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A PATH FOR HORIZING YOUR INNOVATIVE WORK

NUMERICAL SIMULATION OF SCRMAJET INTAKE USING CFD

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Abstract: Ramjets can be particularly useful in applications requiring a small and simple engine for high speed use, such as missiles, while weapon designers are looking to use ramjet technology in artillery shells to give added range. A scramjet propulsion system is a hypersonic air-breathing engine in which heat addition, due to combustion of fuel and air, occurs in the flow that is supersonic relative to the engine. By contrast, the airflow in a pure scramjet remains supersonic throughout the combustion process and does not require a choking mechanism. In general any scramjet engine begins with Mach number of 5. In order maintain some reduction in speed we use turbojet engines which propel from 3.2 to 4.2 Mach and from there the ramjet picks upon and starts to propel to start the scramjet. The design for a scramjet engine is carried out in this paper considering the only entry designs and numerical analysis is carried out using ANSYS FLUENT software. For the Analysis Two dimensional geometry created in the GAMBIT data taking from the public domain literature survey followed by suitable mesh was carry out. By giving the suitable boundary conditions Numerical analysis carried out using FLUENT. Analyzed results will be comparing with the experimental work for the selection of Aeromechanical features.

Keywords: Scramjet, GAMBIT, Mach, Engine

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INTRODUCTION

Before we start the concept of Scramjet let us begin with the ramjet engines. Ramjet engines have no moving parts, instead operating on compression to slow free stream supersonic air to subsonic speeds, thereby increasing temperature and pressure, and then combusting the compressed air with fuel. Lastly, a nozzle accelerates the exhaust to supersonic speeds, resulting in thrust [2,3].

Exceptional to the slowing of the free stream air, the pressure, temperature and density of the flow entering the burner are "significantly higher than in the free stream". On flight Mach numbers of round Mach 6, these rises make it inefficient to continue to slow the flow to subsonic rapidity. Therefore, if the flow is no longer slowed to subsonic speeds, but rather only slowed to suitable supersonic speeds, the ramjet is then termed a 'supersonic combustion ramjet,' resulting in the acronym scramjet [4,5].

II. **Collected Works On Scramjet Engine:**

However the concept of ramjet and scramjet engines may complete like something out of science fiction, scramjet engines have been under expansion for at least forty years. The succeeding subsection will give a brief chronological history of the scramjet engine. Nearby are three main zones that these difficulties lay in, namely Air Inlet, Combustor, and Structures and Materials. Difficulties within these areas vary from inlet starting problems to the inherent difficulty of the ignition of the fuel in a supersonic flow, as the chance of failure exists anywhere from the fuel not igniting to the likelihood that the ignition could take place outside of the combustor due to the extraordinary velocity of the air in the engine. Furthermore, constructions that can withstand the extreme temperatures knowledgeable during hypersonic flight combined with the additional temperatures experienced during combustion are essential[6,7,8].

Notwithstanding the wide range of solicitations possible with scramjet technology, the vehicle must first be impelled to a high enough Mach number for the scramjet to shock. However, if the compulsory scramjet starting Mach number is reduced, a reduction in the number of required additional propulsion systems is possible, as the gap is bridged among the maximum possible velocity of the low speed engine(s) and the scramjet start velocity. This desired have direct advantages from the resulting reduction in overall vehicle weight, the lower mass fraction required for the propulsion system (thereby resulting in more available payload weight), and fewer systems that must work in run reliably, thereby increasing overall vehicle security. The emphasis of this project is to address this issue of falling the starting Mach number [10].

