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NUMERICAL SIMULATION OF SCRAMJET ENGINE

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Abstract - The analysis of scramjet engine is a well-known problem when compared to other engine simulations. I intend to analyze the scramjet engine using the software package Fluent – Gambit. This analysis describes the flow field through the scramjet engine. The engine is modeled using Gambit and imported to Fluent. The boundary conditions are specified accordingly to simulate cold flow conditions. In this context, an attempt has been made to investigate the flow field and analyze the graphical results obtained using Fluent. Here, the computation has been carried out at supersonic speed to solve the flow field variable. The results are obtaining in graphical format for temperature, velocity, pressure and Mach number variation along length of the engine. The analysis is intended for various inlet Mach no (2, 3 and 4) conditions. The results will be further sharpened by refining grid and by using various viscous models. Fluent is a computational fluid dynamics (CFD) software package to simulate fluid problems. It uses the finite-volume method to solve the governing equations for a fluid. It provides the capability to use different physical models such as incompressible or compressible, in viscid or viscous, laminar or turbulent, etc. Geometry and grid generation is done by using Gambit which is the preprocessor bundled with Fluent. Modeling, meshing and solutions of flow variable around the complex geometry have been solved using this software. The various features of the preprocessor, solver and postprocessor of the software are being highlighted in below analysis.

Keywords - scramjet inlet, contraction ratio, ramp, cowl lip, normal shock, oblique shock, shock train

INTRODUCTION

Definition of a Scramjet Engine

In order to provide the definition of a scramjet engine, the definition of a ramjet engine is first necessary, as a scramjet engine is a direct descendant of a ramjet engine. 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. Figure 1 shows a two- dimensional schematic of a ramjet engine

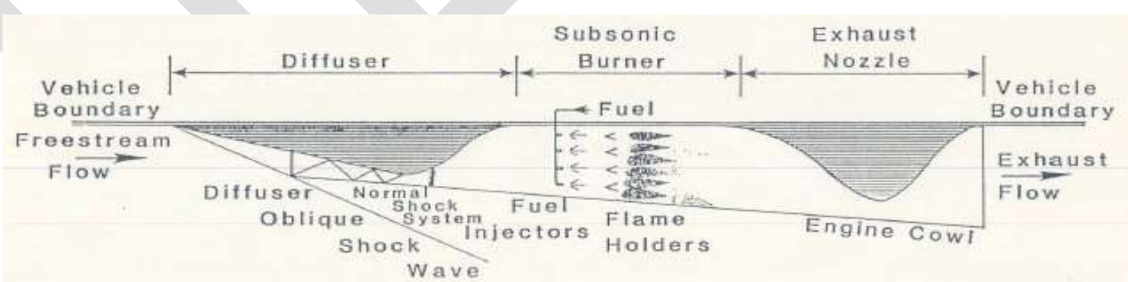

Fig. 1: Two-dimensional Schematic of a Ramjet Engine

Due to the deceleration of the free stream air, the pressure, temperature and density of the flow entering the burner are "considerably higher than in the free stream". At flight Mach numbers of around Mach 6, these increases make it inefficient to continue to slow the flow to subsonic speeds. Thus, if the flow is no longer slowed to subsonic speeds, but rather only slowed to acceptable supersonic speeds, the ramjet is then termed a 'supersonic combustion ramjet,' resulting in the acronym scramjet. Figure 2 shows a two-dimensional schematic of a scramjet engine.

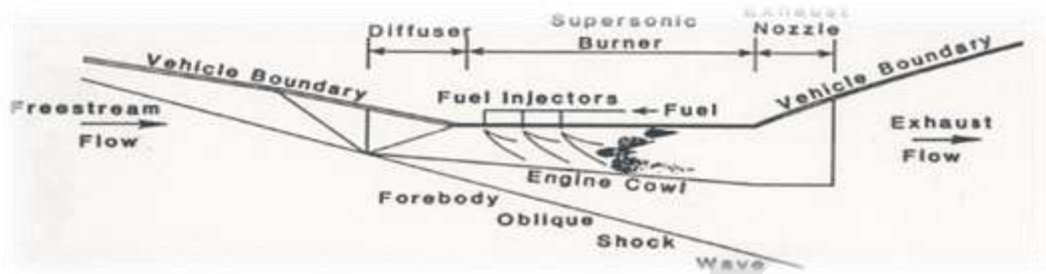

Fig. 2: Two-dimensional Schematic of a Scramjet Engine

Though the concept of ramjet and scramjet engines may sound like something out of science fiction, scramjet engines have been under development for at least forty years. The following subsection will give a brief chronological history of the scramjet engine.

NUMERICAL ANALYSIS

LAWS GOVERNING FLUID MOTION

The laws governing fluid motion are (i) Conservation of Mass (ii) Newton's Laws of Motion (iii) Conservation of Energy.

Continuity Equation

The law of Conservation of Mass expressed in the form of a differential equation is called the continuity equation. If we consider a control volume; then the conservation of mass can be interpreted as the rate of mass leaving an elemental volume minus the mass entering the same volume is equal to the rate of change of mass in the control volume which is equal to the rate of change of density multiplied by the volume of the element.

For Unsteady flow, the continuity Equation can be written as

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \mathbf{V}) = 0$$

For Steady Flow, the above equation Reduces to:

$$\nabla.(\rho \mathbf{V}) = 0$$

Where, V is the Velocity and ρ is the Density.

Momentum Equation

The physical principle involved in the Momentum Equation is the Newton' Second Law of Motion according to which rate of change of Momentum= force.

The total rate of change of Momentum is made of:

- Rate of change of momentum inside the control volume
- The difference between momentum flux leaving and entering (i.e. net flux)

Therefore in differential form momentum equation can be written as

$$\frac{\partial(\rho u)}{\partial t} + \nabla.(\rho u\mathbf{V}) = -\frac{\partial p}{\partial x} + \rho f_x + (F_x)_{Viscous}$$

$$\frac{\partial(\rho v)}{\partial t} + \nabla.(\rho v\mathbf{V}) = -\frac{\partial p}{\partial y} + \rho f_y + (F_y)_{Viscous}$$

$$\frac{\partial(\rho w}{\partial t} + \nabla.(\rho w\mathbf{V}) = -\frac{\partial p}{\partial z} + \rho f_z + (F_z)_{Viscous}$$

Where, □ is the density, P is the pressure acting, V is the Velocity, u,v, w is the velocity vectors, F_x,F_y,F_z is the viscous force and f_x,f_y,f_z is the body force acting in the X-, Y- and Z- axis respectively.

These equations show a viscous flow and are also known as the Navier-Stokes Equation.

For an in-viscid flow, the equations become,

$$\nabla.(\rho u\mathbf{V}) = -\frac{\partial p}{\partial x}$$

$$\nabla.(\rho v\mathbf{V}) = -\frac{\partial p}{\partial y}$$

$$\nabla.(\rho w\mathbf{V}) = -\frac{\partial p}{\partial z}$$

Where, □ is the density, P is the pressure acting, V is the Velocity, u, v, w is the velocity vectors acting in the X-, Y- and Z- axis respectively.

These equations are known as the Euler's Equations.

Energy Equation

The physical principle involved in the energy equation is that; Energy can neither be created nor be destroyed.

Therefore,

Energy equation is given as

$$\frac{\partial}{\partial t}\left[\rho\left(e+\frac{V^2}{2}\right)\right] + \nabla.\left[\rho\left(e+\frac{V^2}{2}\right)\mathbf{V}\right]$$
$$= p\dot{q} - \nabla.(p\mathbf{V}) + \rho(\mathbf{f}.\mathbf{V}) + \dot{Q}'_{Viscous} + \dot{W}'_{Viscous}$$

Where, □ is the density, P is the pressure acting, V is the Velocity, e is the internal energy of the system, Q is the viscous heat source or sink, W is the viscous work done and f is the body force acting on the system. The above equation is a partial differential equation which relates the flow field variables at a given point in space.

