Master Van Huy Khuat, 2026, 14:6
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Study of Airflow Parameter Variations in a Duct with a Gradually Expanding Cross Section Using Ansys Fluent

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Abstract- This paper presents the results of an investigation into the variations of airflow parameters such as pressure and velocity as the flow moves through a diverging nozzle, using the Ansys Fluent software platform. Diverging nozzles are widely employed in the jet engines of supersonic aircraft. This study examines the changes in airflow parameters as the flow passes through such a nozzle, comparing the simulation results from Ansys Fluent with both theoretical and experimental data. This approach enables the determination of specific parameters under varying conditions, as well as the identification of the underlying causes for these parameter changes.

Keywords- Jet engine; Nozzle; Supersonic; Ansys Fluent

I. INTRODUCTION

In jet engines, the nozzle is the component that converts the thermal energy of the airflow into kinetic energy, discharging the gas at high velocity to generate thrust. For supersonic aircraft, an essential feature is a diverging nozzle section, which allows the exhaust flow to accelerate beyond the speed of sound. This section is typically positioned downstream of a converging duct. Subsonic airflow accelerates through this converging section, reaching sonic velocity at the narrowest point the throat before continuing to accelerate within the diverging section. Consequently, the airflow is accelerated from subsonic to supersonic speeds. This article presents the findings of an investigation into the variations of airflow parameters within the diverging section of the nozzle.

II. METHODOLOGY

The selection of a computational method for a specific problem depends on the required level of accuracy, the simplicity and consistency of the method, economic considerations, available resources, and the degree of control over the process—including the verification of the obtained results.

We chose to survey various types of pipes with progressively expanding cross-sections using Ansys Fluent software. This is a powerful software that can easily build many different models, provides quick calculation results, and allows for easy parameter changes to conduct surveys while still meeting accuracy requirements.

To study how parameters change as fluid flows through a diverging nozzle, we have adopted a model consisting of three sections: an initial section with a constant cross-section, a second section with a gradually expanding cross-section, and a third section with a constant cross-section. Smooth curves are used for the transitions between these regions to avoid abrupt changes in parameters. The dimensional parameters can be easily modified to facilitate the investigation.

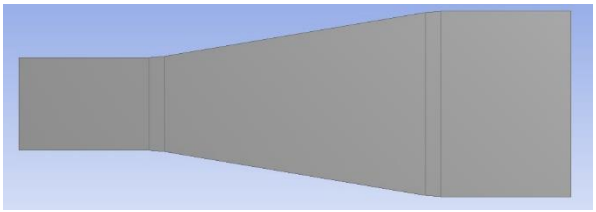


Figure 1: Pipeline diagram for the survey

After defining the geometric model of the test duct, we developed a simulation model using ANSYS Fluent to construct ducts with various expansion

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angles. We then generated a mesh within the region of interest, applied boundary conditions, and analyzed the airflow dynamics through the ducts. For the airflow simulation, we employed an automated structured meshing approach using quadrilateral elements. The mesh sizing across the duct cross-sections was defined by specifying a fixed number of divisions, ensuring a consistent number of grid cells. Additionally, the mesh spacing along the duct walls was set to be proportional to the length, ensuring uniform cell dimensions. This approach yielded a highly consistent and stable mesh (Figure 3)..

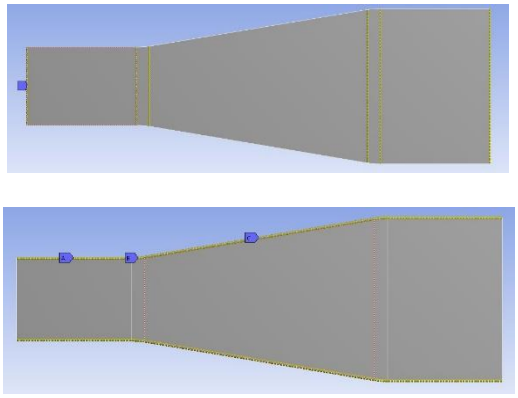


Figure 2: Determining dimensions during the meshing process.

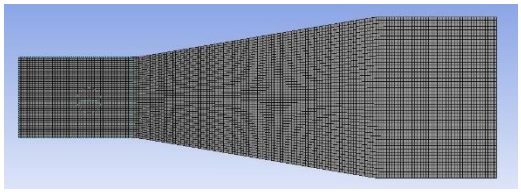


Figure 3: Survey grid results

III. RESULTS AND DISCUSSION

Once the computational model was constructed, we proceeded to conduct an analysis using it. To perform this analysis, we specified the airflow velocity at the model's inlet and established appropriate boundary conditions for studying airflow within a converging duct. We then varied the dimensions of the duct outlet to examine how the degree of constriction affects airflow velocity.

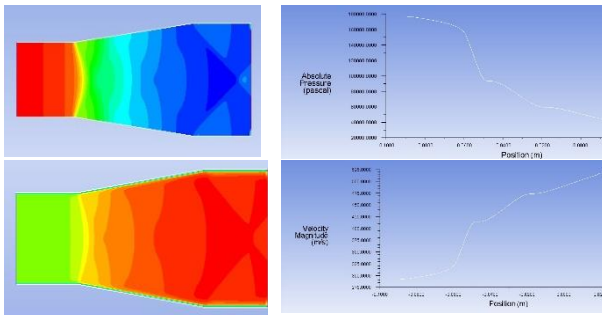


Figure 4: Images and graphs showing changes in pressure and airflow velocity for a duct with an inlet width of 20 mm and an outlet width of 30 mm.

