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CFD Analysis of a Rocket Nozzle withFour Inlets at Mach 2.1.

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ABSTRACT

In this work CFD investigation of weight and temperature for a rocket spout with four channels at Mach 2.1 is examined with the assistance of familiar programming. at the point when the fuel and air enter in the ignition chamber as indicated by the x and y plot, it is smoldering because of high speed and temperature and afterward temperature increments quickly in burning chamber and joined a portion of the spout and after that temperature diminishes in the way out some portion of the spout. it is deduced in this paper Four gulf rocket spout is having preferred execution over single channel and two delta as seen from the past exploration work done.

Keywords:CFD[1], examined[2], ignition[3], temperature[4].

INTRODUCTION

A **rocket engine** is a type of jet engine that uses only stored rocket propellant mass for forming its high speed propulsive jet. Rocket engines are reaction engines, obtaining thrust in accordance with Newton's third law. Most rocket engines are internal combustion engines, although non-combusting forms also exist. Vehicles propelled by rocket engines are commonly called rockets. Since they need no external material to form their jet, rocket engines can perform in a vacuumand thus can be used to propel spacecraft and ballistic missiles.Rocket engines as a group have the highest thrust, are by far the lightest, but are the least propellant efficient (have the lowest specific impulse) of all types of jet engines. The ideal exhaust is hydrogen, the lightest of all gases, but chemical rockets produce a mix of heavier species, reducing the exhaust velocity. Rocket engines become more efficient at high velocities (due to greater propulsive efficiency and Oberth effect). Since they do not benefit from, or use, air, they are well suited for uses in space and the high atmosphere.

1.1 Principle of Operation:

Rocket engines produce thrust by the expulsion of exhaust which has been accelerated to a high-speed.

The exhaust must be a fluid, usually a gas created by high pressure (10-200 bar) combustion of solid or liquid propellants, consisting of fuel and oxidiser components, within a combustion chamber. (An exception is water rockets, which use water pressurised by compressed air, carbon dioxide, nitrogen, or manual pumping.)The exhaust is then passed through a supersonic propelling nozzle which uses heat energy of the gas to accelerate the exhaust to very high speed, and the reaction to this pushes the engine in the opposite direction.In rocket engines, high temperatures and pressures are highly desirable for good performance as this permits a longer nozzle to be fitted to the engine, which gives higher exhaust speeds, as well as giving better thermodynamic efficiency.

1.2. Introducing propellant into a combustion chamber:

Rocket propellant is mass that is stored, usually in some form of propellant tank, prior to being ejected from a rocket engine in the form of a fluid jet to produce thrust.Chemical rocket propellants are most commonly used, which undergo exothermic chemical reactions which produce hot gas which is used by a rocket for propulsive purposes. Alternatively, a chemically inert reaction mass can be heated using a high-energy power source via a heat exchanger, and then no combustion chamber is used.

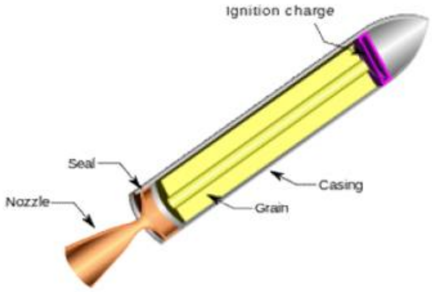
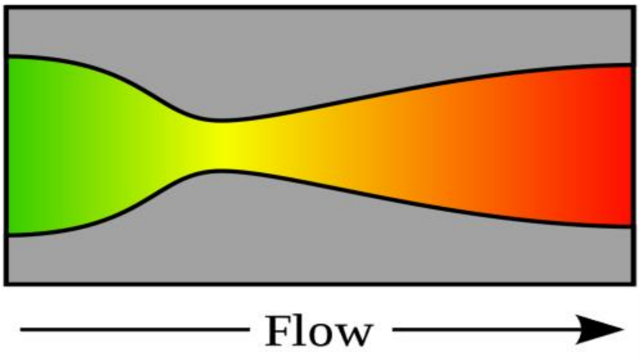


Fig:1.A solid rocket motor.