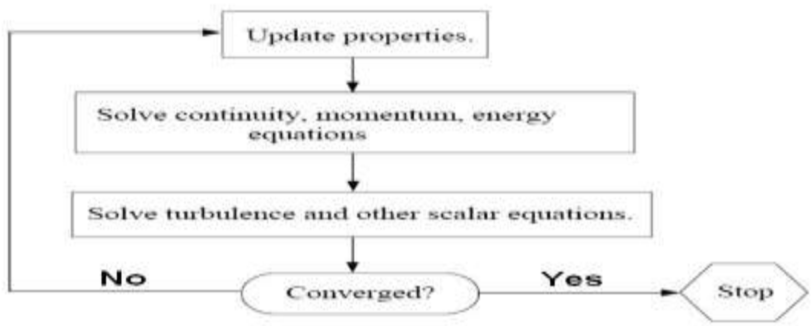

Fig. 3. Overview of the Coupled Solution Method

THEORITICAL CALCULATIONS

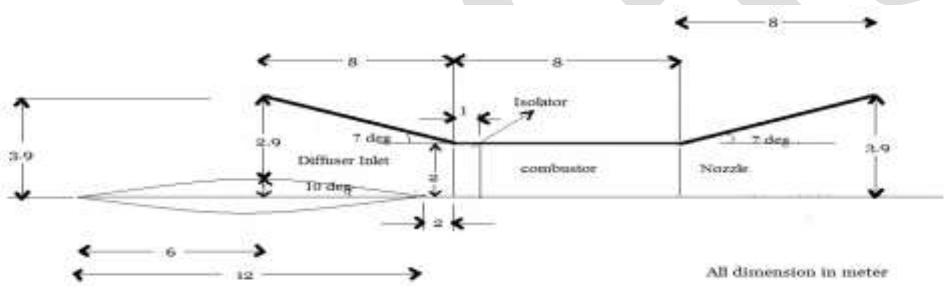

Fig. 4: Scramjet engine theoretical parameter

THEORY DESCRIPTION

The starting mach number of this engine is 5; at the corner cone section creates the oblique shock in front the engine. According to the shock, the mach value is reducing to 4 at the diffuser inlet. Using the area-mach number relation the mach value is decreasing to the diffuser section because of the decreasing the area, at the diffuser exit the mach value is 3.1. The step of the decreasing mach value is shown in below diagram and theoretical calculations are given in below. Area ratio, pressure and temperature values are finding to the respective Mach number in using gas tables. In the isolator and combustion chamber mach value is same 3.1, because of constant area value. At the nozzle inlet the Mach number is 3.1, it also increasing for increasing the divergent area section. In the divergent exit or nozzle exit Mach number value is increasing to 4.7 for according to the theoretical calculation. Pressure and temperature values are finding to the same gas tables.

EFFECT OF OBLIGUE SHOCK FORMATION IN CORNER OF THE CONE SECTION

The effect of shock in cone section will reducing the Mach number value 5 to 4 in the engine using oblique shock in perfect gas table.

TABLE 1: EFFECT OF AN OBLIQUE SHOCK IN CONE SECTION

M_1	Θ	β	$\frac{P_2}{P_1}$	M_2
5	10	19.38	3.043	3.999

TABLE 2: PHYSICAL PARAMETER

RADIUS (m)	**AREA** (m^2)	$\frac{A}{A^*}$	**M**	$\frac{P}{P_\circ}$	$\frac{T}{T_\circ}$	**P** (pa)	**T** (k)
2.90	26.40	10.71	4.0	0.0066	0.2381	668.74	71.43
2.65	22.00	8.96	3.8	0.0086	0.2572	871.39	77.16
2.47	19.21	7.81	3.6	0.0106	0.2729	1074.04	81.87
2.25	15.89	6.46	3.4	0.0141	0.2958	1428.68	88.74
2.00	12.56	5.10	3.1	0.0208	0.3309	2107.56	99.27
2.25	15.89	6.46	3.4	0.0141	0.2958	1428.68	88.74
2.80	24.61	10.00	3.9	0.0072	0.2446	729.54	73.38
3.40	36.29	14.75	4.4	0.0041	0.2083	415.43	62.49
3.90	47.75	19.41	4.7	0.0027	0.1846	273.57	55.38

SCRAMJET ENGINE SECTIONAL PARAMETER

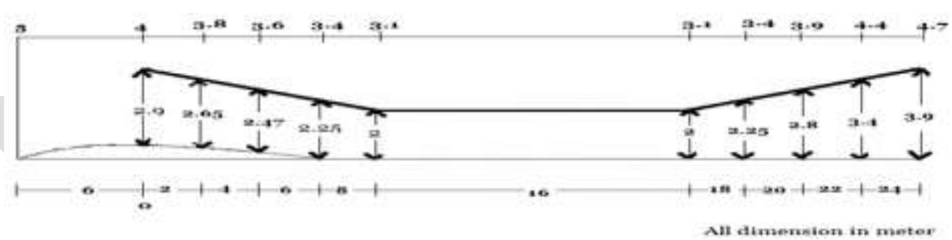

Fig. 5. Scramjet engine sectional parameter.

NUMERICAL ANALYSIS OF COLD FLOW IN 2 - D SECTION

SIMPLE PROBLEM DESCRIPTION

Initially, it is to analyze the simple 2-D section of scramjet engine is without front and back domain and cone. This scramjet engine consists of a convergent diffuser section, combustion chamber and divergent nozzle section. The engine has been designed using gambit software. Boundary conditions are applied in each section of the engine using gambit. Next this model meshed by appropriate mesh size and the mesh model is exported to the mesh option. This mesh model can be solved using fluent software in appropriate solving condition, until the results are converged. The convergent results are showed in the graphical formats according to the pressure, velocity and temperature along the position of the length of an engine. Here three types of convergent results can be analyzed in fluent convergent criteria according to the Mach number. That Mach numbers are 2, 3, 4 respectively. Above all the Mach number convergent results are given below. Changes occur as per the mesh size of the model.

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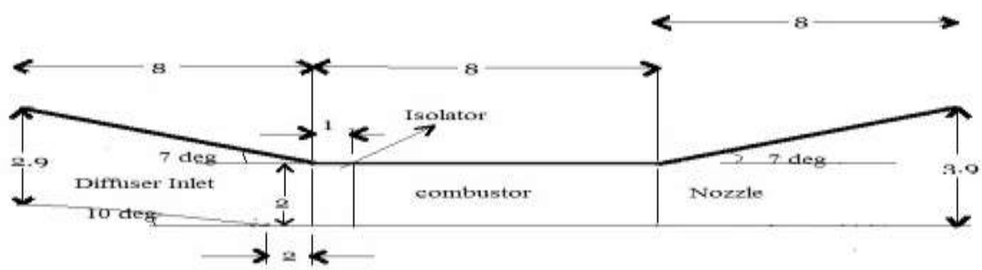
SIMPLE GEOMETRY OF 2-D SCRAMJET ENGINE



DESIGN OF THE SIMPLE SCRAMJET

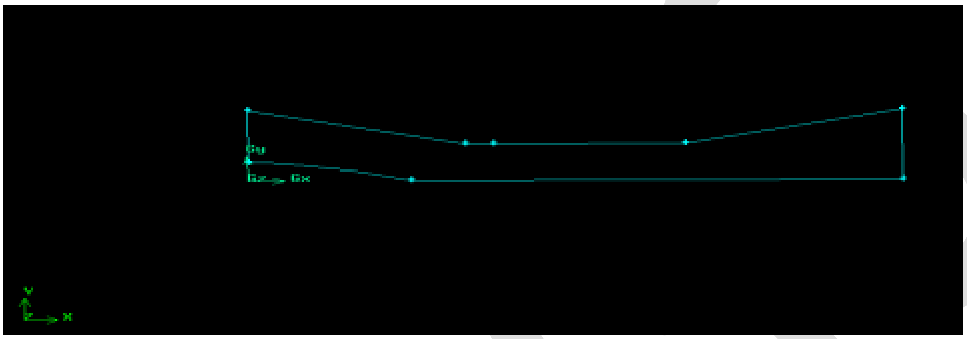


Fig. 6. Simple 2-D scramjet engine

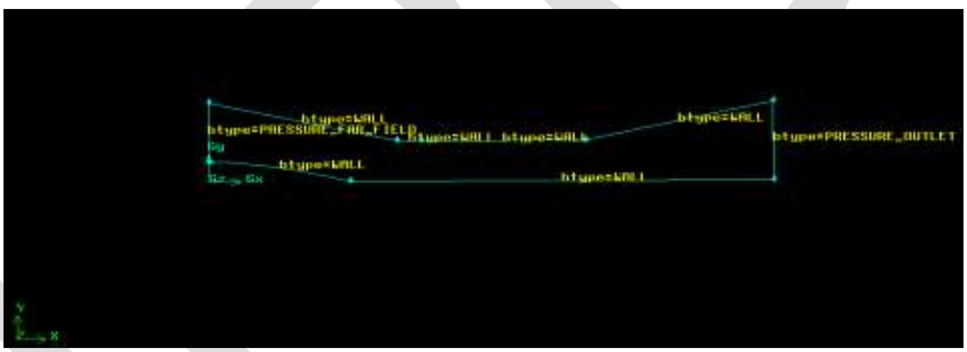


Fig. 7. Simple scramjet engines boundary condition

MESH MODEL OF SCRAMJET ENGINE WITHOUT CONE

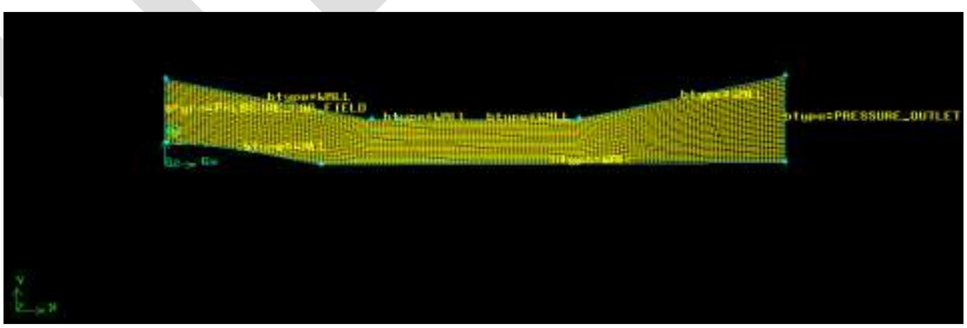


Fig. 8. Mesh size of 2-D section is 0.2.

