AERODYNAMIC DESIGN AND PERFORMANCE OF NOZZLES WITH DIFFERENT MACH NUMBERS USING CFD ANALYSIS

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Abstract—The exhaust nozzle system plays a flagship role in aircraft and the design of nozzle have a supersonic cruise mission is optimized for a cruise condition and in takeoff conditions it must give the required quantity of thrust action at other most lynchpin operating points. In contrast, for a vehicle the exhaust nozzle system is to an accelerating mission must provide limited action across the flight envelop as there is not a fixed cruise point were the operates of aircraft the majority of the time. The aerodynamic design and performance analysis of convergent and convergent – divergent nozzle with different lengths 110.236mm and 135.636mm with subsonic and supersonic flow conditions is analyzed using CFD analysis. The comparisons are made for pressure distribution, velocity and mass flow rates in 3D models are done in CATIA and CFD analysis.

Key words—Nozzles, Cad, Mesh.CFD analysis.

1. INTRODUCTION

While choosing the nozzles make sure its capabilities with your current systems. The perform flow testing to ensure you get adequate water and also consider the penetration and reaction force on the firefighter.

To the extinguish a fire we will use the any nozzle, keep in mind that actual flow may be affected by many variables, such as differences in piping from the pump to the discharge point, augment friction loss, changes in the types and their individual friction loss, different pump pressures, water supply issues and debris passing through the water system. So be sure to test your nozzle under ideal conditions and under poor conditions to decide how it will works in both quality and inadequate of water-flow situations.

By the characteristics of nozzles there are many features are available and uses. The key point is determining which nozzle is right for your needs. To help you make that determination, here’s a breakdown of some of the basic nozzle types, and the pros and cons of each. Typically, the smooth-bore nozzle produces the greatest reach/rpm combination of all nozzles while at the same time using the lowest engine pump.

1.1 NOZZLE

Fig-1: Water nozzle

To control the direction of a fluid flow the device is used is called as nozzle it exits (or enters) an enclosed chamber or pipe.

1.2 AERODYNAMIC NOZZLE

We can metamorphose a gas turbine into a jet engine by utilizing the propelling nozzle. Power obtained from the gas turbine exited it can transfer into a high speed propelling jet by using the nozzles. Engines like turbofan may have separate and separated propelling nozzle which gives the high speed to propelling jet from the energy from the air is send through the fan. In addition, by using the nozzle we can determine how the gas generator and fan operate as it acts as a downstream restrictor.

Propelling nozzles are moving quickly the obtained gas to subsonic and transonic velocities rely on the power setting of engine. The Convergent-divergent (C-D) are the internal shape which can move quickly the jet to supersonic velocities within the divergent section, whereas a convergent nozzle cannot accelerate the jet beyond sonic speed.

1.3 Types of nozzle

1) Ejector nozzle

Ejector type of nozzle is used for pumping action of the more scalding, high speed, engine exit entraining to an ambient air flow. Nozzle manipulates the expansion of the exhaust of engine.

2) Thrust vectoring nozzle

Nozzles for vectored thrust include fixed geometry Bristol Snidely Pegasus and variable geometry.
3) Rocket nozzle

Rocket motors also used convergent-divergent nozzles, but these are usually of fixed geometry, to minimize weight.

1.4 MACH

In compressible flow theory the mesh is most flagship parameter, and it comparing with the speed of sound in a fluid (excellent measure of compressibility effects) and the speed at which the fluid is flowing.

1.5 MACH ANGLES

This isentropic wave front is analogous to the oblique shock wave, and the angle between the wave front and the direction of the disturbance's motion is called the Mach wave angle or Mach angle.

2. INTRODUCTION TO CAD

As we know to design of an object in computer is difficult in computer in past days but now a day's it's so simple firstly we know Computer-aided design (CAD) it is software now a day's it's made so easy to draw 2D and 3D diagrams in computers. It's also called as computer-aided design and drafting (CADD). By the using of Computer Aided Drafting which explains the drafting process in computer. For many of design engineering CADD software is a flagship tool by using this software they shows the elegant designs of the objects as per the requirements. The output of CADD is in the form of print or machining operations.

The required output information is also important for CAD such as materials, processes, dimensions, and tolerances, according to specific applications. The design curves and figures in two-dimensional (2D) space and solids surface in three-dimensional (3D) objects are shown in CAD software. The design of geometric objects for object shapes, in particular, is often called computer-aided geometric design (CAGD).