Solid rocket propellants are prepared as a mixture of fuel and oxidising components called 'grain' and the propellant storage casing effectively becomes the combustion chamber. Liquid-fuelled rockets typically pump separate fuel and oxidiser components into the combustion chamber, where they mix and burn. Hybrid rocket engines use a combination of solid and liquid or gaseous propellants. Both liquid and hybrid rockets use *injectors* to introduce the propellant into the chamber. These are often an array of simple jets - holes through which the propellant escapes under pressure; but sometimes may be more complex spray nozzles. When two or more propellants are injected, the jets usually deliberately cause the propellants to collide as this breaks up the flow into smaller droplets that burn more easily.



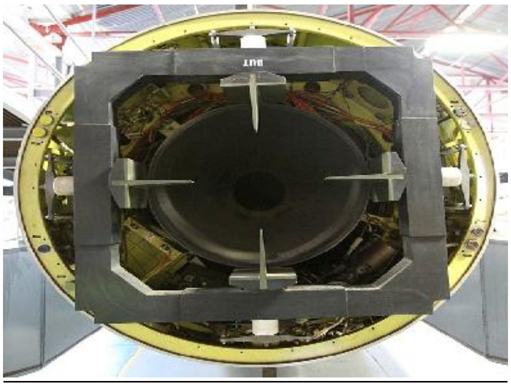


Fig: 2.Rocket

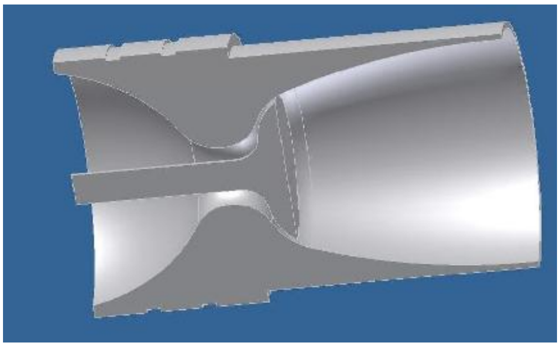


Fig:3.This section through an ED nozzle clearly shows the pintle. In this example the outer wall appears similar to the internal contour of a bell nozzle.

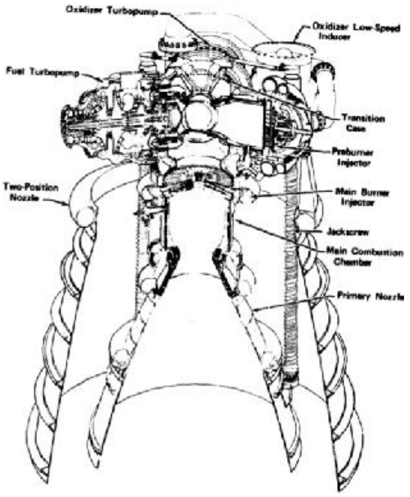
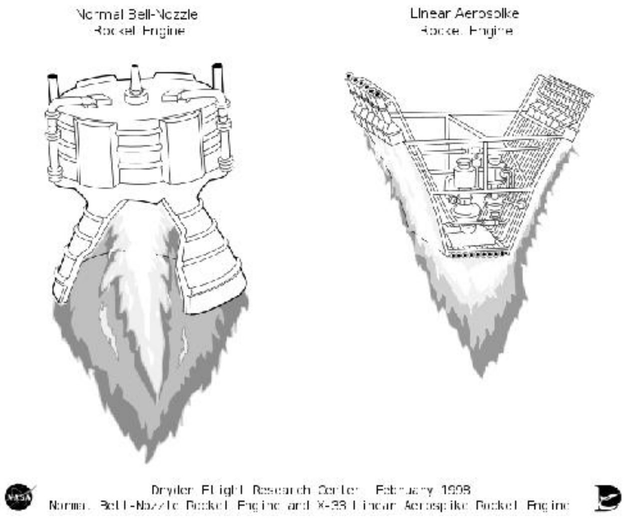


Fig: 4.half section view of rocket

The basic concept of any engine bell is to efficiently expand the flow of exhaust gases from the rocket engine into one direction. The exhaust, a high-temperature mix of gases, has an effectively random momentum distribution, and if it is allowed to escape in that form, only a small part of the flow will be moving in the correct direction to contribute to forward thrust.

