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DESIGN OPTIMIZATION AND CFD ANALYSIS OF A SCRAMJET ENGINE WITH DIFFERENT MACH NUMBERS

MIYYAPURAM.HARISH[1*], DR E.SURENDAR [2] N.SURESH [3]

[1]M.Tech, Student, *Department of Mechanical Engineering, Warangal Institute of technology and science, Warangal-506342, India*

[2]*Assisociate professor, Department of Mechanical Engineering, Warangal Institute of technology and science, Warangal-506342, India*

[3]*Assistant professor, Department of Mechanical Engineering, Warangal Institute of technology and science, Warangal-506342, India*

Abstract:
In this thesis, Generally a Scramjet Engine starts at a hypersonic frees stream Mach no. 5.00. In order to propel to those speeds, we use turbojet engines which propel to around 3.00-4.00 Mach and from there the ramjet picks upon and starts to propel to start the scramjet engine. If we increasing the scramjet engine starting Mach number to say 3.0,5.0,7.0 and 9.0.

We can eliminate one propulsion engine, i.e., ramjet engine and thus reducing weight and complexity. The design for such a scramjet engine is carried out in this project considering only the inlet designs and the flow analysis is carried out in CFD. FLUENT is used to cover the flow analysis.

Keywords:CAD, CREO,CFD AND FEM,

1. INTRODUCTION

A scramjet (supersonic combusting ramjet) is a variant of a ramjet airbreathing jet engine in which combustion takes place in supersonic airflow. As in ramjets, a scramjet relies on high vehicle speed to forcefully compress the incoming air before combustion (hence ramjet), but a ramjet decelerates the air to subsonic velocities before combustion, while airflow in a scramjet is supersonic throughout the entire engine. This allows the scramjet to operate efficiently at extremely high speeds.

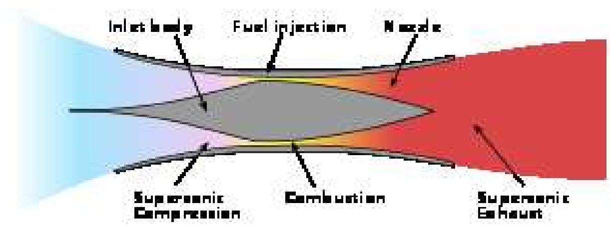


Fig.1.1 Scram jet combustion chamber before 2000.

2. LITERATURE SURVEY

[1] Analysis and design of a hypersonic scramjet engine with a starting mach number 4.00

When pressures and temperatures become so high in supersonic flight that it is no longer efficient to slow the oncoming flow to subsonic speeds for combustion, a scramjet (supersonic combustion ramjet) is used in place of a ramjet. Currently, the transition to supersonic combustion generally occurs at a free stream Mach number around 5.0 to 6.0. This research details analysis completed towards extending scramjet operability to lower Mach numbers, while maintaining performance at higher Mach numbers within the same flow path as detailed in the Air Force solicitation AF073-058. The specific goal is to determine whether the scramjet starting Mach number can be lowered to Mach 3.50 and, if not, what the constraints are that prohibit it and what the lowest possible starting Mach number for a scramjet is with today's technology. This analysis has produced many significant insights into the current and required vii capabilities for both fuel and overall engine design in lowering the starting Mach number; these results are presented here. The analysis has shown that a scramjet with a starting Mach number of 3.50 is not currently possible with the fuels researched unless fuel additives or another addition to the system are used. However, a scramjet with a starting Mach number of 4.00 is possible with today's existing technology. This paper has designed the engine flowpath for this case; its specifications and resulting performance are also detailed here.

INTRODUCTION TO CAD

3.1 Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

INTRODUCTION TO CREO

3.2 CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

INTRODUCTION TO FINITE ELEMENT METHOD

FEM/FEA helps in evaluating complicated structures in a system during the planning stage. The strength and design of the model can be improved with the help of computers and FEA which justifies the cost of the analysis. FEA has prominently increased the design of the structures that were built many years ago.