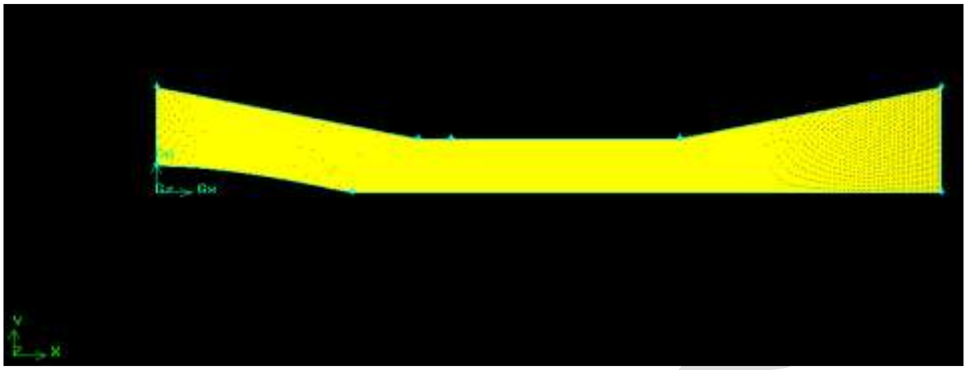


Fig. 9. Mesh size of 2-D section is 0.05

ANALYSIS IN FLUENT

PROCEDURE: (2D VERSION OF FLUENT)

➢ **FILE READ CASE**

The file channel mesh is selected by clicking on it under files and grid is checked.

➢ **GRID CHECK**

The grid was scaled to 1 in all x, y and z directions.

➢ **GRID SCALE**

The grid was displayed.

➢ **DISPLAY GRID**

Grid is copied in ms-word file.

➢ **DEFINE**

- **MODELS** **SOLVER**

  Solver is segregated

  Density based solver

  Implicit formulation

  Space 2-D

  Time steady

  ENERGY

  Energy equation

  VISCOUS MODEL

  K-epsilon

- **MATERIALS** **TYPE**

  Fluid

  FLUENT FLUID MATERIAL

  Air

  CONDITIONS

  Dynamic Viscosity, μ = 1.7894 x 10-5 kg/m-s

  Density, ρ = ideal gas

  Thermal Conductivity, K= 0.0242 W/m-K

  Specific heat, Cp= 1006.43 J/kg- K

- **OPERATING CONDITIONS**

Operating pressure= 101325 Pa

- **BOUNDARY CONDITIONS**

PARTS	CONDITION
Inlet	Pressure far field
Body	Wall
Outlet	Pressure outlet

➢ **SOLVE**

- **CONTROLS** **SOLUTIONS**

All energy equations are used.

Under relaxation factors

Pressure = 0.3

Density = 1

Body Force = 1

Momentum = 0 .7

- **INTIALIZE**

Compute form inlet

Temperature = 300 k

- **MONITOR**

Residual

- **ITERATE**

Convergence was checked.

➢ **PLOT XY PLOT**

Y AXIS - pressure, velocity and temperature

X AXIS - grid

1. X AXIS = X CO-ORDINATE
2. Y AXIS = Y CO-ORDINATE

Find the pressure, velocity, temperature and Mach number on line varying y co-ordinates with respect to x co-ordinates as length of an engine.

RESULTS AND DISCUSSIONS

MACH 2 INLET CONDITION RESULTS

CONTOUR RESULTS FOR MACH 2

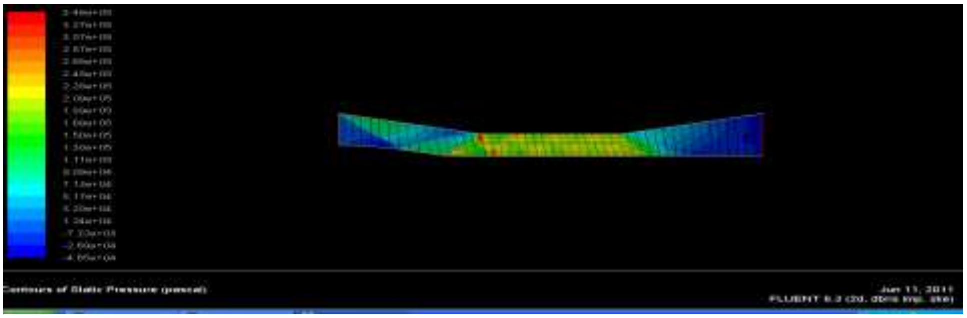


Fig. 10. Contours of pressure in Mach 2

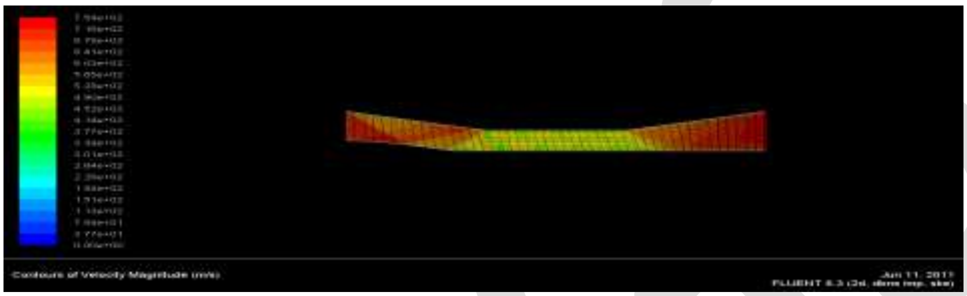


Fig. 11. Contours of velocity in Mach 2

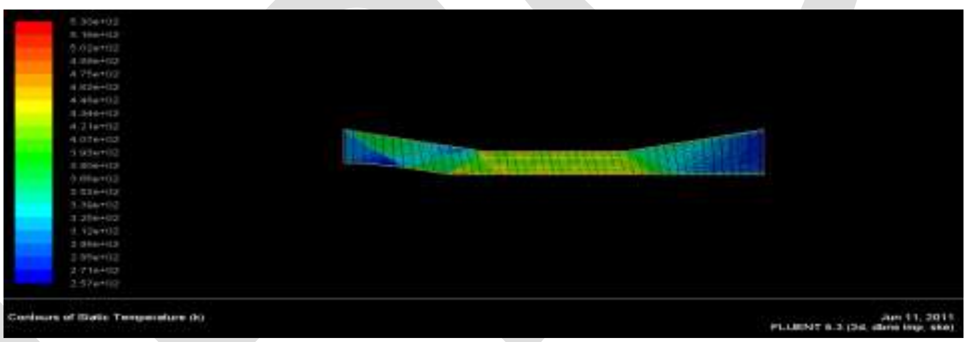


Fig. 12. Contours of Temperature in Mach 2

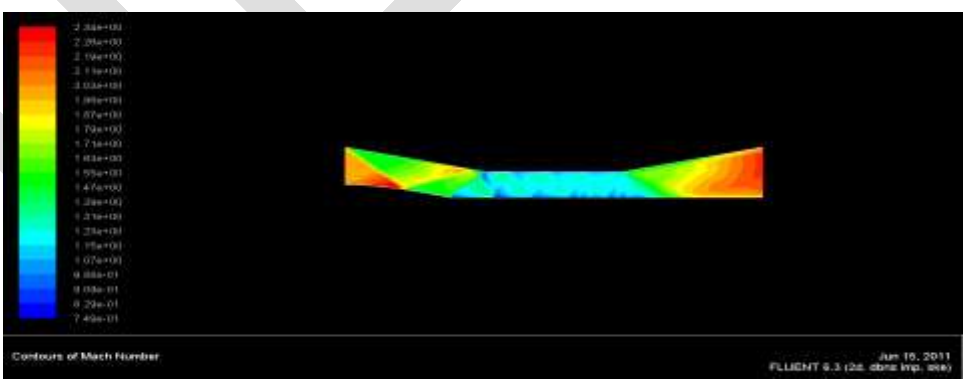


Fig. 13. Contours of Mach number in Mach 2.