Comparison between the design of a bell-nozzle rocket (left) and an aero spike rocket (right)



Instead of firing the exhaust out of a small hole in the middle of a bell, an aero spike engine avoids this random distribution by firing along the outside edge of a wedge-shaped protrusion, the "spike". The spike forms one side of a virtual bell, with the other side being formed by the outside air—thus the "aero spike".

The idea behind the aero spike design is that at low altitude the ambient pressure compresses the wake against the nozzle. The recirculation in the base zone of the wedge can then raise the pressure there to near ambient. Since the pressure on top of the engine is ambient, this means that the base gives no overall thrust (but it also means that this part of the nozzle doesn't lose thrust by forming a partial vacuum, thus the base part of the nozzle can be ignored at low altitude).

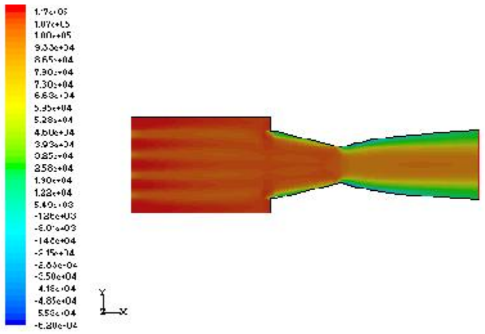
RESULTS AND DISCUSSION

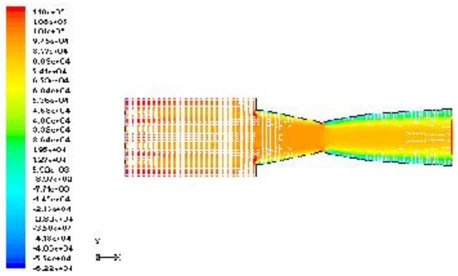
This CFD numerical experiment allows us to study in details the physical difference between the laminar and turbulent flows, all other parameter being equal in a fashion impossible to obtain in an actual levorotatory experiment. A numerical study has been conducted to understand the gas flow in a nozzles using 2D continuum axi symmetric model, which solves the properties of combustion by the control volume method. The numerical model was validated with exiting experimental data employing slip and no-slip boundary condition at the wall. The numerical results showed good agreement with experimental data on exit.

A. Rocket Nozzle with Combustion Chamber

1) Total Pressure

The maximum total pressure in the combustion chamber is 1.17e+05, and the average total pressure in the combustion chamber is 1.10e+05, the average total pressure in the conversion portion of the nozzle is 1.40e+05,while the average total pressure in combustion chamber,pressure increase in combustion chamber and after that pressuregoes on decrease in the convergent portion and at the throattotal pressure is cover the negative value, due tosupersonic nozzle total pressure in the convergent part is lessand velocity increase in this portion. You can easily visualizethe figure2that.Thereisdecreaseinstagnationpressure nearthe nozzle wall due to viscouseffect.





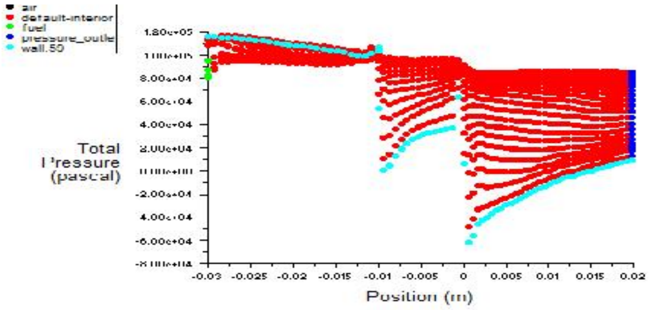
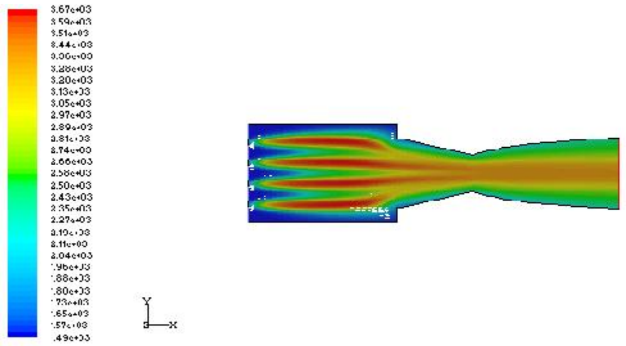
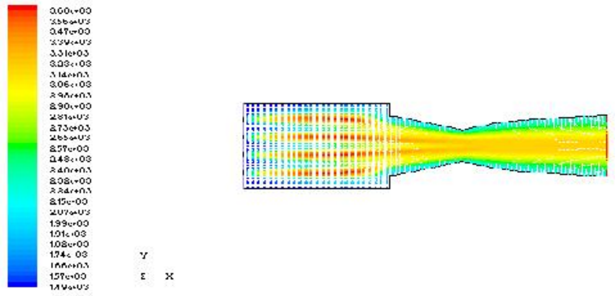