III. Computational Fluid Dynamics:

The transport of fluid comprises gases/liquid from one component to other in power/process equipment are described through mass, momentum and energy conservation principles. The Navier Stokes (transport) equations are derived from these principles and are discussed by Hoffman, K.A [1993] which are represented mathematically as-

$$\frac{\partial \rho\varphi}{\partial t} + div\left(\rho\varphi\vec{u}\right) = div\left(\Gamma grad\varphi\right) + q_{\varphi} \quad 1$$

The terms on Left Hand Side (LHS) defines acceleration of flow over time with inertia depends on the sum of the external forces, diffusion and sources acting on the fluid element. If the value of φ is 1, the eqn. (1) results in continuity equation. If the value of φ is either u or v or w, the above eqn. describes momentum equation in x, y, z directions. If the value of φ is h then the above eqn. yields to energy equation.

In order to resolve wide spectrum of scales in turbulent eddies, normally two approaches are employed. This requires dense mesh points for proper resolution and its solution depends on heavy computational resources that are expensive, time consuming process and therefore very rarely used simulation technique. The other approach generally used for most of the applications are Reynolds' averaging process wherein flow variables are decomposed into mean and fluctuating components as

$$u_i = \overline{u}_i + u_i^{'} \quad 2$$

where i=1.2,3 denotes in x, y, z direction [7]. Likewise the pressure and other scalars can be expressed as

$$\phi = \overline{\varphi} + \phi^{'} \quad 3$$

Substituting flow variables in this form into the instantaneous continuity and momentum equations and taking a time (or ensemble) average (and dropping the over bar on the mean velocity) yields to

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_i}\left(\rho u_i\right)=0 \qquad 4$$

$$\frac{\partial}{\partial t}\left(\rho u_i\right)+\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right)= \qquad 5$$

$$-\frac{\partial p}{\partial x_i}-\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}-\frac{2}{3}\delta_{i,j}\frac{\partial u_l}{\partial x_l}\right)\right]+\frac{\partial}{\partial x_j}\left(\overline{-\rho u_i' u_j'}\right)$$

Eqn (4-5) are called RANS equations. The term $\overline{\rho u_i' u_j'}$ in the eqn (4.5) results from averaging process and is called Reynolds' Stress. With the help of Boussinesq hypothesis to relate the Reynolds stresses, choosing Kronecker delta δ=1 if *i=j* and $\overline{u_i' u_i'}=2k$ the Reynolds's stress term in the eqn (5) is rewritten as -

$$\overline{-\rho u_i' u_i'}=\mu_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\left(\rho k+\mu_t\frac{\partial u_k}{\partial x_k}\right)\delta_{i,j} \qquad 6$$

where μ_t is turbulent viscosity. To resolve turbulence viscosity and Reynolds' stresses, eddy viscosity models based on Boussinesq hypothesis will leads to zero, one and two equation turbulence models and Reynolds's Stress Models (RSM). The strength and weakness of these models for prediction of turbulence effects are extensively studied.

IV.Methodology:

Using these values, we create the desired model, domain and mesh it. The lower part of the inlet is same for all the models, be it First deg/Second deg/Third Deg/ Fourth Deg Intake model. The deeper the mesh is, the more exact is the result we accomplish. As this paper is on the inlet part of the engine, we impenetrable the mesh more on the inlet part than in other areas of the domain. Few areas were tried out in the process and a couple of them were create to be appropriate for the project. The concluding product of the design in GAMBIT is transferred to FLUENT. Consequences are captured for Mach numbers, pressure and temperature. The effectiveness and performance of the models are discussed based on Compression efficiency and temperature ratio. The model in this paper is a 2-d model. In GAMBIT the key thing for study is enmeshing. The meshing had to be compressed near the inlet of the engine intake when related to the rest of the domain. For generating a intake model, The elevation of the exhaust as discussed earlier is 3.2134m. The Analysis results are well matching with the theoretical results shown in figures from Fig 14 to F 16.

