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COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF JET NOZZAL AT DIFFERENT ALTITUDES

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Abstract

Supersonic flows associated with missiles, aircraft, missile engine intake and rocket nozzles are often steady. The shape of the nozzle geometry is increasingly attractive in heating, ventilation and air conditioning applications. The objective of the present work is to simulate and understand Supersonic flows with single jet Flow at various atitude that is ground level "0" meters and 500meters above sea level.The purpose is to precisely understand the fluid dynamics and variation of flow properties such as velocity, pressure and mach number. A single jet nozzle is designed in solid works software premium 2016 and CFD analysis is carried out in solidworks flow simulation.

Introduction

The development of the gas turbine engine as an plane strength plant has been so fast that it is difficult to appreciate that prior to the 1950s very few human beings had heard of this method of aircraft propulsion. The opportunity of using a response jet had involved plane designers for a long time, but initially the low speeds of early aircraft and the unsuitably of a piston engine for generating the huge high speed airflow essential for the ëjetí provided many boundaries. 2. A French engineer, RenÈ Lorin, patented a jet propulsion engine (fig. 1-1) in 1913, however this was an athodyd (para. eleven) and was at that duration not possible to manufacture or use, on account that appropriate warmth resisting substances had no longer then been developed and, within the 2d location, jet propulsion might had been extremely inefficient on the low speeds of the aircraft of those days. However, today the modern ram jet is very much like Lorin's concept. three. In 1930 Frank Whittle became granted his first patent for the use of a gas turbine to produce a propulsive jet, however it become 11 years earlier than his engine completed its first flight. The Whittle engine shaped the basis of the present day fuel turbine engine, and from it changed into developed the Rolls-Royce Welland, Derwent, Nene and Dart engines. The Derwent and Nene turbo-jet engines had global-extensive military applications; the Dart faster-propeller engine have become world famous because the energy plant for the Vickers Viscount aircraft. even though other aircraft can be fitted; with later engines termed dual-spool, triple-spool, with the aid of-bypass, ducted fan, unducted fan and propfan, those are inevitable developments of Whittle's early engine.

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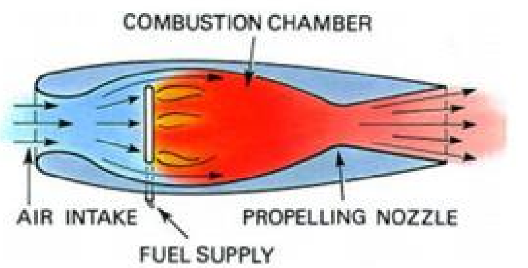

Fig Lorin's jet engine

. The Derwent and Nene turbo-jet engines had world-wide military applications; the Dart turbo-propeller engine became world famous as the power plant for the Vickers Viscount aircraft. Although other aircraft may be fitted; with later engines termed twin-spool, triple-spool, by-pass, ducted fan, unducted fan and propfan, these are inevitable developments of Whittle's early engine.

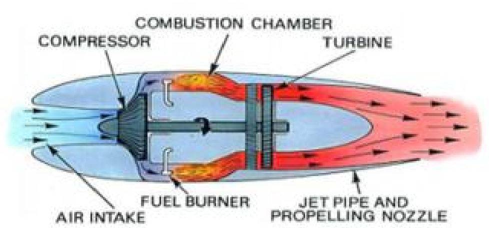

Fig. 1-2 A Whittle-type turbo-jet engine.

4.

The jet engine (fig. 1-2), although acting so extraordinary from the piston engine-propeller aggregate, applies the same fundamental principles to impact propulsion. As proven in fig. 1-3, each propel their plane entirely by way of thrusting a big weight of air backwards. five. despite the fact that these days jet propulsion is popularly related with the fuel turbine engine, there are different varieties of jet propelled engines, along with the ram jet, the heart beat jet, the rocket, the turbo/ram jet, and the turbo rocket.