Figure-6 Total Pressure

1) *TotalTemperature*

The average temperature in combustion chamberis 2.54e+03, and maximum temperature is 3.67e+03, thetotal temperature decrease in the divergent part of thenozzle compared the combustion chamber and convergent partof the nozzle. When the fuel and air is enter in thecombustion chamberaccordingtothexandyplot,itsburnduetohigh velocity and temperature and then temperatureincrease rapidlyincombustionchamberandconvergentpart ofthe nozzle and after that temperature decrease in the exit partof the nozzle. A maximum of 3.67e+03 is attained andbeyond which the temperature steadilydecreases.





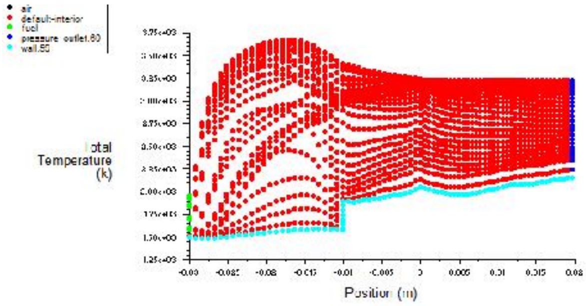
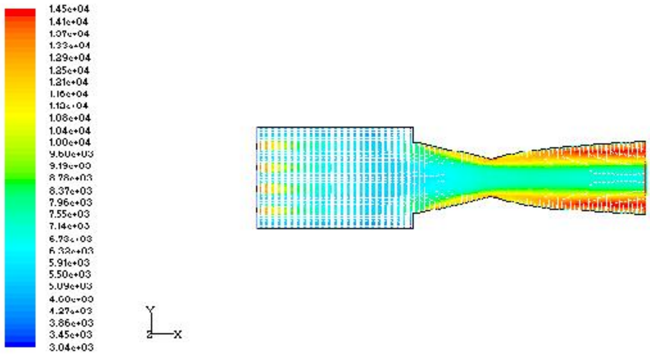


Figure – 7 TotalTemperatures

2) *Turbulence Intensity*

The nozzle is designed for stream line flow and hencethe intensity has high of turbulence is less inside thecombustion chamber compared to divergent part of the nozzle.The turbulenceintensityhashighvalueabout1.45e+04 atfuel inlet and nozzle exit. Further downstream as flowgets stabilizes, the turbulence intensity also reduces.Turbulence intensity at the fuel inlet is 1.45e+04. A maximumof 1.45e+04(%) is attained and beyond which theturbulent intensity steadilydecreases.