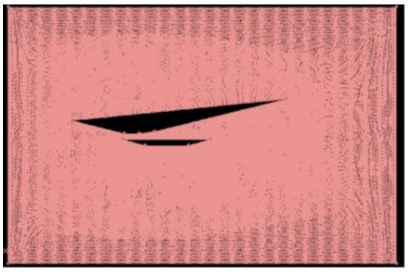

Fig 1: Gambit Intake Meshing in GAMBIT

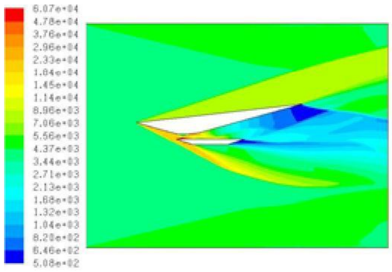

Fig 2: Presssure contour at 2 Deg

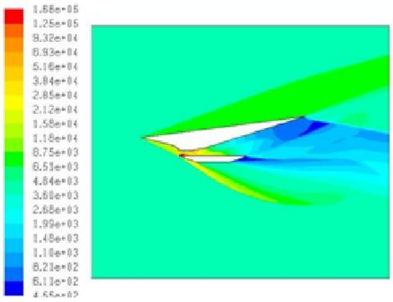

Fig 3: Pressure contour at 3 Deg

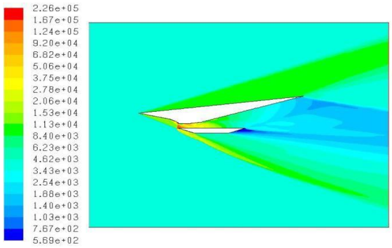

Fig 4: Pressure contour at 4 Deg

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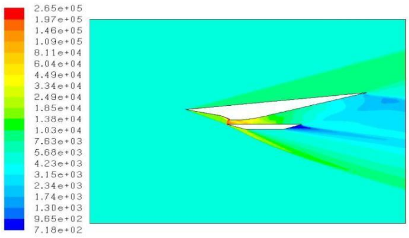