PRINCIPLES OF JET PROPULSION

Jet propulsion is a practical application of Sir Isaac Newton's third law of motion which states that, 'for every force acting on a body there is an opposite and equal reaction'. For aircraft propulsion, the 'body' is atmospheric air that is caused to accelerate as it passes through the engine. The force required to give this acceleration has an equal effect in the opposite direction acting on the apparatus producing the acceleration. A jet engine produces thrust in asimilar way to the engine/propeller combination. Both propel the aircraft by thrusting a large weight of air backwards (fig. 1-3), one in the form of a large air slipstream at comparatively low speed and the other in the form of a jet of gas at very high speed.

7. This identical precept of response occurs in all varieties of movement and has been usefully carried out in many methods. The earliest acknowledged instance of jet response is that of Hero's engine (fig. 1-four) produced as a toy in 120 B.C. This toy showed how the momentum of steam issuing from some of jets should impart an equal and contrary reaction to the jets themselves, hence causing the engine to revolve. 8. The familiar whirling garden sprinkler (fig. 1-5) is a more realistic instance of this principle, for the mechanism rotates through distinctive feature of the response to the water jets. The high strain jets of current firefighting device are an example of 'jet response', for regularly, due to the response of the water jet, the hose can not be held or

managed through one fireman. perhaps the only example of this principle is afforded with the aid of the carnival balloon which, whilst the air or gasoline is launched, rushes unexpectedly away in the path opposite to the jet. nine. Jet response is actually an inner phenomenon and does now not, as is often assumed, result from the pressure of the jet at the ecosystem. In truth, the jet propulsion engine, whether rocket, athodyd, or rapid-jet, is a piece of apparatus designed to accelerate a movement of air or fuel and to expel it at excessive pace. There are, of course, a number of ways

METHODS OF JET PROPULSION

The kinds of jet engine, whether ram jet, pulse jet, rocket, gas turbine, turbo/ram jet or faster-rocket, fluctuate only inside the way wherein the 'thrust provider', or engine, components and converts the energy into energy for flight.

The ram jet engine (fig. 1-6) is an athodyd, or 'aero-thermodynamic-duct to offer it its complete name. It has no most important rotating components and consists of a duct with a divergent access and a convergent or

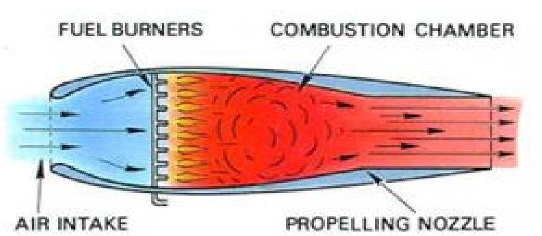

Fig. 1-6 A ram Jet engine.

Convergent-divergent exit. whilst ahead movement is imparted to it from an outside source, air is pressured into the air consumption where it loses pace or kinetic electricity and will increase its pressure energy because it passes via the diverging duct. the total strength is then expanded via the combustion of fuel, and the expanding gases accelerate to surroundings through the outlet duct. A ram jet is frequently the electricity plant for missiles and .target cars; but is improper as an aircraft power plant "as it requires forward motion supplying to it before any thrust is produced.

The pulse jet engine (fig. 1-7) uses the principle of intermittent combustion and in contrast to the ram jet it may be run at a static condition. The engine is formed by an aerodynamic duct just like the ram jet however, due to the better pressures worried, it is of extra robust creation. The duct inlet has a series of inlet 'valves' that are spring-loaded into the open positon. Air drawn via the open valves passes into the combustion chamber and is heated by way of the burning of gas injected into the chamber. The resulting enlargement reasons a upward push in pressure, forcing

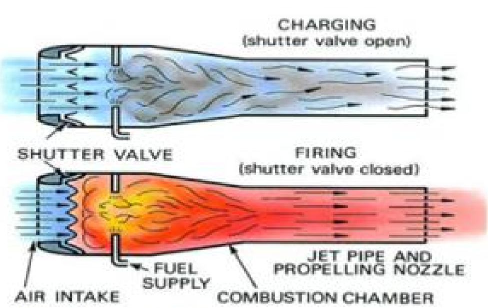

Fig. 1-7 A pulse jet engine.