The results of the analysis are presented through images and graphs that illustrate the variations in pressure and airflow velocity along the length of the test duct for different configurations.

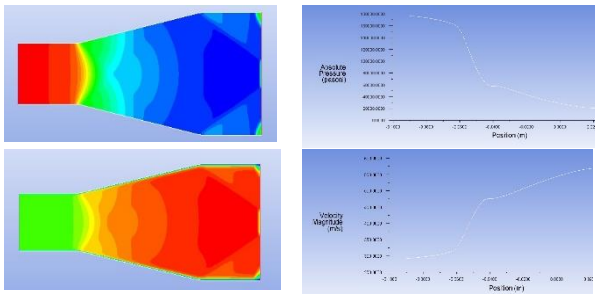


Figure 5: Images and graphs showing changes in pressure and airflow velocity for a duct with an inlet width of 20 mm and an outlet width of 40 mm.

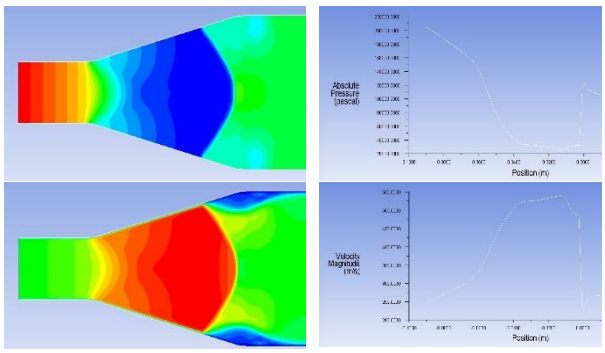
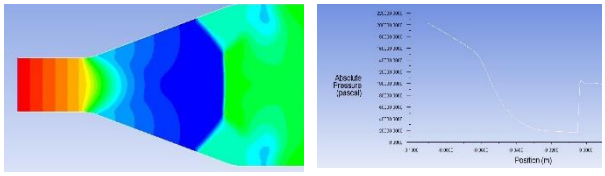


Figure 6: Images and graphs showing changes in pressure and airflow velocity for a duct with an inlet width of 20 mm and an outlet width of 50 mm.



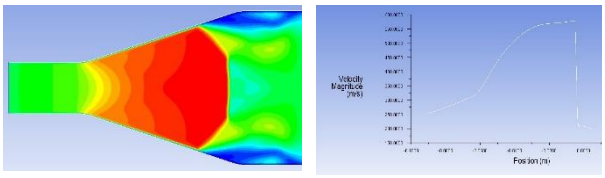


Figure 7: Images and graphs showing changes in pressure and airflow velocity for a duct with an inlet width of 20 mm and an outlet width of 60 mm.

Based on the calculation results—as illustrated in the provided images and graphs—we observe the following:

- When a gas flow moves at supersonic velocities through a diverging duct, the flow velocity increases along the length of the duct, while the static pressure decreases;
- Variations in duct dimensions indicate that a greater degree of divergence leads to more rapid changes in flow parameters;
- However, when the degree of divergence exceeds a certain limit, the flow parameters reach a threshold beyond which they can no longer change; at this point, flow separation occurs along the duct walls to ensure that the parameters do not exceed these established limits.
- Significance: Through the investigation of how gas flow parameters change as the fluid moves through a diverging duct, we find that:
- The obtained results are entirely consistent with theoretical principles;
- The analysis allows for the determination of specific gas velocity and pressure values at any given position within the duct;
- The results provide a visual representation of the gas flow, including the variations in velocity and pressure throughout the analyzed region. This offers an intuitive view of the flow process within the duct, making it easier to observe and clearly understand the underlying nature of the phenomenon. - The survey results can be utilized during the students' course of study at the institution;
- This survey method can be employed for further research into the variations of airflow parameters across different types of piping.

IV. CONCLUSION

Based on the computational results obtained from the model, we have determined the variations in airflow parameters as the flow moves through a converging duct. The analysis reveals that when using a converging nozzle, the airflow velocity increases as it travels through the duct; however, once the velocity reaches a maximum value equal to the speed of sound at the exit, it ceases to increase further. This acceleration of the airflow at the nozzle ensures the generation of the necessary thrust for the engine.

The study also facilitates an analysis of the airflow dynamics, helping to identify the underlying causes of these parameter changes. Visual data obtained during the study can be utilized in instruction to provide students with a clear, visual understanding of the physical phenomena occurring as the airflow passes through the nozzle.

Thank You

The authors wish to express their gratitude to the various agencies, organizations, and individuals who provided support, assistance, and encouragement during the preparation of this paper. Special thanks go to the faculty members of the Air Force Officer School, as well as friends and colleagues, for their cooperation and assistance. The authors would like to thank the leadership of the Air Force Officer School and the entire faculty of the Aircraft and Engine Department for their dedication in sharing valuable knowledge and for their support throughout the research process. Despite significant effort, this research may still contain shortcomings. The authors welcome feedback and suggestions from experts, interested parties, and colleagues to help refine and improve the work.

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