4.2 INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows.

RESULTS AND DISCUSSION

CFD ANALYSIS OF SCRAMJET INLET
5.1 CONDITION-SINGLE RAMP
CASE ANGLE-10^0
MACH NUMBER-3.0

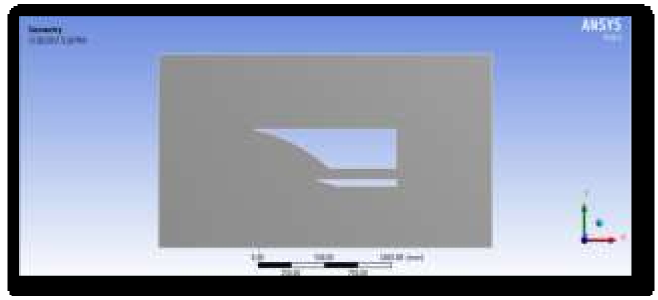


Fig5.1 single ramp part modelling component

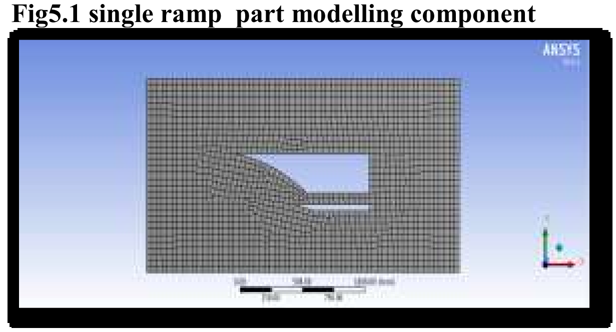


Fig5.2 single ramp meshed modeling part component

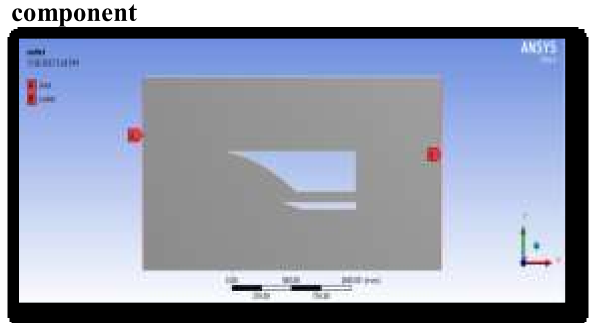
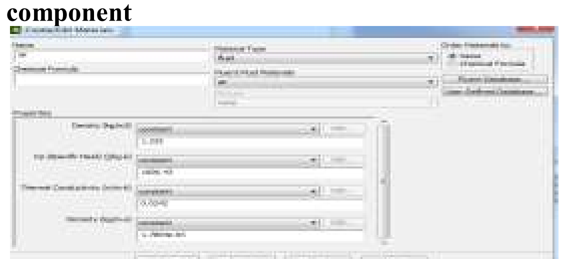


Fig 5.3 boundary couditions of the part component



5.1.1(a) MACH NUMBER-3.0

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PRESSURE

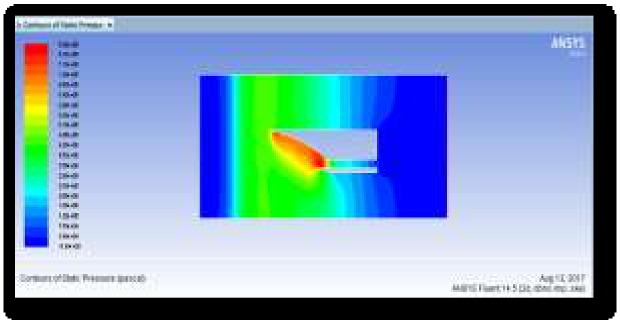

Fig5.4(a) pressure of the single ramp at 10° of mach number 3.0

According to the counter plot ,the maximum pressure at inlet of the scram jet because of boundary conditions at inlet and minimum pressure at edges.

MACH NUMBER

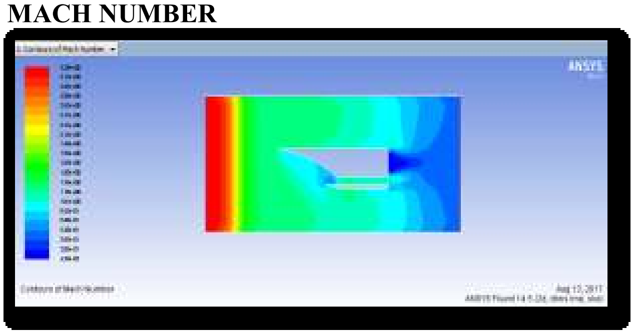

Fig5.4(b) Velocity of the single ramp at 10° of mach number 3.0

According to the counter plot ,the maximum mach number at inlet of the scram jet because of boundary conditions at inlet and minimum mach number at outlet.

