Analytical Investigation of Performance of De-Laval Nozzle

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Abstract— To control fluid properties like density, velocity, temperature and pressure a Nozzle is utilized. By converting heat and pressure in to KE flow velocity is increased, this is the main application of nozzle. The ratio of exit area to throat area is the nozzle expansion ratio. A typical De-Laval nozzle may be a nozzle that incorporates a converging area, throat and diverging area. In this thesis, the performance analysis of De-Laval nozzle by changing the expansion ratios at different Mach numbers is analyzed. The considered expansion ratios are 7.84 and Mach Numbers are 2.8 for CFD analysis is done on the nozzle and the comparisons are made for pressure distribution, velocity. Static structural analysis is done on the nozzle by applying the pressures obtained from CFD analysis using different materials Brass, Titanium. 3D models are done in Creo 2.0 and CFD and Static Structural analysis is done in Ansys

Key words: De-Laval nozzle, Brass, Titanium, Ansys and CFD

I. Introduction

The C-D nozzles each conic and contour are designed on an assumption of the physical property flow of the proper gas [1]. The pc code that uses the strategy of characteristics and therefore the stream perform to outline high potency nozzle profile for physical property, in viscid, rotational supersonic flows of any operating fluid for any user-defined exit ratio [2]. The designed nozzle space ratio is compared to theoretical space ratios for the chosen fluid and desired exit ratio. The nozzle geometry obtained from the code is severally checked with the business machine Fluid Dynamics (CFD) code. Current research yields package that improves the accuracy and speed of complicated simulation situations like sonic or turbulent flows [3]. Initial experimental validation of such package is performed employing a wide tunnel with the ultimate validation coming back in full scale testing, e.g. flight tests. The defining of boundary conditions that involves specifying the behaviour of fluid and boundary properties of the problem. Defining of initial conditions is required for transient problems [4]. The simulation is started and a steady state or transient conditions are considered to solve the equations iteratively as a steady-state or transient. Finally a postprocessor is utilized for the analysis and visualization of the resulting solution [5].

II. Experimental details

A. Materials Used

- Brass
- Titanium

III. Sketch of Throat Nozzle

Initially the sketch is drawn in 2-D by using different commands like line, revolve, extrude and mirror in Auto cad software as shown in the figure 1.

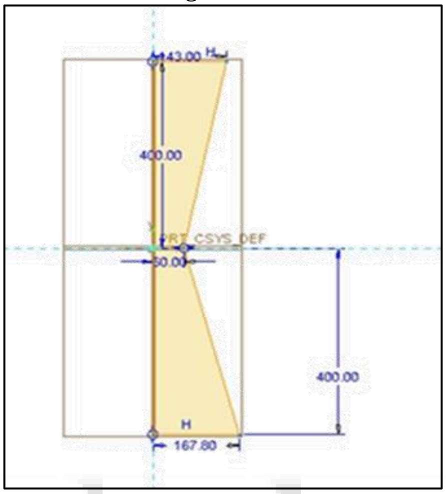

Fig. 1: Sketch of Throat Diameter 60 mm

IV. Modelling of Throat Nozzle

3-D model of throat nozzle as shown in the figure 2. For different materials the modelling of the throat nozzle will be same.

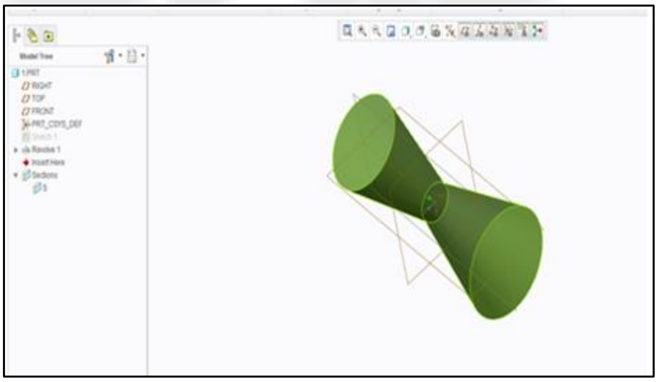

Fig. 2: Modelling of Throat Nozzle

V. Static Structural Analysis

The input pressure to perform Static Structural analysis is taken from the results of CFD analysis for respective throat diameters at respective Mach numbers.
Throat Radius – 105 mm
Material – Brass and Titanium
Pressure - 0.178mpa (Mach number – 2.8)