Fig 5: Pressure contour at 5 Deg

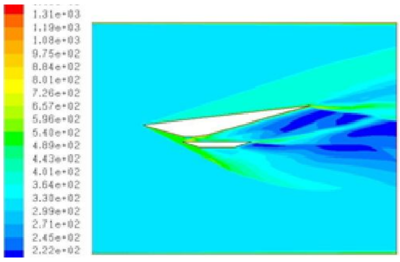

Fig 6: Temperature contour at 2 Deg

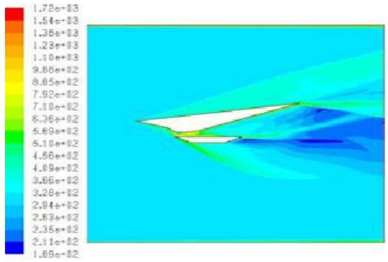

Fig 7: Temperature contour at 3 Deg

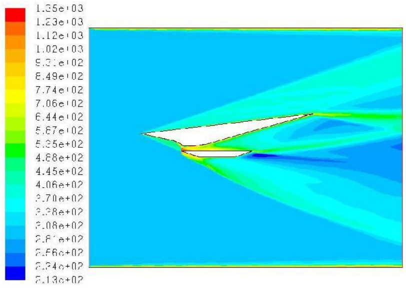

Fig 8: Temperature contour at 3 Deg

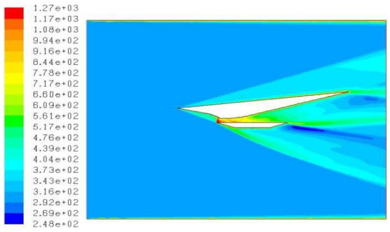

Fig 9: Temperature contour at 4 Deg

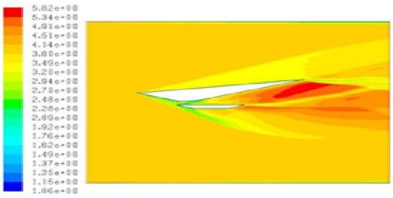

Fig 10: Temperature contour at 5 Deg

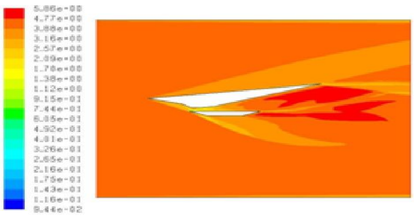

Fig 11: Velocity contour at 3 Deg

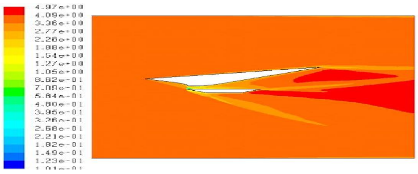

Fig 12: Velocity contour at 4 Deg

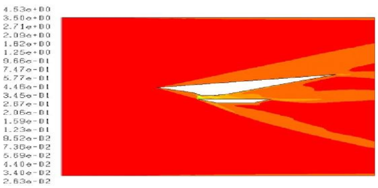

Fig 13: Velocity contour at 5 Deg

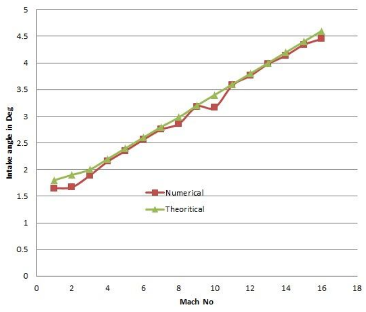

Fig 14: Comparison results for 2 Deg

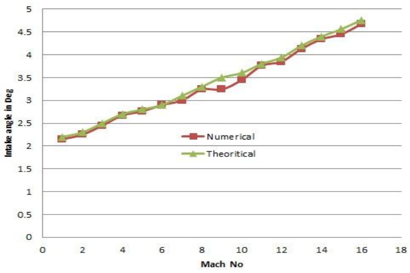

Fig 15: Comparison results for 3 Deg

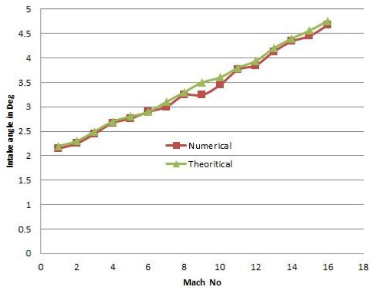

Fig 16: Comparison results for 5 Deg

The distance of the exhaust is also cited in that section as 7.25m and therefore the statistics for modelling the key (upper) part of the engine is done. Now for the additional part of the engine (lower part), it ranges from the end of x0 and beginning of x1.5 in the inlet part to the point where l6 terminates and where l32in the exhaust part starts.

Using these standards, we create the preferred model, area and mesh it. The lower part of the inlet is same for all the models, be it Two/Three/Four/Five Deg Intake scramjet engine model. The denser the mesh is, the more precise is the result we achieve. As this paper is on the inlet part of the engine, we dense the mesh more on the inlet part than in other areas of the domain. Few domains were tried out in the process and a couple of them were found to be appropriate for the Paper.

The final product of the design in GAMBIT is transferred to FLUENT. Results are captured for Mach numbers, pressure and temperature see Fig 1. The efficiency and performance of the models are discussed based on Compression efficiency and temperature ratio. Initially analysis was done with a lesser amount of dense mesh in GAMBIT and the consequences were not in any way closer to the critical values. Hence in order to get more precise values, we mesh the model denser to about one lakh elements for all the four Intakes individually.