TEMPERATURE

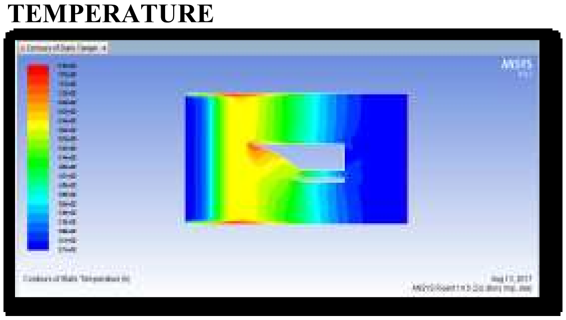

Fig5.4(c) Temperature of the single ramp at 10° of mach number 3.0

According to the counter plot ,the maximum temperature at scram jet edges because of boundary conditions at inlet and minimum temperature at boundary .

TURBULENCE INTENSITY

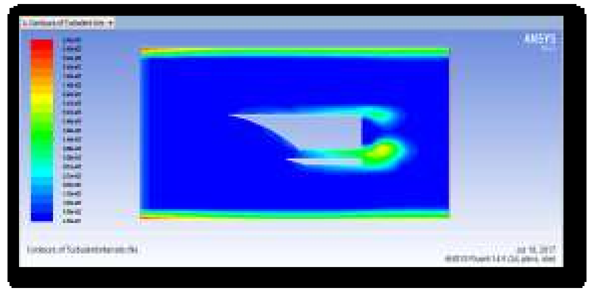

Fig5.4(d) Turbulance of intensity of the single ramp at 10° of mach number 3.0

According to the counter plot,the maximum turbulence at outlet of the scram jet because of boundary conditions at inlet and minimum turbulence at boundary.the maximum velocity is 9.50+03 and minimum is 4.36e+01.

DENSITY

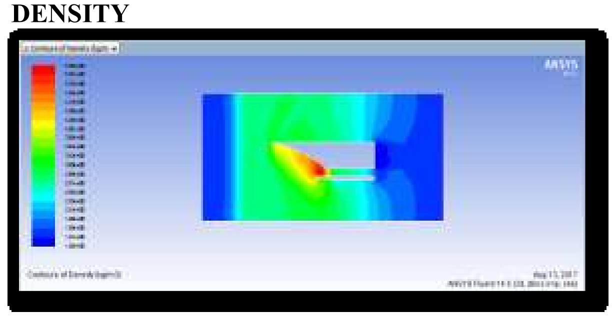

Fig5.4(e) Density of the single ramp at 10° of mach number 3.0

According to the counter plot, the maximum density at outlet of the scram jet because of boundary conditions at inlet and minimum density at boundary.

5.1.1(b) MACH NUMBER-5.0

PRESSURE

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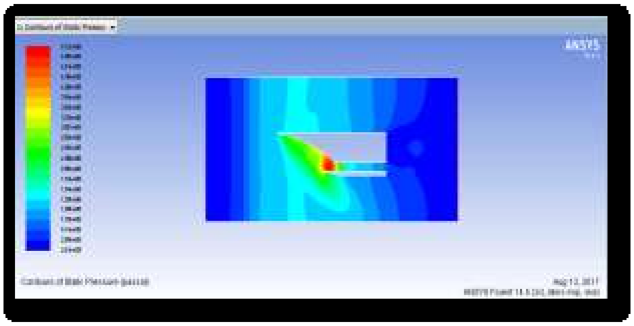

Fig5.5(a) Pressure of the single ramp at 10° of mach number 5.