VI. Material properties of Brass

Density : 8.73g/cc
Young's modulus: 125Gpa
Poisson's ratio : 0.34

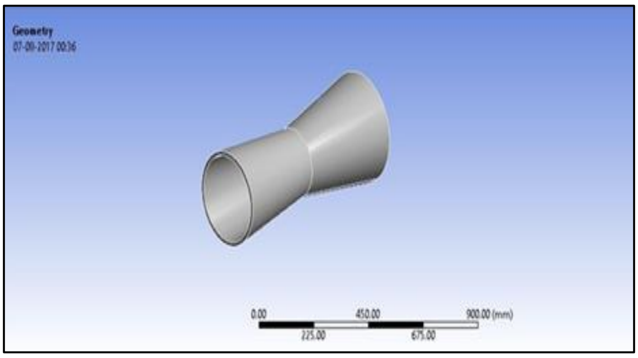

Fig. 3: Imported Model of 105mm Throat Radius Nozzle

Select model>right click on it> select edit> window will be open in that select mesh>right click on it>select generate mesh as shown in the figure 4.

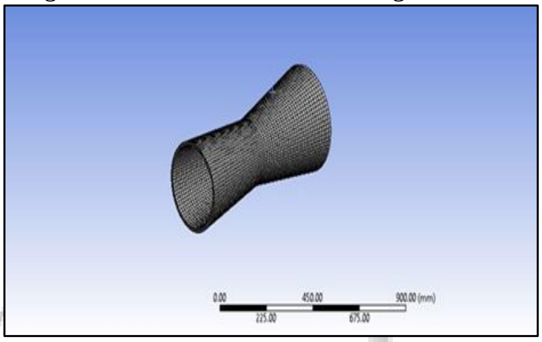

Fig. 4: Meshed Model of 105mm Throat Radius Nozzle

Right click on solution> insert > Deformation >Total>Right click on solution> insert> Strain> Equivalent (Von-misses)> Right click on solution> insert> Stress> Equivalent (Von-misses). Right click on solution> insert > Solve. Static pressure applied inside of the nozzle as shown in the figure 5.

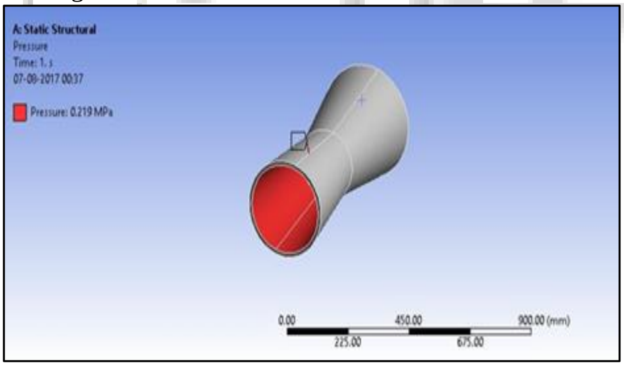

Fig. 5: Pressure applied inside the Nozzle

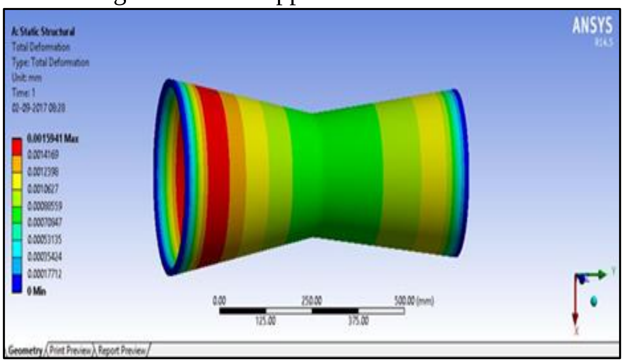

Fig. 6: Deformation of 105mm Throat Radius Nozzle at Mach number 2.8 using Brass

Initially the deformation of the brass material is low when compared with titanium material at Mach number 2.8. The stress for 105 mm throat nozzle at mach number 2.8 of Brass material are increasing more when compared with that of 105 mm throat radius nozzle at mach number 2.8 of Titanium material as shown in the figure 7.