The valves to shut, and the expanding gases are then ejected rearwards. A despair created by means of the laborious gases lets in the valves to open and repeat the cycle. Pulse jets were designed for helicopter rotor propulsion and some dispense with inlet valves through careful layout of the ducting to control the

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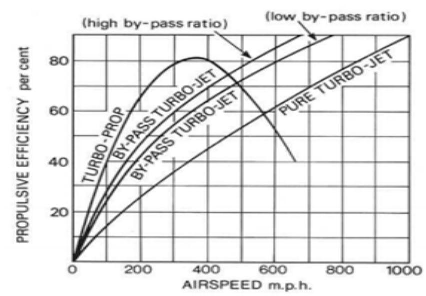
converting pressures of the resonating cycle. the pulse jet is fallacious as an aircraft electricity plant as it has a excessive gas intake and is unable to equal the performance of the modern gasoline turbine engine.

despite the fact that a rocket engine (fig. 1-8) is a jet engine, it has one most important distinction in that it does not use atmospheric air because the propulsive fluid movement. instead, it produces its very own propelling fluid with the aid of the combustion of liquid or chemically decomposed gas with oxygen, which it includes, for this reason permitting it to operate outdoor the earth's ecosystem. it's far, therefore, best appropriate for operation over brief intervals.

The application of the fuel turbine to jet propulsion has averted the inherent weak point of the rocket and the athodyd, for by the introduction of a turbine-pushed compressor a method of producing thrust at low speeds is provided. The turbo-jet engine operates at the 'operating cycle' as defined in component 2. It attracts air from the environment and after compressing and heating it, a system that takes place in all heat engines, the strength and momentum given to the air forces It out of the propelling nozzle at a velocity of up to 2,000 feet per second or about 1,400 miles per hour. On its way through the engine, the air gives up some of its energy and momentum to drive the turbine that powers the compressor.

The mechanical association of the gas turbine engine is simple, for it consists of only two predominant rotating components, a compressor (element 3) and a turbine (component five), and one or some of combustion chambers (part 4). The mechanical association of numerous fuel turbine engines is shown in fig. 1 -9. This simplicity, however, does no longer observe to all elements of the engine, for as defined in subsequent components the thermo and aerodynamic troubles are truly complicated. They end result from the excessive working temperatures of the combustion chamber and turbine, the effects of varying flows across the compressor



WORKING CYCLE

The running cycle of the fuel turbine engine is similar to that of the 4-stroke piston engine. however, in the gasoline turbine engine, combustion takes place at a constant stress, while inside the piston engine it occurs at a regular volume. both engine cycles (fig. 2-1) show that during each example there is induction, compression, combustion and exhaust. those techniques are intermittent inside the case of the piston engine at the same time as they occur constantly inside the gas turbine. inside the piston engine handiest one stroke is applied within the manufacturing of strength, the others being concerned inside the charging, compressing and exhausting of the working fluid. In comparison, the turbine engine gets rid of the 3 'idle' strokes, therefore allowing more fuel to be burnt in a shorter time; therefore it produces a greater strength output for a given size of engine. 3. due to the non-stop action of the turbine engine and the truth that the combustion

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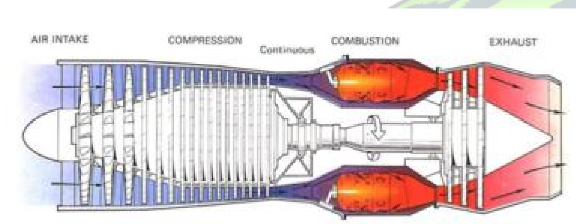
chamber is not an enclosed area, the stress of the air does not rise, like that of the piston engine, in the course of combustion but its extent does boom. This system is called heating at constant strain. underneath those conditions there are no height or fluctuating pressures to be withstood, as is the case with the piston engine with its top pressures in extra of one,000 lb. in keeping with sq. in. it's far those height pressures which make it vital for the piston engine to appoint cylinders of heavy construction and



to use high octane fuels, in evaluation to the low octane fuels and the light fabricated combustion chambers used on the turbine engine. 4. The running cycle upon which the fuel turbine engine functions is, in its most effective shape, represented via the cycle proven on the strain volume diagram in fig. 2-2. point A represents air at atmospheric strain this is compressed alongside the road AB. From B to C warmth is added to the air by way of introducing and burning fuel at regular strain, thereby drastically growing the volume of air. strain losses in the combustion chambers (part four) are indicated by means of the drop between B and C. From C to D the gases attributable to combustion expand through the turbine and jet pipe lower back to surroundings. for the duration of this a part of the cycle, some of the power within the expanding gases is became mechanical energy through