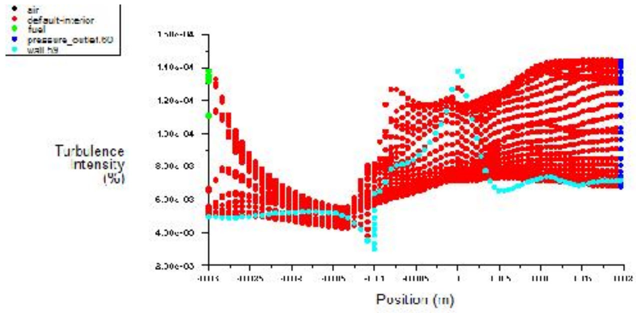


Figure- 7 Turbulence Intensity

1) *Mass fraction ofC_5H_{12}*

The maximum mass fraction of pentane is 1.00e-01 atthe fuel inlet is attained beyond which the mass fractionsteadily decrease,neartothewallmassfractionofpentaneis zero. When the chemical reaction occurs, the bondwithin molecules of the reactance is broken, and electronsrearrange to form product. in combustion reaction rapid oxidationof combustible element of the fuel results in energy releaseas combustion product are formed .When the fuel enter inthe combustionchamberisone.whileaswellasfuelenterin combustion chamber it cover higher value

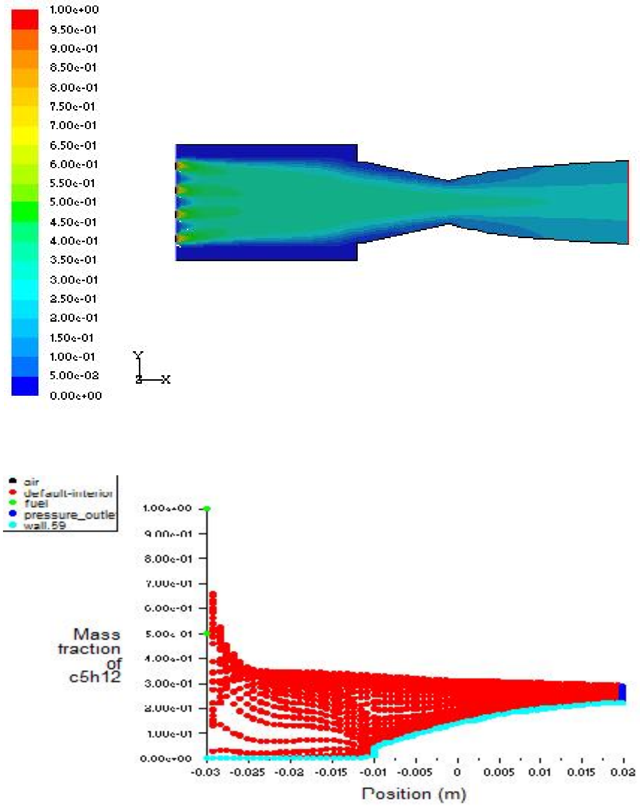


Figure-7 Mass fractionofC_5H_{12}

2) *Mass Fraction ofO_2*

For the same value of air and fuel if increase the fuelinlettheamountofairisdecreasecomparedtofuelamount .When the air is enter in the combustion chamber and burnedwith fuel,thenmassfractionhashighvalue2.10e-01inthe combustion chamber and minimum value2.10e-02,andgoes on decreasing in part of the nozzle, while near to thenozzle wallmassfractionofoxygenhaszero.Duetothestreamline flow mass fraction of O_2 flow straight in thenozzle. AccordingtoxandyPlotmassfractionvalueofoxygen increase in combustion chamber while it enters inthe divergent part of thenozzle.