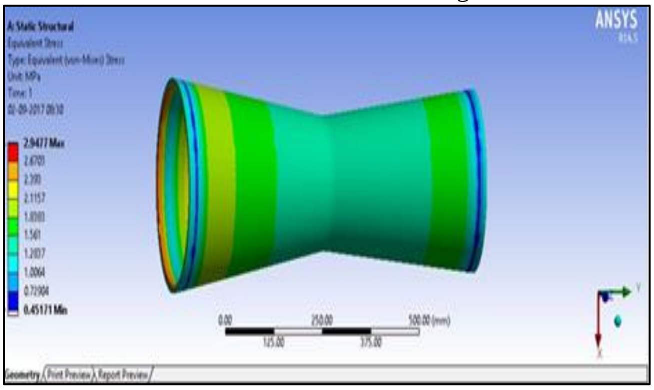

Fig. 7: Stress Analysis of 105 mm Throat Radius Nozzle at Mach number 2.8

The strain for 105 mm throat nozzle at mach number 2.8 of Brass material are decreasing more when compared with that of 105 mm throat radius nozzle at mach number 2.8 of Titanium material as shown in the figure 8.

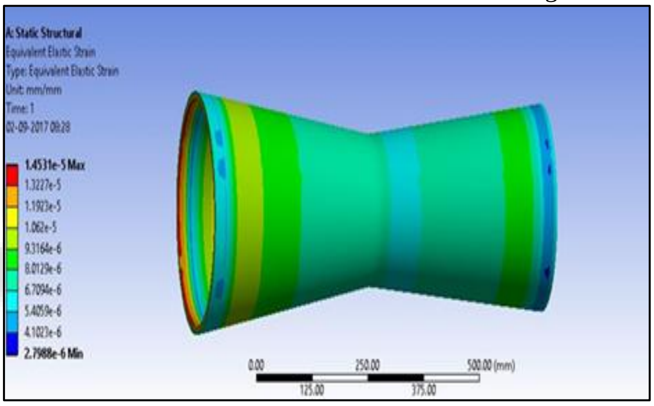

Fig. 8: Strain Analysis of 105 mm Throat Radius Nozzle at Mach number 2.8

VII. MATERIAL PROPERTIES OF TITANIUM

Density : 4.506 g/cc
Young's modulus: 110 Gpa
Poisson's ratio : 0.37

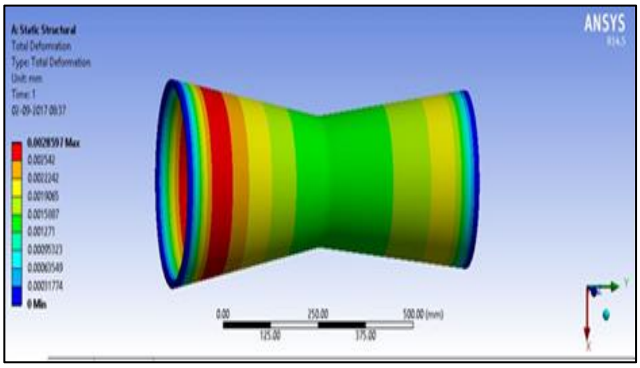

Fig. 9: Deformation of 105mm Throat Radius Nozzle at Mach number 2.8 using Titanium