MACH NUMBER

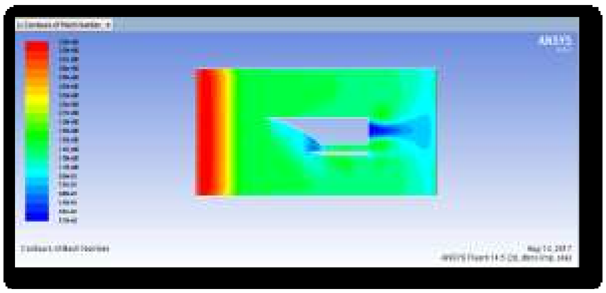

Fig5.5(b) Velocity of the single ramp at 10° of mach number 5.0

TEMPERATURE

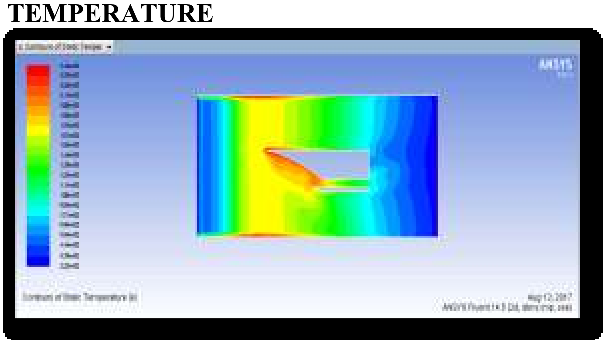

Fig5.5(c) Temperature of the single ramp at 10° of mach number 5.0

TURBULENCE INTENSITY

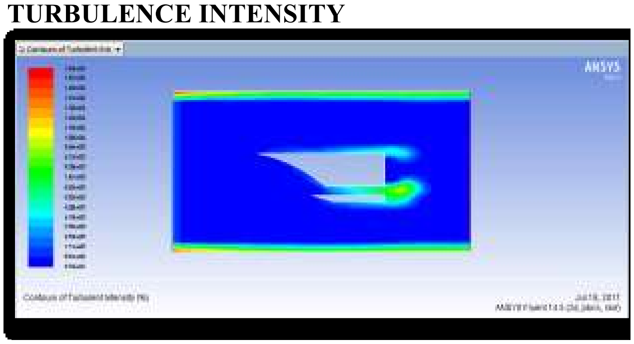

Fig5.5(d) Turbulance intensity of the single ramp at 10° of mach number 5.0

DENSITY

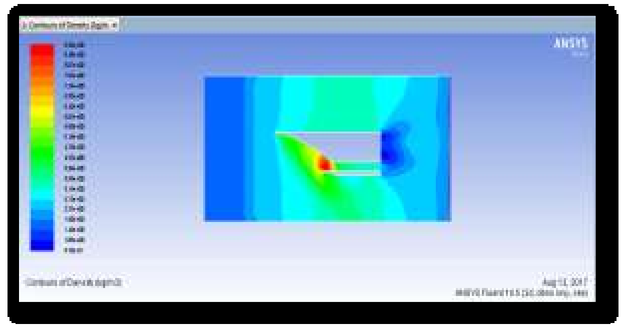

Fig5.5(e) Density of the single ramp at 10° of mach number 5.0

5.2 CONDITION-DOUBLE RAMP

CASE -ANGLE-10^0

MACH NUMBER-3.0

IMPORTED MODEL

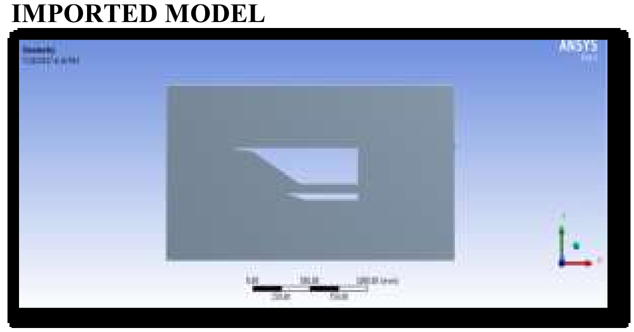

Fig.5.12 Double ramp part modeling component

MESHED MODEL

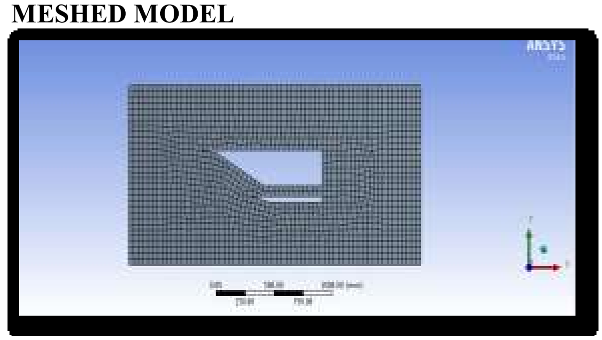

Fig.5.13 Double ramp meshed part modeling component

5.2.1(a)MACH NUMBER 3.0

PRESSURE

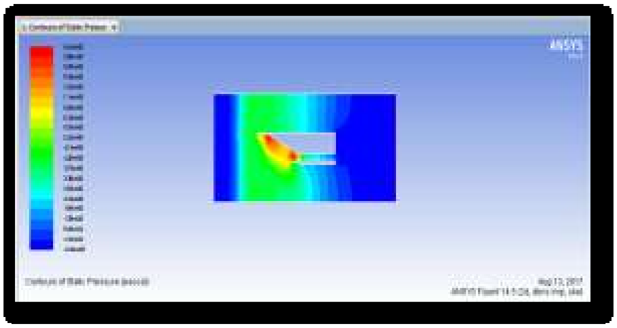

Fig5.14(a) Pressure of the double ramp at 10° of mach number 3.0

MACH NUMBER

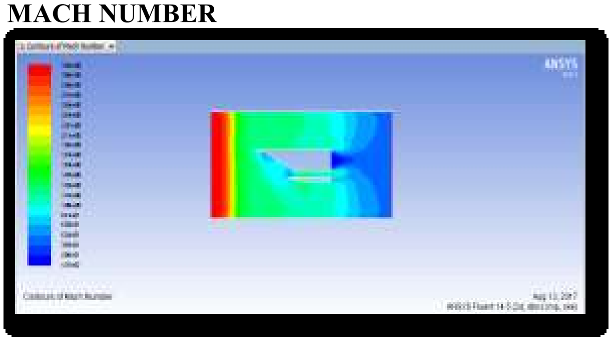

Fig5.14(b) Velocity of the double ramp at 10° of mach number 3.0

TEMPERATURE

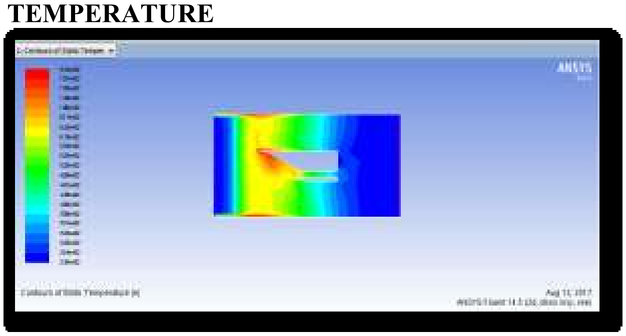