Figure 10. The initial pressure value is assumed to be sea level condition. According to the contour, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped.

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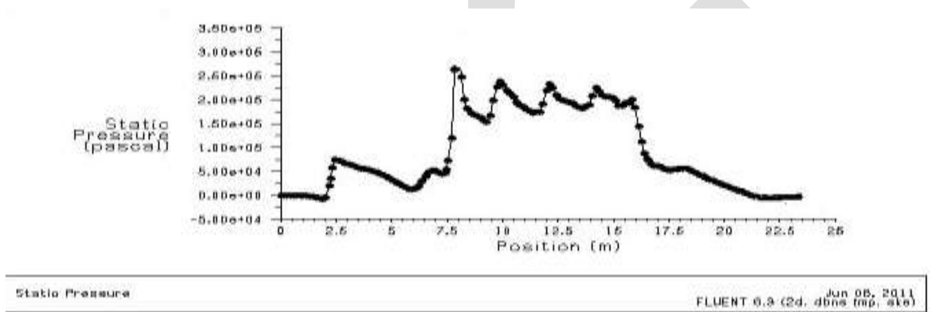
Figure 11 The initial velocity is assumed to be 600 m/s. According to the contour, in the diffuser section due to the area convergence the velocity is dropped. At the combustion chamber, the velocity remains constant because of the constant area. As the area is diverged at the final in nozzle section, the velocities are raised.

Figure 12. The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

Figure 13 .The initial Mach number is assumed to be 2. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

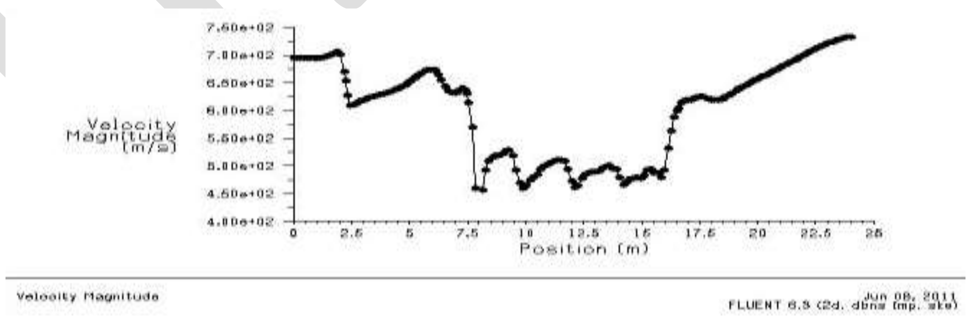
GRAPH FOR MACH 2

PRESSURE GRAPH FOR MACH 2



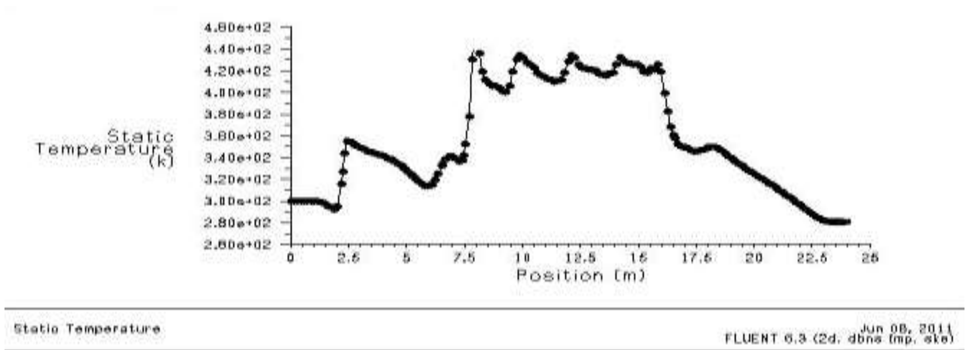
The initial pressure value is assumed to be sea level condition. According to the graph, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped. Because of the oscillations, Pressure raising and dropping are not in expected format. Since, it is due to an unsatisfied condition.

VELOCITY GRAPH FOR MACH 2



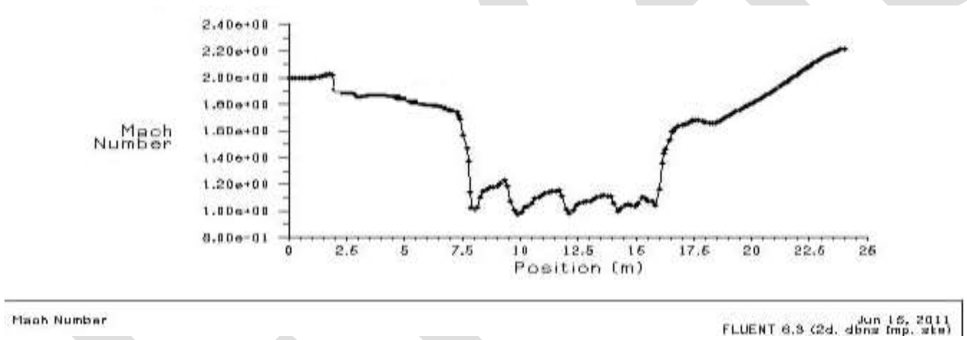
The initial velocity is assumed to be 600 m/s. According to the contour, in the diffuser section due to the area convergence the velocity is dropped. At the combustion chamber, the velocity remains constant because of the constant area. As the area is diverged at the final in nozzle section, the velocities are raised. Because of the oscillations, velocity raising and dropping are not in expected format. Since, it is due to an unsatisfied condition.

TEMPERATURE GRAPH FOR MACH 2



The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

MACH NUMBER GRAPH FOR MACH 2



The initial Mach number is assumed to be 2. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