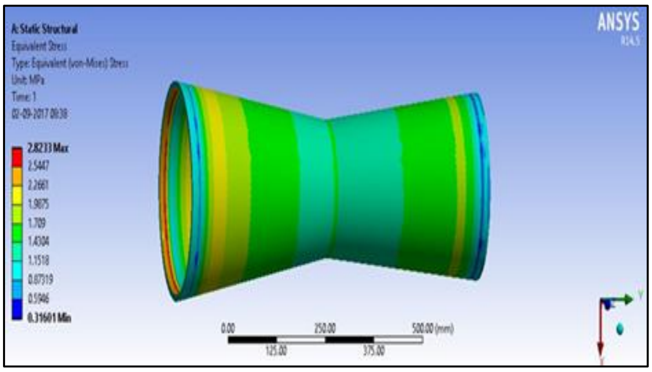

Fig. 10: Stress Analysis of 105 mm Throat Radius Nozzle at Mach number 2.8

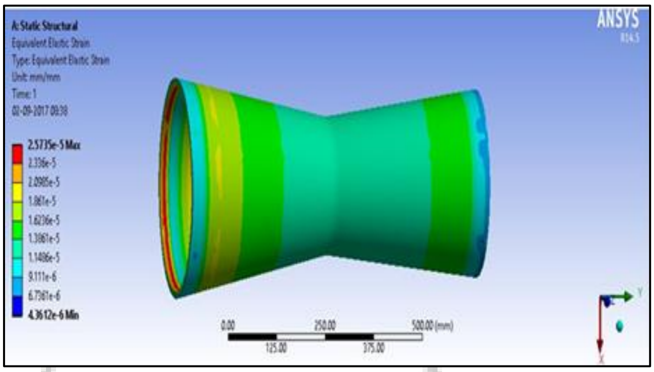

Fig. 11: Strain Analysis of 105 mm Throat Radius Nozzle at Mach number 2.8

Materials	Stress (MPa)	Strain	Deformation (mm)
Brass	2.9477	0.000014547	0.0015941
Titanium	2.8233	0.00002573	0.0028597

Table 1: Variation of Mechanical Properties with different Materials

Similarly for different throat nozzles at different mach number the variation of mechanical properties will be same but the deformation of the nozzle will be changes based upon of the material.

VIII. Conclusions

CFD analysis is done on the nozzle and the comparisons are made for pressure distribution, velocity. By observing CFD analysis results, the pressures and velocities are increasing by decreasing the expansion ratio and increasing by changing the Mach number. The stress for 105 mm throat nozzle at mach number 2.8 of Brass material are increasing more when compared with that of 105 mm throat radius nozzle at mach number 2.8 of Titanium material. The strain for 105 mm throat nozzle at mach number 2.8 of Brass material are decreasing more when compared with that of 105 mm throat radius nozzle at mach number 2.8 of Titanium material.

References

[1] Nikhil D. Deshpande, Suyash S. Sidwans, Pratik R. Mahale, Rutuja S. Joshi, K.R. Jagtap, Theoretical & CFD Analysis of De Laval Nozzle, Journal of mechanical and production engineering, issn: 2320-2092, volume- 2, issue- 4, april-2014

[2] Malay S Patel, Sulochan D Mane and Manikant Raman, Concepts and CFD analysis of De-Laval Nozzle, International Journal of Mechanical Engineering and Technology (IJMET)Volume 7, Issue 5, SeptemberOctober2016,pp.221240

[3] Ms. K. Sree Lakshmi, Modeling and Simulation of Supersonic Nozzle Using Computational Fluid Dynamics, International Journal & Magazine of Engineering, Technology, Management and Research, Vol No.3, Issue 9, September 2016

[4] Venkatesh .V, C Jaya pal Reddy, Modelling and Simulation of Supersonic Nozzle Using Computational Fluid Dynamics, International Journal of Novel Research in Interdisciplinary Studies Vol. 2, Issue 6, pp: (16-27), Month: November-December 2015

[5] K.M. Pandey, Member IACSIT and A.P. Singh, CFD Analysis of Conical Nozzle for Mach 3 at Various Angles of Divergence with Fluent Software, International Journal of Chemical Engineering and Applications, Vol. 1, No. 2, August 2010 ISSN: 2010-0221