Fig5.14(c) Temperture of the double ramp at 10° of mach number 3.0

DENSITY

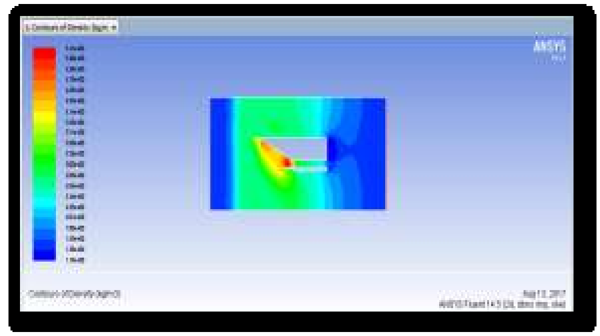

Fig5.14(d) Density of the double ramp at 10° of mach number 3.0

5.2.1(b) MACH NUMBER-5.0

PRESSURE

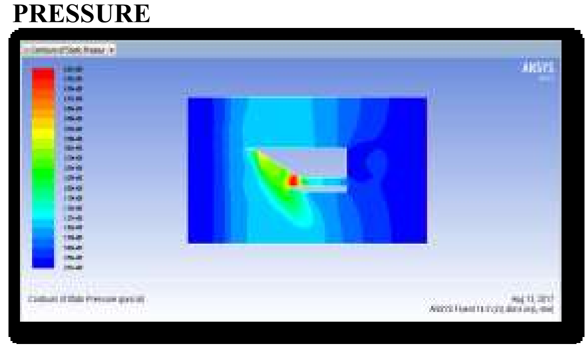

Fig5.15(a) Pressure of the double ramp at 10° of mach number 5.0

MACH NUMBER

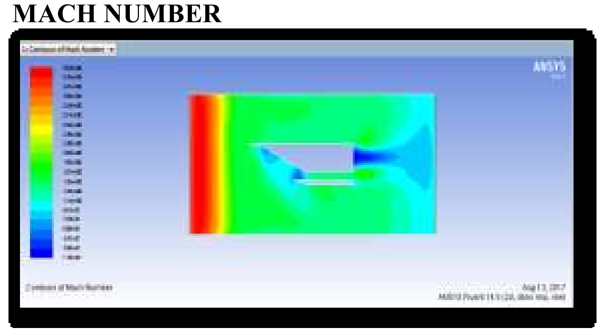

Fig5.15(b) Velocity of the double ramp at 10° of mach number 5.0

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TEMPERATURE

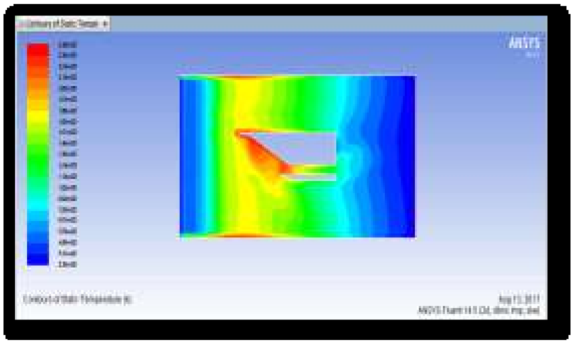


Fig5.15(c) Temperature of the double ramp at 10° of mach number 5.0

DENSITY

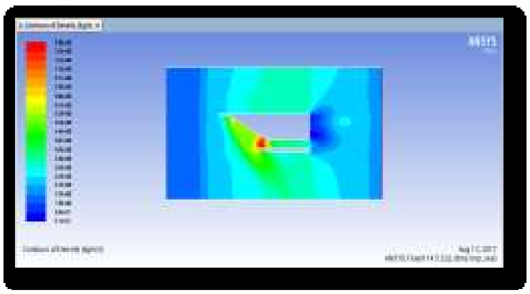


Fig5.15(d) Density of the double ramp at 10° of mach number 5.0

RESULT TABELS

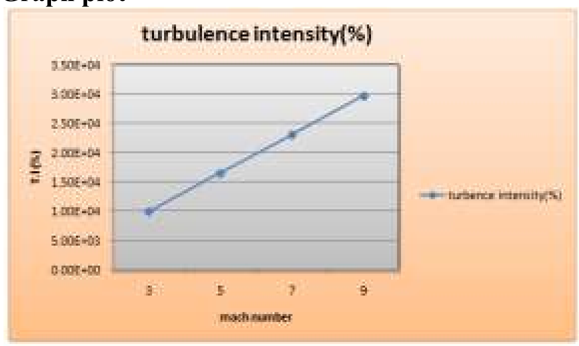
CONDITION-SINGLE RAMP AT 10^0

Ramp angle (^{0})	Mach number	Pressure (pa)	Mach number	Temperature (k)	Density (kg/m^3)
10	3	8.59e+05	3.28e+00	8.10e+02	5.59e+00
	5	5.12e+06	3.56e+00	2.44e+03	8.89e+00

CONDITION-DOUBLE RAMPAT 10^0

Ramp angle (^{0})	Mach number	Pressure (pa)	Mach number	Temperature (k)	Density
10	3	9.54e+05	3.22e+00	8.16e+02	5.41e+00
	5	5.07e+06	3.63e+00	2.46e+03	8.30e+00

Graph plot



Mach number v/s turbulence intensity(%)

CHAPTER 6

CONCLUSION

In this thesis, to determine which model is best when compared to other model (single & double ramp) at ramp angles(10^0 and 12^0) with Mach numbers. Hence, a Scramjet engine was then modeled in CREO and analysis was carried out in CFD for the same with different design models.

Among all designs, a design with single ramps at angle 12^0 yielded better results than the other designs. By this Analysis we can conclude the "Komega turbulence model exactly simulates the flow field characteristics in hypersonic conditions" in capturing shocks at leading edges.The result obtained in the present study and its analysis is applicable only to a similar or a congruent geometry to the geometry that has been proposed in this work.

The mach number increases ,increasing the turbulence intensity ,pressure and Mach number.

So we can conclude that higher mach number and single ramp model with angle 12^0.

CHAPTER 7

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