V. Results and Discussions:

From the complete analysis the above Figures from Fig 2 to Fig shocks can be envisioned due to which the change in flow parameters like Mach number, pressure and temperature can be gained. The above model is with Two Deg such that single shock is obtained but the compression effectiveness is very less. So, to increase the density efficiency it is desired to increase the number of oblique shocks by growing the number of degree(s). The next model is with double deg to get two shocks. After studying the following flow outlines have been captured. We can detect that the final model, i.e., four deg model with around 1, 55,000 elements is very nearby to the theoretical result of Mach 1.85. It was marked from the analysis that results were improved achieved with four degrees amongst all tried degrees. As discussed earlier, a turbojet engine can provide thrust from take off to a speed of Mach 3.1 or 4.0. Therefore, if the scramjet is designed applied to a hypersonic cruiser it could presumably allow for a reduction in total propulsion system. The analysis done also backings the theory with concrete evidence in the results tabulated above with small difference in values. Off-design conditions were also checked out with four ramp model with Mach Numbers 3, 3.5, 6, 6.5, 8.5, 10.5 but the results were not required and moreover, Mach number 3.5 and 10.5 gave unstart connected snags. The Values also matching with the theoretical data.

VI.**Conclusion**

The determination of this paper was to determine at which lower free stream Mach number the Scramjet Engine will start so as to reduce the weight of the craft by eliminating one of the propulsion system while performance is maintained in the same flow path at the higher, off-design Mach numbers and to define how it could be accomplished. The present analysis shows that with this design Starting Mach number of Scramjet can be reduced to Mach number 4.5

but with the same design Scramjet is facing the unstarting conditions for off design Mach number of 3.5 and 10.5

Finally from this paper it is evident that there are important areas which call for future research and analysis. The first of these is that analyzing three dimensional scramjet inlet and the next is application of a fully designed expansion system engaging the use of method of characteristics or CFD codes. As for the practical design of this scramjet, the use of cavity-based fuel injectors should be reconnoitered. Moreover, the method of fuel-air mixing, combustion time required, and overall potential benefit of cooling scramjet with the fuel should be explored. Absolutely these results ensure that the good aeromechanical features in the field of air breathing engines.

REFERENCES

1. Powell, O.A., J.T. Edwards, R.B. Norris, K.E. Numbers, and J.A. Pearce. "Development of Hydrocarbon-Fueled Scramjet Engines: the Hypersonic Technology (HyTech) Program." Journal of Propulsion and Power, Volume 17, No. 6, November- December 2001: 1170-1176.

2. Curran, Edward T., "Scramjet Engines: The First Forty Years." Journal of Propulsion and Power, Volume 17, No. 6, November-December 2001. Waltrup, Paul J. "Upper Bounds on the Flight Speed of Hydrocarbon-Fueled Scramjet-Powered Vehicles." Journal of Propulsion and Power, Volume 17, No. 6, November-December 2001: 1199-1204. 133

3. Thompson, Elvia, Keith Henry, and Leslie Williams. "Faster Than a Speeding Bullet: uinness Recognizes NASA Scramjet." NASA. 20 June 2005. RELEASE :05-156. http://www.nasa.gov/home/hqnews/2005/jun/HQ_05_156_X43A_Guinness.html>.

4. William H., David T. Pratt, Daniel H. Daley, and Unmeel B. Mehta. Hypersonic Airbreathing Propulsion. Washington, D.C.: American Institute of Aeronautics and Astronautics, 1994.

5. Fry, Ronald S. "A Century of Ramjet Propulsion Technology Evolution." Journal of Propulsion and Power, Volume 20, No. 1, January-February 2004: 27-58.

6. HyShot Program Secures Place in Flight History." The University of Queensland in Australia. 16 Aug. 2002. <http://www.uq.edu.au/news/index.html?article=3469>.

7. Townend, L.H. "Domain of the Scramjet." Journal of Propulsion and Power, Volume 17, No.6, November-December 2001: 1205-1213.

8. Analysis And Design Of A Hypersonic Scramjet Engine With A Starting Mach Number Of 4.00 By Kristen Nicole Roberts. August 2008

9. Anderson, Jr., John D. Modern Compressible Flow with Historical erspective. 2nd Ed. New York: McGraw-Hill Company, 1990.

10. Waltrup, Paul J. "Upper Bounds on the Flight Speed of Hydrocarbon-Fuelled Scramjet-Powered Vehicles." Journal of Propulsion and Power, Volume 17, No. 6, November-December 2001: 1199-1204.