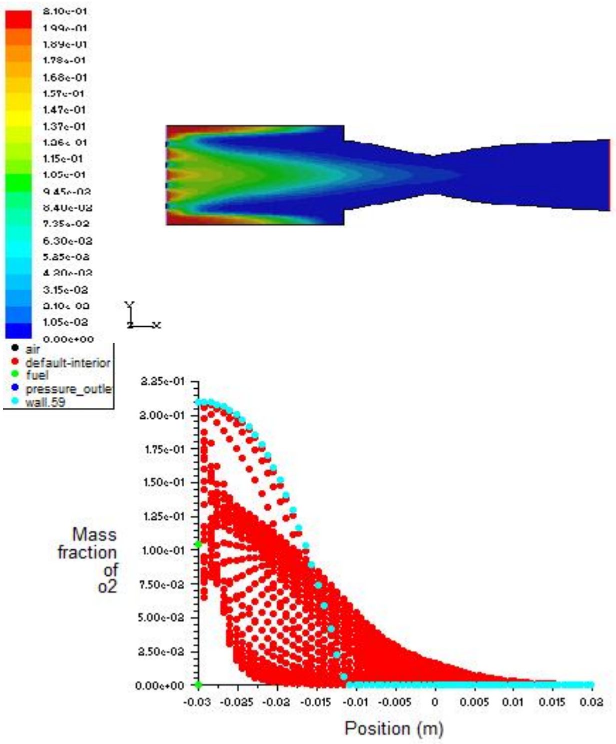
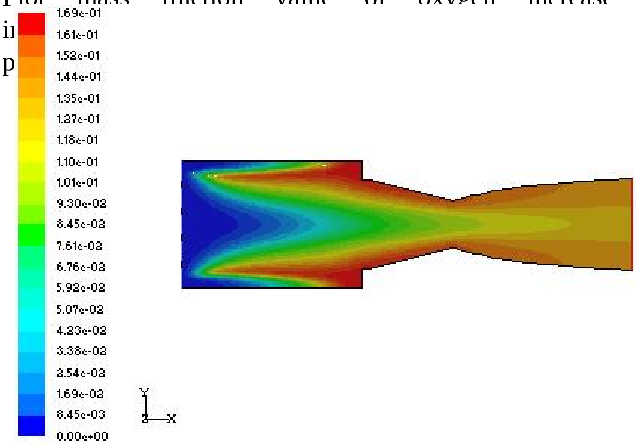


Figure-8 Mass fraction ofO_2

3) *Mass fraction ofCo2*

For the same value of air and fuel if increase the fuelinlettheamountofairisdecreasecomparedtofuelamount .When the air is enter in the combustion chamber and burnedwith fuel,thenmassfractionhashighvalue1.69e-01inthe combustion chamber and minimum value.0791,and goeson decreasinginpartofthenozzle,whileneartothenozzlewall mass fraction co_2 has zero. Due to the stream line flowmass fractionofco_2flowstraightinthenozzle.Accordingtoxand y Plot mass fraction value of oxygen increase



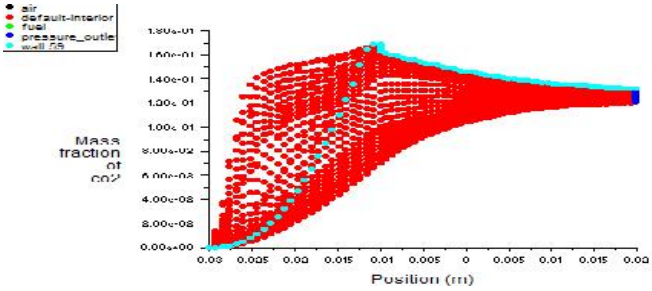
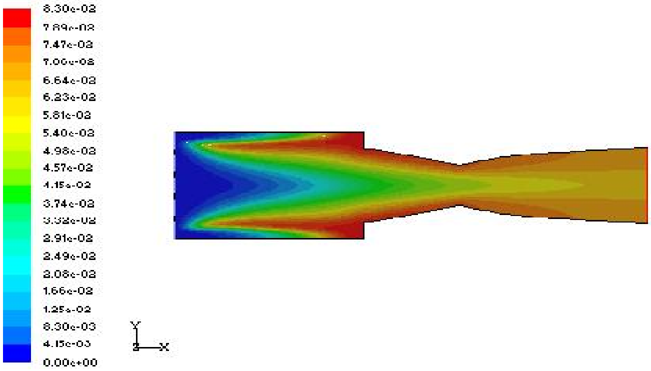


Figure-9 Mass fraction ofCo_2

4) Mass fraction ofH2o

In combustion reaction rapid oxidation ofcombustible element of the fuel results in energy release ascombustion products formed. The three major combustible chemical element sinmost common fuel are carbon ,hydrogenand sulphur ,combustion is complete when all the carbonpresent inthefuelisburned,allhydrogenburnedintowater,and other combustible element are fully oxidized. Herethe carbon dioxide is has the