MACH 3 INLET CONDITION RESULTS

CONTOUR RESULTS FOR MACH 3

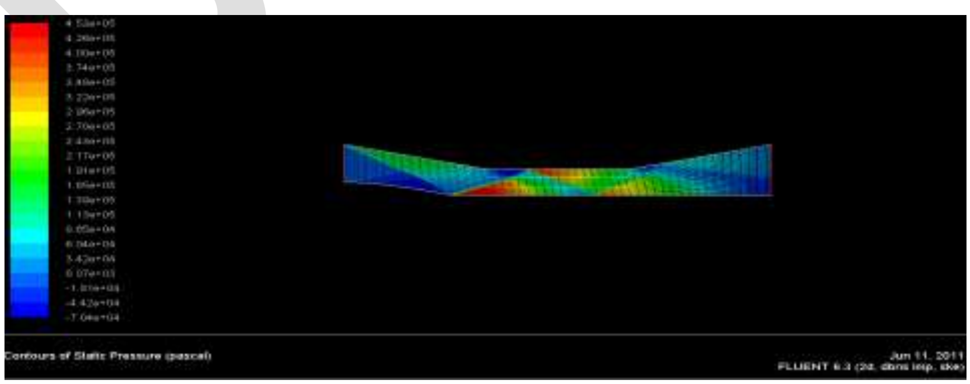


Fig. 14. Contours of pressure in Mach 3

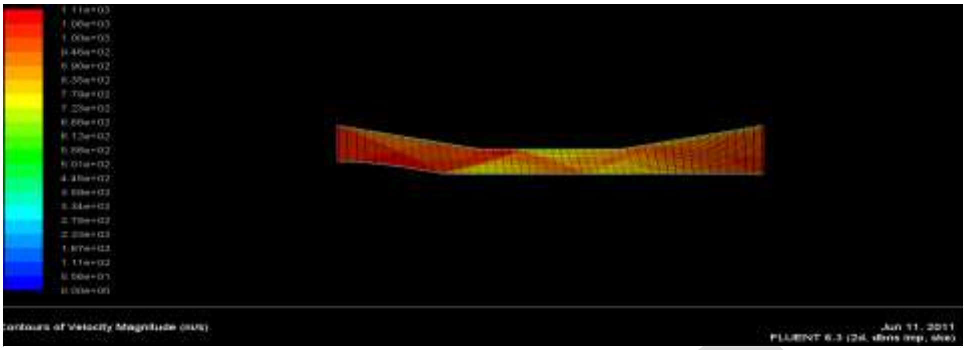


Fig. 15. Contours of velocity in Mach 3

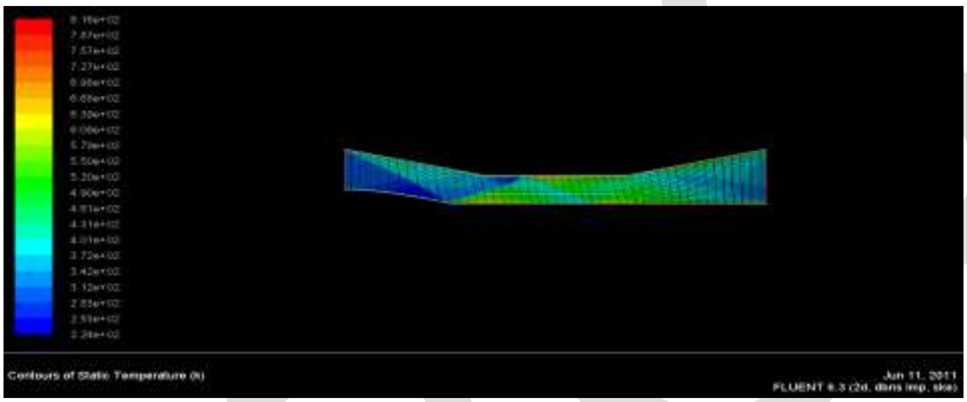


Fig. 16 Contours of Temperature in Mach 3

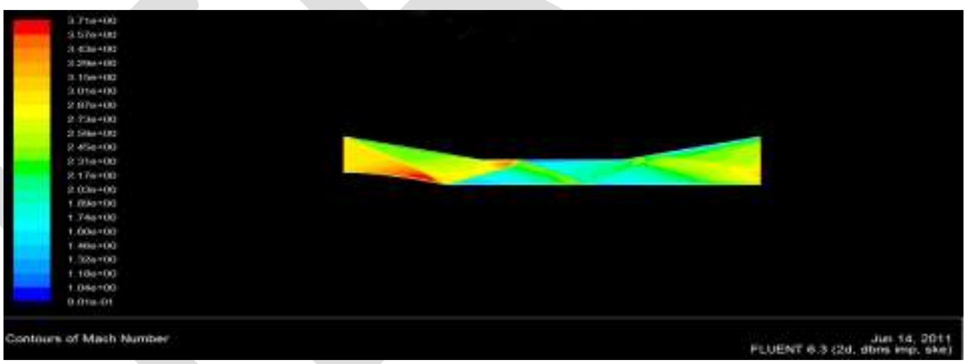


Fig. 17 Contours of Mach number in Mach 3

Figure 14. The initial pressure value is assumed to be sea level condition. According to the contour, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped.

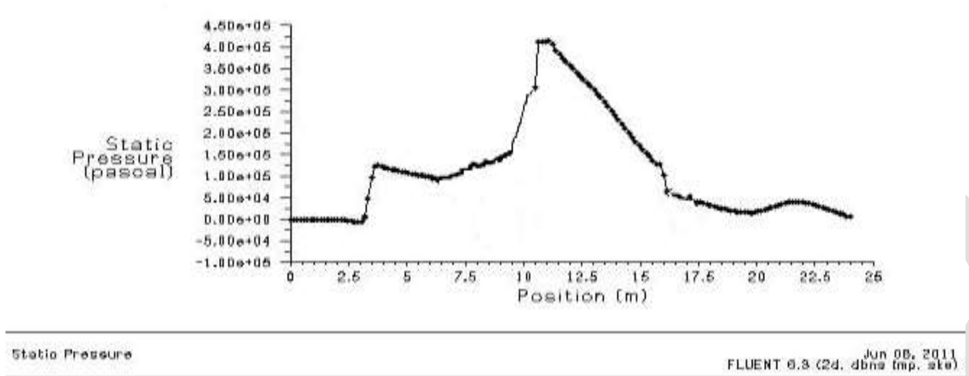
Figure 15. The initial velocity is assumed to be 912 m/s. According to the contour, in the diffuser section due to the area convergence the velocity is dropped. At the combustion chamber, the velocity remains constant because of the constant area. As the area is diverged at the final in nozzle section, the velocities are raised.

Figure 16. The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

Figure 17.The initial Mach number is assumed to be 3. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

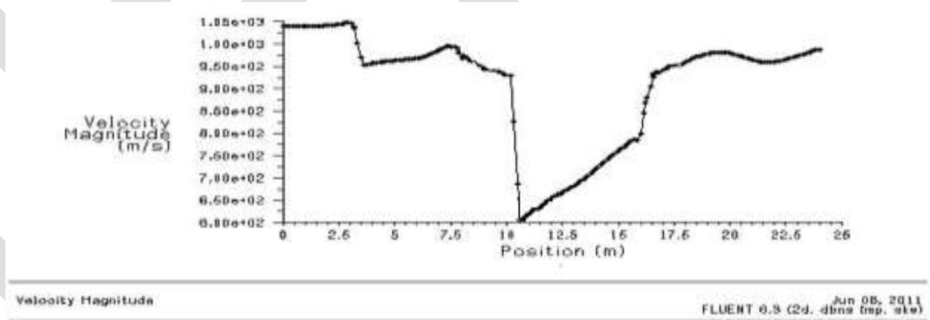
GRAPH FOR MACH 3

PRESSURE GRAPH FOR MACH 3



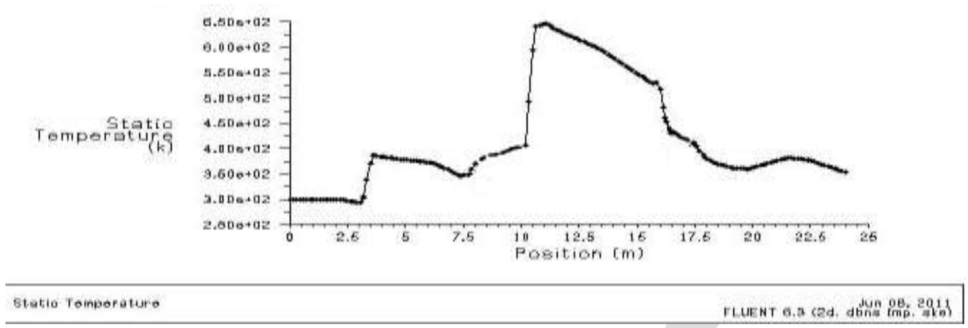
The initial pressure value is assumed to be sea level condition. According to the graph, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped. Because of the oscillations, Pressure raising and dropping are not in expected format. Since, it is due to an unsatisfied condition.

VELOCITY GRAPH FOR MACH 3



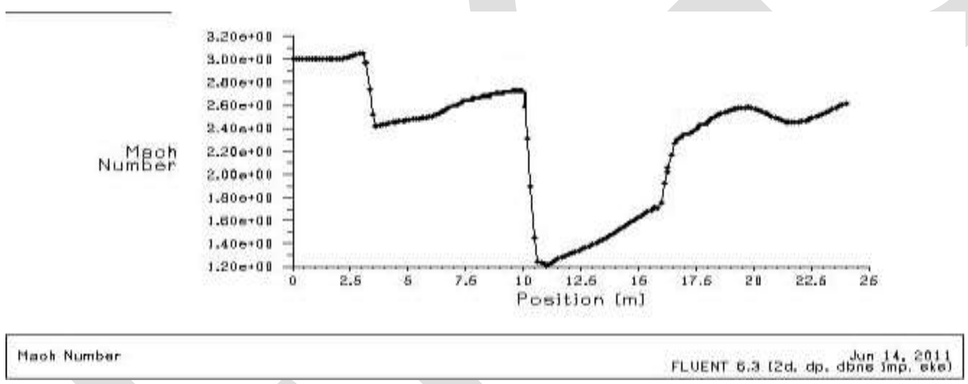
The initial velocity is assumed to be 1050 m/s. According to the contour, in the diffuser section due to the area convergence the velocity is dropped. At the combustion chamber, the velocity remains constant because of the constant area. As the area is diverged at the final in nozzle section, the velocities are raised. Because of the oscillations, velocity raising and dropping are not in expected format. Since, it is due to an unsatisfied condition.