3. 3D MODELING CONVERGENT MODEL

Length 110.236 mm

2d Sketch

CONVERGENT DIVERGENT MODEL

Length 110.236 mm

2d Sketch

Surface model

The mach numbers or taken from the national aeronautics and space administration

Mach number = \( \frac{\text{object speed}}{\text{speed of sound}} \)

THE SPEED OF SOUND \( C = 343 \text{ METERS PER SECOND (M/S)} \)

CFD ANALYSIS FOR AERODYNAMIC NOZZLE

CONVERGENT MODEL

FLUID – NITROGEN OXIDE

MODEL LENGTH – 110.236 mm

FLOW- SUBSONIC FLOW (MACH NUMBER 0.4)

3d Sketch
Fig-5: Meshed model
Specifying boundaries for inlet, outlet and wall
Select edge → right click → create named section → enter name → inlet

Fig-6: Inlet

Fig-7: Outlet
Select edge → right click → create named section → enter name → outlet

Wall

Fig-8: Inlet and outlet of wall
Select fluid nitrogen oxide
Boundary conditions → select air inlet → Edit → Enter Inlet Velocity → 171.5 m/s

Fig-9: Velocity inlet
Solution → Solution Initialization → Hybrid Initialization → done
Run calculations → no of iterations = 30 → calculate → calculation complete as shown in Fig.9

Fig-10: Pressure difference graph

Fig-11: Velocity

Fig-12: Reynolds number
Mass Flow Rate (kg/s)

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<tr>
<td><strong>Net</strong></td>
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**MODEL LENGTH – 135.636 mm**

FLOW - SUPERSONIC FLOW (MACH NUMBER 1.0)

CONVERGENT DIVERGENT MODEL

FLUID – NITROGEN OXIDE

MODEL LENGTH – 110.236 mm

Select fluid nitrogen oxide

![Fig-13: pressure](image1)

![Fig-14: velocity](image2)

![Fig-15: Reynolds number](image3)

![Fig-16: Inlet](image4)

![Fig-17: Outlet](image5)

![Fig-18: Wall](image6)

![Fig-19: Select fluid nitrogen oxide](image7)
Fig-20: Velocity inlet

FLOW- SUBSONIC FLOW (MACH NUMBER 1.0)

Fig-21: Pressure

Fig-22: Velocity

Fig-23: Reynolds number

Mass Flow Rate (kg/s)

<p>| | |</p>
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Wall 0

Net 0.026726723

FLOW-SUPER SONIC FLOW (MACH NUMBER 1.0)

Fig-24: Pressure

Fig-25: Velocity

Fig-26: Reynolds number

Mass Flow Rate (kg/s)

<p>| | |</p>
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Net 0.065441132

MODEL LENGTH – 135.636mm
RESULTS TABLE

CONVERGENT

Table-1: Subsonic flow

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Pressure (Pa)</th>
<th>Velocity (m/s)</th>
<th>Reynolds number</th>
<th>Mass flow Rate (kg/s)</th>
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<tr>
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Table-2: Supersonic flow

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<th>Velocity (m/s)</th>
<th>Reynolds number</th>
<th>Mass flow Rate (kg/s)</th>
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CONVERGENT DIVERGENT

Table-3: Subsonic flow

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<tr>
<th>Length (mm)</th>
<th>Pressure (Pa)</th>
<th>Velocity (m/s)</th>
<th>Reynolds number</th>
<th>Mass flow Rate (kg/s)</th>
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Table-4: Supersonic flow

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Convergent model

Chart-1: Comparison of pressure values for different flows and lengths

Chart-2: Comparison of velocity values for different flows and lengths

Chart-3: Comparison of cell Reynolds number values for different flows and lengths

Chart-4: Comparison of mass flow rate values for different flows and lengths

Convergent divergent model

Chart-5: Comparison of pressure values for different flows and lengths
Chart-6: Comparisons of velocity values for different flows and lengths

Chart-7: Comparison of cell Reynolds number values for different flows and lengths

Chart-8: Comparison of mass flow rate values for different flows and lengths

CONCLUSIONS

The aerodynamic design and performance analysis of convergent and convergent – divergent nozzle with different lengths 110.236mm and 135.636mm with subsonic and supersonic flow conditions is analyzed. The comparisons are made for pressure distribution, velocity and mass flow rates.

3D models are done in CATIA and CFD analysis is done in Ansys.

By observing the results, the augment of velocity and diminish of Pressure along the length of the nozzle accepts little bit increasing during the shocking. However, the augment will not show any significant to the total pressure decreases. As per the Bernoulli’s equation the diminish of pressure as augment of velocity. Mass flow rates are increasing by increase of mach numbers and increase of lengths. The values are increasing by increasing the length of the nozzle. This is due to fact that by increasing the lengths the fluid is compressed inside the nozzle. The pressure distribution, velocities are more under supersonic flow conditions due to high inlet velocities. So it can be concluded that increasing mach numbers and lengths yields to better performance of nozzle.

REFERENCES


