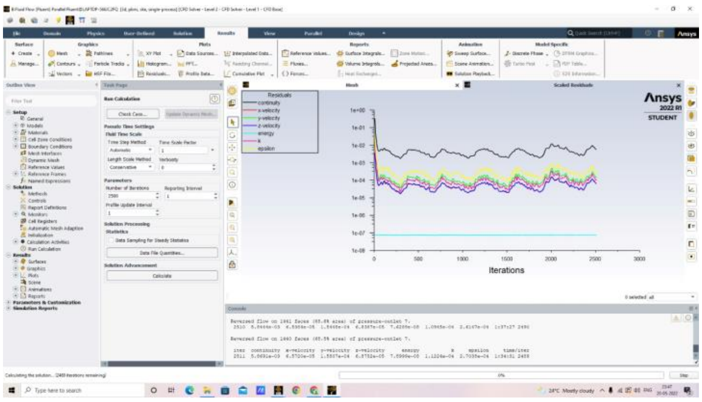

Fig. 9.2 Thermal analysis graph

Above graph shows iterations of continuity and velocity of the fluid in the nozzle.

Table 9.1 Boundary conditions

Inlet	
Velocity Specification method	Magnitude, Normal to Boundary
Reference Frame	Absolute
Velocity Magnitude [m	331
Supersonic/Initial Gau pressure [pa]	101325
Temperature [k]	300

Outlet	
Backflow Reference Fra	Absolute
Gauge Pressure [pa]	0
Pressure Profile Multipl	1
Backflow direction specification method	Normal to boundary

Backflow pressure specification	Total pressure
Specification method	Intensity and viscosity rat
Backflow turbulent inten [%]	5
Backflow turbulent visco ratio	10
Temperature [k]	300

Results	Minimum	Maximum
Total deformati [mm]	0	2.0701e-003
Equivalent stres [mpa]	0.20742	2.7611
Equivalent elast strain [mm/mm	3.1891e-006	3.896e-005
Equivalent stress [mpa]	0.22677	2.7611
Equivalent stress [mpa]	1.3557	2.6982

Table 9.2 Results summary

By comparing theoretical results with analytical results, it is known that theoretical Equivalent stress, Equivalent elastic strain and Total deformation are more than the analytical Equivalent stress, Equivalent elastic strain and Total deformation.

10 CONCLUSION

By applying boundary conditions, it is observed that the Stress, Strain ad Total deformation is increasing gradually from inlet to outlet of the supersonic nozzle. This study is applicable for both gaseous and fluid flow analysis. This study says that the Stress, strain and Deformation increases as the fluid is flowing from inlet to the outlet of the supersonic nozzle and the velocity is increasing from the inlet to outlet of the supersonic nozzle. When inlet pressure is remained constant the outlet velocity increases gradually from the inlet to the outlet of the supersonic nozzle.

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