TEMPERATURE GRAPH FOR MACH 3



The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

MACH NUBER GRAPH FOR MACH 3



The initial Mach number is assumed to be 3. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

7.3. MACH 4 INLET CONDITION RESULTS

7.3.1. CONTOURS FOR MACH 4

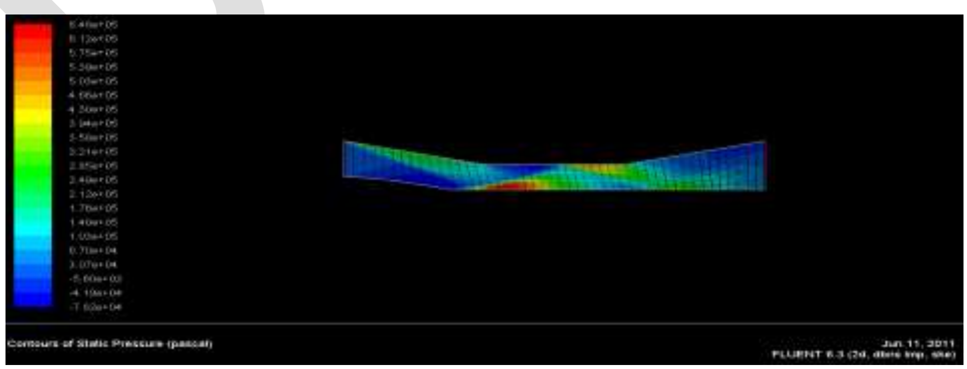


Fig. 18. Contours of pressure in Mach 4

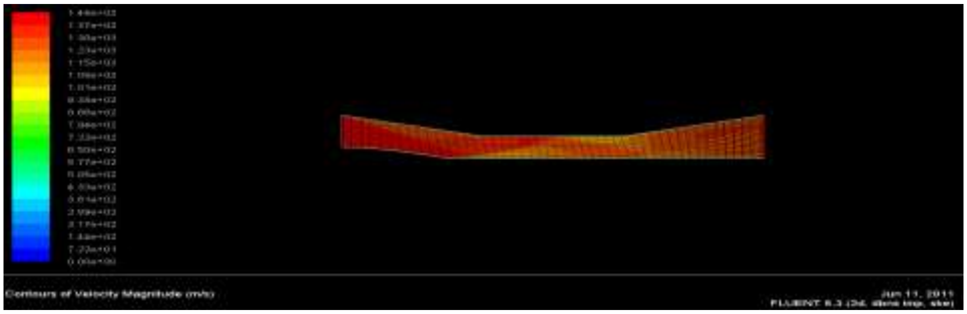


Fig. 19 Contours of Velocity in Mach 4

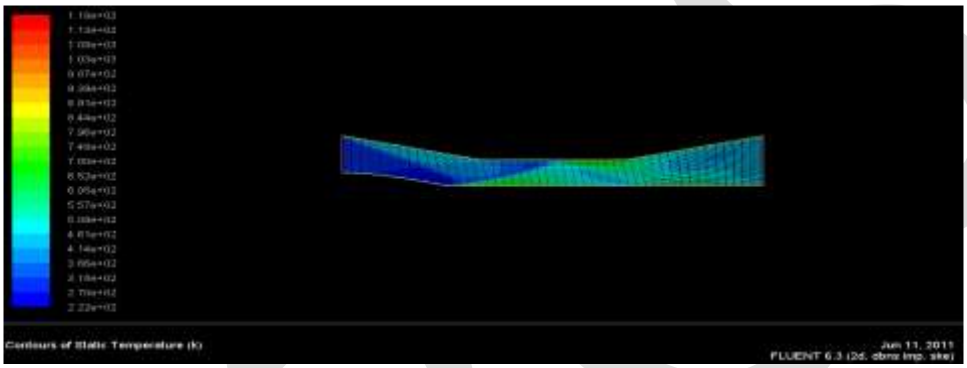


Fig. 20 Contours of Temperature in Mach 4

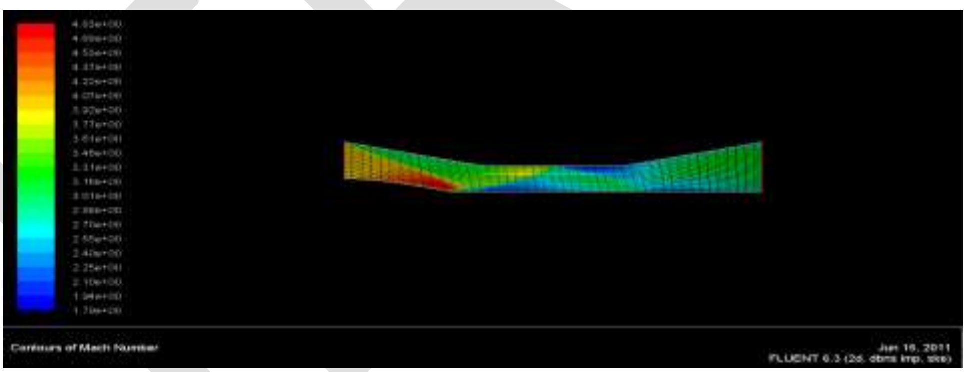


Fig. 21. Contours of Mach number in Mach 4

Figure 18. The initial pressure value is assumed to be sea level condition. According to the contour, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped.

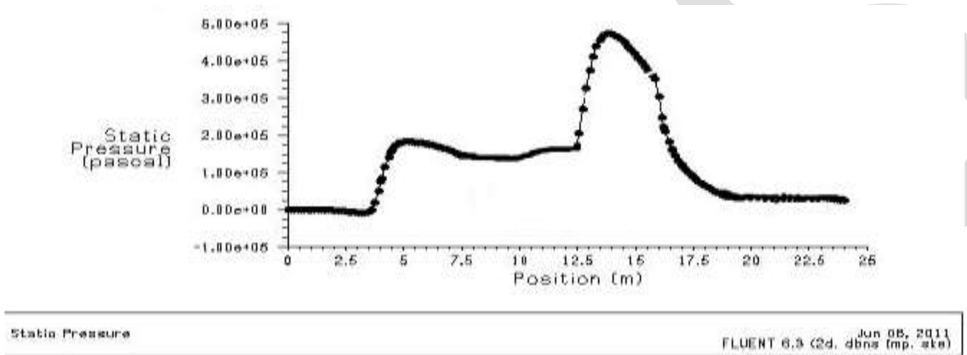
Figure 19 The initial velocity is assumed to be 1340 m/s. According to the contour, in the diffuser section due to the area convergence the velocity is dropped. At the combustion chamber, the velocity remains constant because of the constant area. As the area is diverged at the final in nozzle section, the velocities are raised.

Figure 20. The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

Figure 21.The initial Mach number is assumed to be 4. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

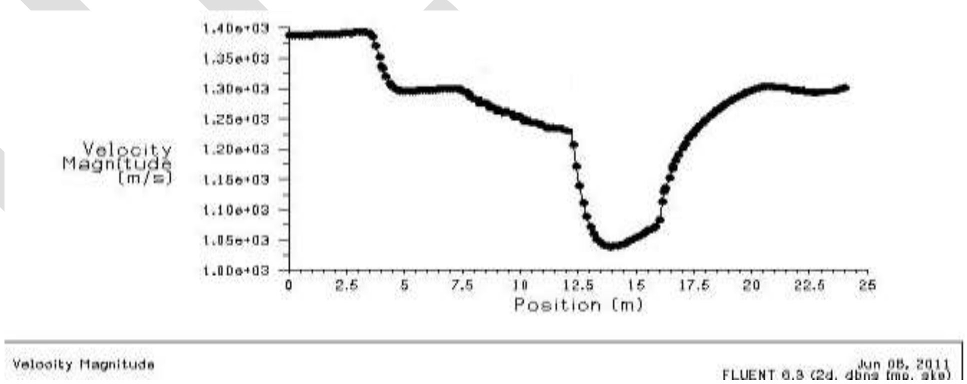
GRAPH FOR MACH 4

PRESSURE GRAPH FOR MACH 4



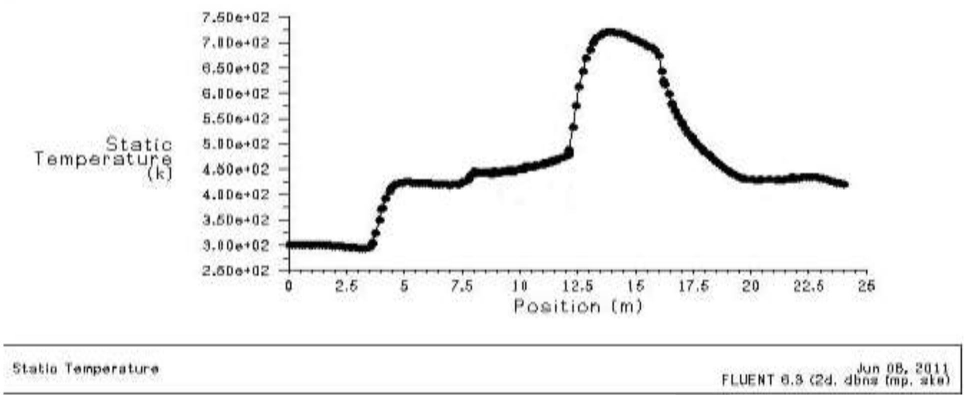
The initial pressure value is assumed to be sea level condition. According to the contour, in the diffuser section due to the area convergence the pressure is raised. At the combustion chamber, the pressure values remains constant because of the constant area. As the area is diverged at the final in nozzle section, the pressure values are dropped.