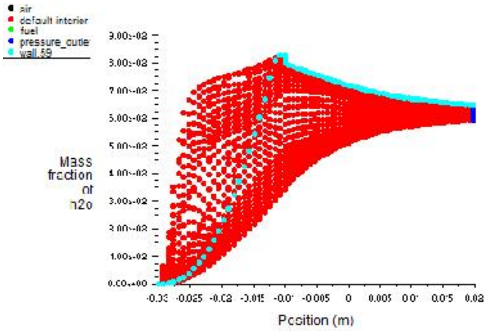
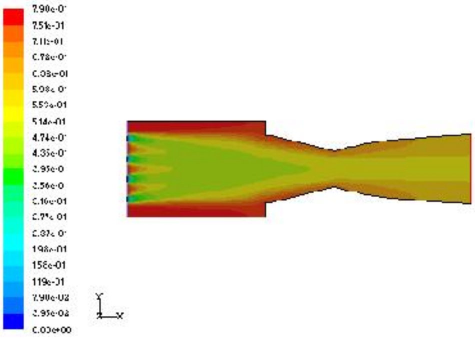
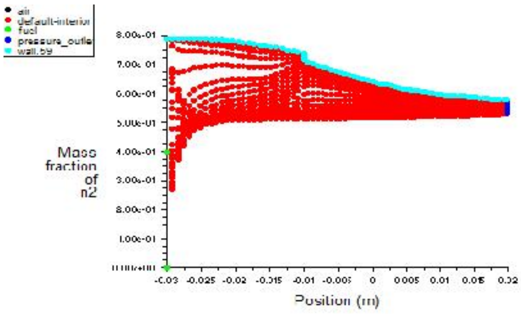


Figure-8 Mass fraction ofH_2o

5) *Mass fraction ofN2*

Mass fraction near to the combustion chamber wallhas highervalueis0.79,andaveragevalveis0.474andminimum valueneartothefuelinlet,whileaslongasaircoverthe distance in the combustion chamber the value goeson decrease.





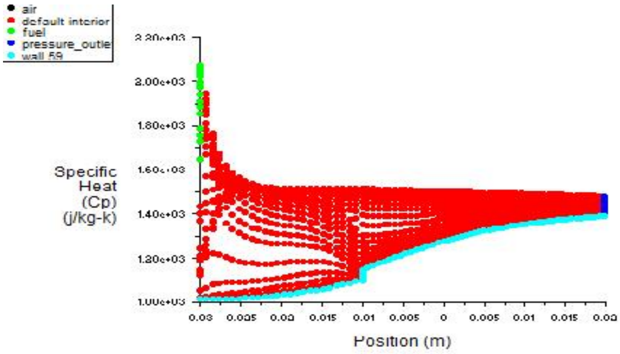


Figure-10 Specific Heat

CONCLUSION

A model was developed to determine the pressure, emperatureandflowdistributioninthe combustion chamber region on. Themo delinclude svarious parametersof thejet-and ambient gas and can therefore be used for hot gases.Several steps of the model were validated with good agreementwith experimental data and numerical results found inthe literature. The maximum total pressure in thecombustion chamber is 1.17e+05, and the average total pressure inthe combustion chamber is 1.10e+05, the average totalpressure in the conversion portion of the nozzle is 1.40e+05,whilethe average total pressure in combustion chamber,pressure increase in combustion chamber and after that pressuregoes on decrease in the convergent portion and at the throattotal pressure is cover the negative value, due to supersonic nozzle total pressure in the convergent part is lessand velocity increase. The average temperature incombustion chamberis2.54e+03,andmaximumtemperatureis 3.67e+03, hetotal temperature decreaseinthe divergentpartofthe nozzle compared the combustion chamber andconvergent partofthenozzle.Whenthefuelandairisenterinthe combustion chamber according to the x and y plot, itsburn due to high velocity and temperature and thentemperature increase rapidly in combustion chamber and convergentpart of the nozzle and after that temperature decrease in theexitpart of the nozzle. A maximum of 3.67e+03 is attainedand beyond which the temperature steadily decreases.The maximummassfractionofpentaneis1.00e-01atthefuel inlet is attained beyond which the mass fractionsteadily decrease, near to the wall mass fraction of pentane is zero.

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