VELOCITY GRAPH FOR MACH 4



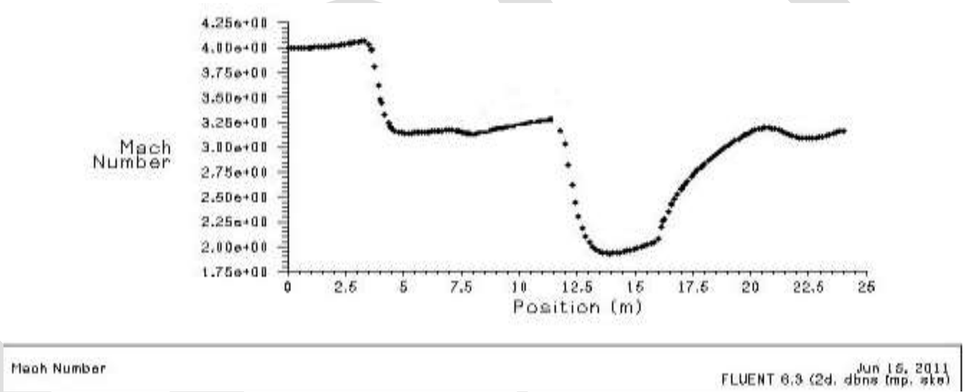
The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

TEMPERATURE GRAPH FOR MACH 4



The initial temperature value is assumed to be sea level condition. According to the contour, in the diffuser section due to the pressure raised, temperature value also raised. At the combustion chamber, temperature values remains constant because of the constant pressure. As the final in nozzle section, the temperature values are decreases to decrease the pressure value.

7.3.2.4. MACH NUMBER GRAPH FOR MACH 4



The initial Mach number is assumed to be 4. According to the contour, in the diffuser section due to the area convergence the Mach number is raised. At the combustion chamber, Mach number remains constant because of the constant area. As the area is diverged at the final in nozzle section, the Mach number is dropped.

MODIFICATION RESULTS IN MACH 4

PROBLEM DESCRIPTION

The results that have been found in above are not in expected form. This is due to an unsatisfied condition respectively. Their by, this drawback undergoes another check for an expected result. The parameter like boundary condition and viscous model has been changed. And again iterate this problem continuously, until the results are converged. Then convergent results are showed to the contour and graph format. This modification results are shown in below.

Changes made in viscous model- Spalart-Allamaras model.

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Changes made by boundary condition

PARTS	CONDITION
Inlet	Pressure far field
Body	Wall
Outlet	Pressure outlet
Symmetry	Axis

Here boundary conditions are different from above the section. Solver has been run in to the axi-symmetric condition.

Inlet condition:

Starting Mach number = 4

Temperature = 229 k

Gauge pressure = 100659 pa

Space = axi-symmetric

Density = ideal gas

MODIFICATION OF CONTOUR RESULTS FOR MACH 4

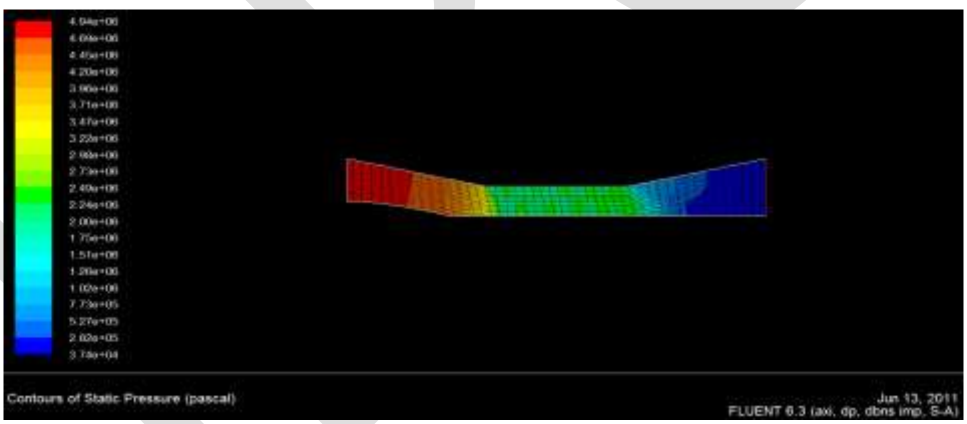


Fig.22. Modify Contours of pressure in Mach 4

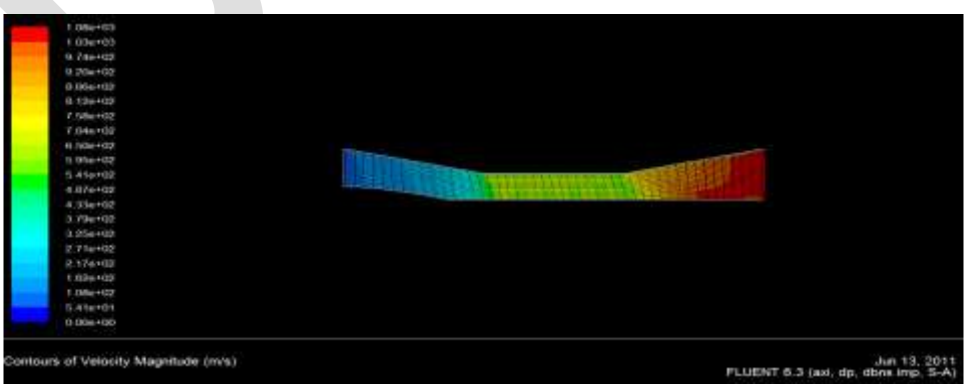


Fig.23. Modify Contours of Velocity in Mach 4

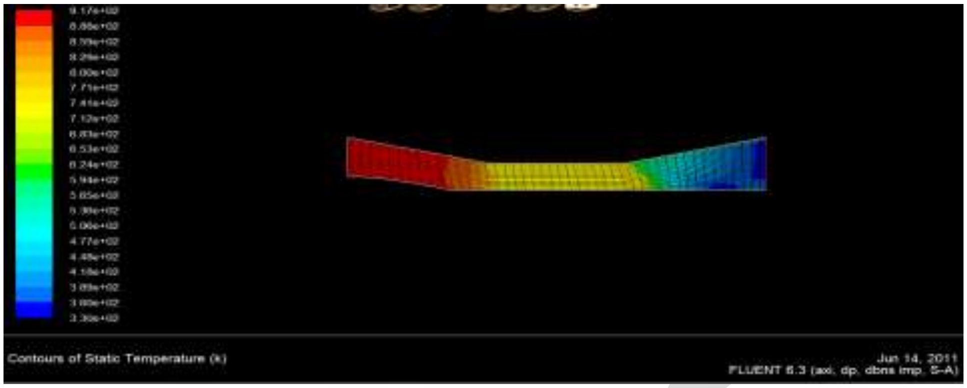


Fig.24. Modify Contours of Temperature in Mach 4

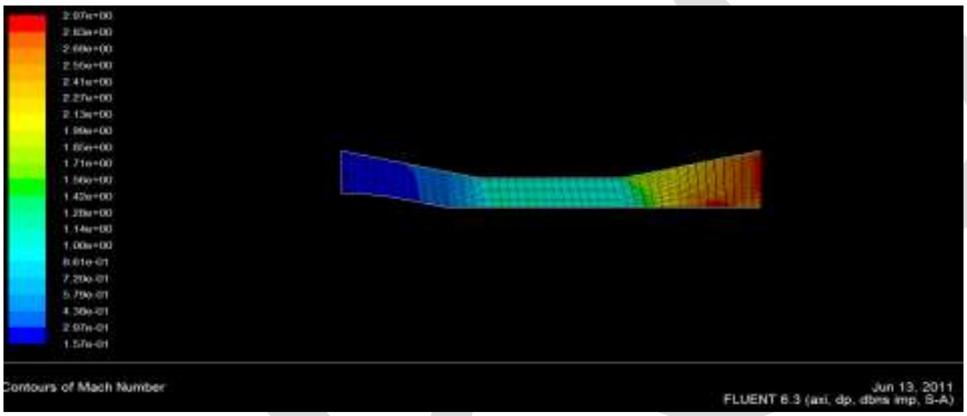


Fig.25. Modify Contours of Mach number in Mach 4

Fig.22. The air is passed through the scramjet engine without cone section. The initial pressure is assumed to be gauge pressure value; the pressure value is increased, when the air is passed out through the diffuser due to the convergent of area section. At combustion chamber the pressure value is remains constant, at the constant area section. Again the value gets decreased as the area gets diverged.

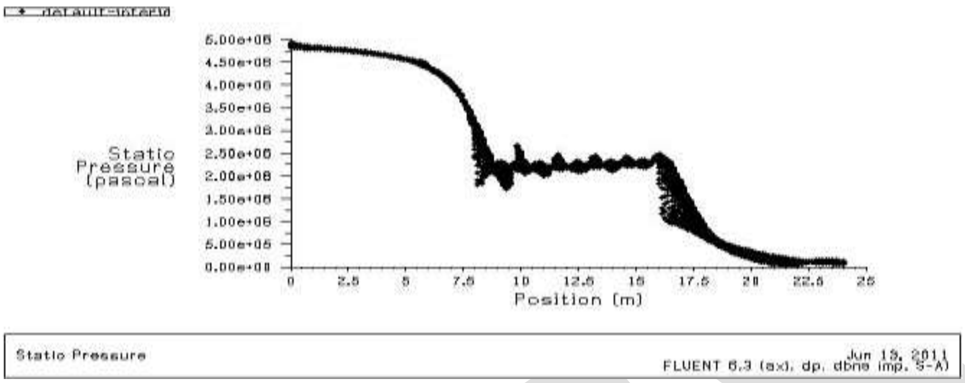
Fig. 23 Initially, the velocity is assumed to be 1340 m/s, the velocity is converged when the air is passed out through the diffuser section. The velocity is decreases as the area gets converged. At combustion chamber velocity becomes constant at the constant area section. Again the value gets increased as the area gets diverged.

Fig. 24 The air is passed through the scramjet engine without cone section. The initial temperature is assumed to be 229 K, Here temperature must be increased, when the air is passed out through the diffuser due to the increase in pressure. At combustion chamber the temperature value is remains constant, at the constant pressure. Again this value gets decreased as the pressure gets decreased.

Fig. 25The air is passed through the 2-D scramjet engine without cone section. The initial condition of the Mach number is assumed to be value 4; the Mach number is converged when the air is passed out through the diffuser section. The Mach number decreases as the area gets converged. At combustion chamber the Mach number becomes constant at the constant area section. Again the value gets increased as the area gets diverged.

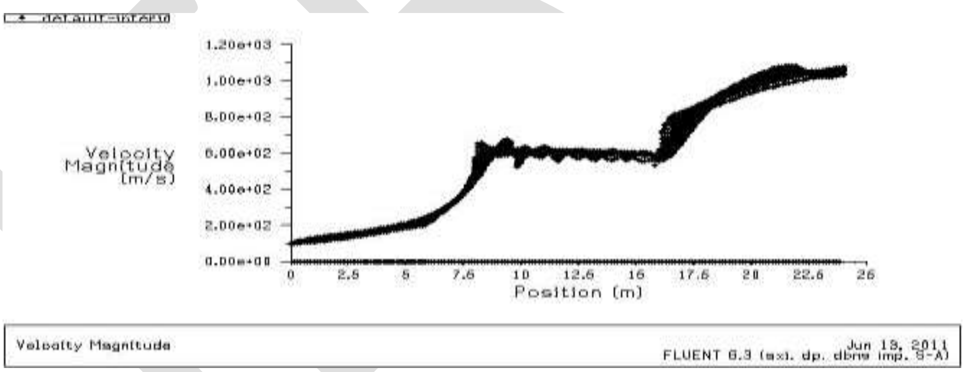
GRAPH RESULTS

PRESSURE GRAPH



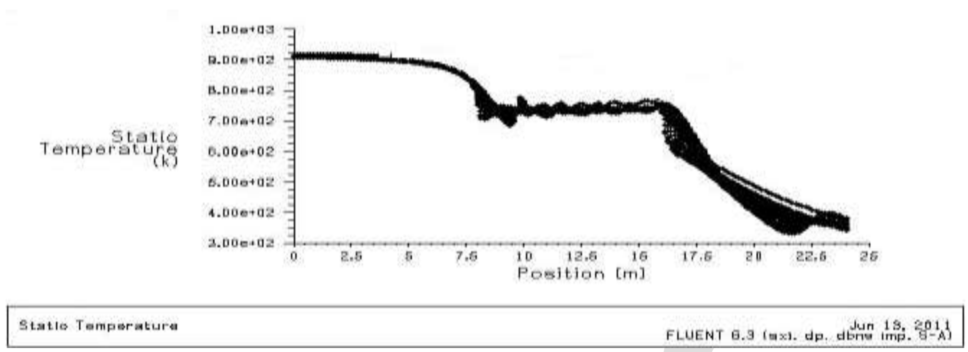
The air is passed through the scramjet engine without cone section. The initial pressure is assumed to be gauge pressure value; the pressure value is increased, when the air is passed out through the diffuser due to the convergent of area section. At combustion chamber the pressure value is remains constant, at the constant area section. Again the value gets decreased as the area gets diverged. The draw back specified here is that the assumed pressure value is gauge pressure, but the value considered by the software is different and occurs in higher value. This non convergence result of the diffuser section is alone showed in the above graph and this is considered to be main draw back of the proposed system.

VELOCITY GRAPH



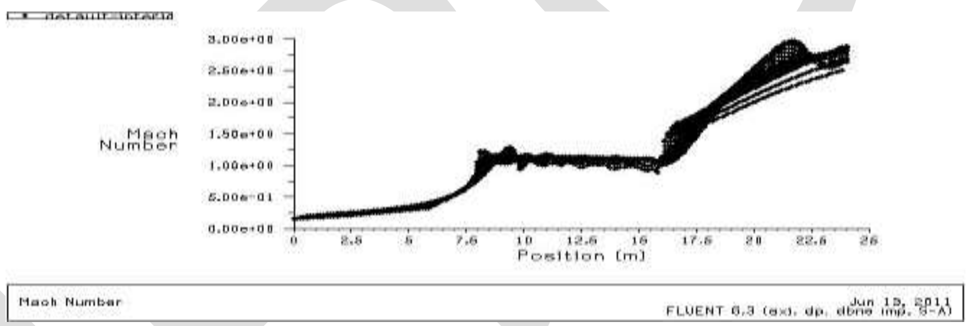
Initially, the velocity is assumed to be 1340 m/s, the velocity is converged when the air is passed out through the diffuser section. The velocity is decreases as the area gets converged. At combustion chamber velocity becomes constant at the constant area section. Again the value gets increased as the area gets diverged. . The draw back specified here is that the assumed velocity is 1340 m/s, but the value considered by the software is different and occurs in low value. This non convergence result of the diffuser section is alone showed in the above graph and this is considered to be main draw back of the proposed system.

TEMPERATURE GRAPH



The air is passed through the scramjet engine without cone section. The initial temperature is assumed to be 229 K; Here, temperature must be increased, when the air is passed out through the diffuser due to the increase in pressure. At combustion chamber the temperature value remains constant, at the constant pressure. Again this value gets decreased as the pressure gets decreased. The draw back specified here is that the assumed temperature is229 K, but the value considered by the software is different and occurs in higher value. This non convergence result of the diffuser section is alone showed in the above graph and this is considered to be main draw back of the proposed system.

MACH NUMBER GRAPH:



The air is passed through the 2d scramjet engine without cone section. The initial condition of the Mach number is assumed to be value 4, the mach number is converged when the air is passed out through the diffuser section. The Mach number decreases as the area gets converged. At combustion chamber the Mach number becomes constant at the constant area section. Again the value gets increased as the area gets diverged. The draw back specified here is that the assumed Mach number is 4, but the value considered by the software is different and occurs in negative value. This non convergence result of the diffuser section is alone showed in the above graph and this is considered to be main draw back of the proposed system.

CONCLUSION

The project has been successfully accomplished, where as partial results are produced. Despite of variation made in Mach number and mesh size of model. The results where found to be unexpected form**,** Because of an unsatisfied condition. So again further changes made in boundary condition and viscous model. Compare to the previous analysis, the project was found to better results. But these results are not in an expected form. Some few draw back is there. The draw back specified here is that the assumed Mach number is 4, but the value considered by the software is different and gets in negative value. The diffuser section is alone showed non Convergence results. This is considered to be main draw back of the proposed system.

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