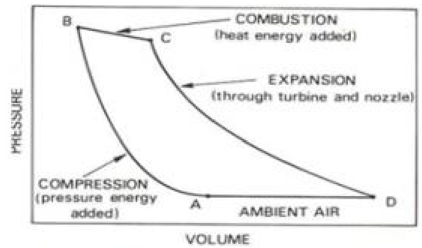
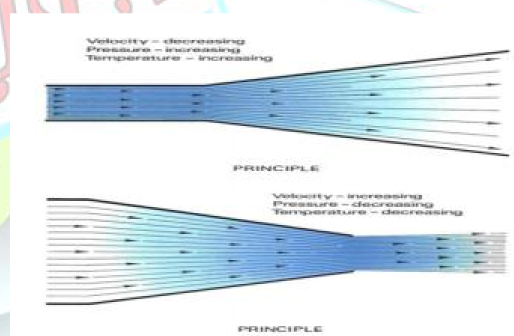


Fig. 2-2 The working cycle on a pressure-volume diagram.

the turbine; the remainder, on its discharge to environment, offers a propulsive jet. 5. due to the fact the rapid-jet engine is a warmness engine, the better the temperature of combustion the more is the expansion of the gases. The combustion temperature, however, must now not exceed a value that gives a turbine gasoline entry temperature suitable for the layout and materials of the turbine meeting. 6. the usage of air-cooled blades within the turbine meeting lets in a higher gas temperature and a therefore higher thermal performance



JET ENGINE EXHAUST

Aero gasoline turbine engines have an exhaust gadget which passes the turbine discharge gases to environment at a speed, and inside the required route, to offer the resultant thrust. the rate and pressure of the exhaust gases create the thrust within the faster-jet engine (para. 5) but within the turbopropeller

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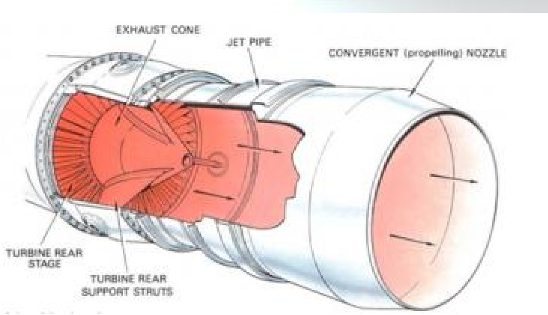
engine handiest a small quantity of thrust is contributed via the exhaust gases, because most of the electricity has been absorbed by way of the turbine for using the propeller. The design of the exhaust device therefore, exerts a extensive influence at the overall performance of the engine. The areas of the jet pipe and propelling or outlet nozzle affect the turbine access temperature, the mass airflow and the speed and pressure of the exhaust jet. 2. The temperature of the gas getting into the exhaust gadget is between 550 and 850 deg. C. according to the form of engine and with the usage of afterburning (component sixteen) may be 1,500 deg. C. or better. therefore, it's far vital to use substances and a shape of construction on the way to face up to distortion and cracking, and save you warmness conduction to the plane shape. 3. A fundamental exhaust system is shown in fig. 6-1. the usage of a thrust reverser (part 15), noise suppressor (part 19) and a two role propelling nozzle involves a extra complicated device as shown in fig. 6-2. The low with the aid of-skip engine might also consist of a mixer unit (fig. 6-four) to encourage a radical blending of the new and cold gas streams.



CONSTRUCTION AND MATERIALS

The exhaust system must be able to withstanding the excessive fuel temperatures and is consequently manufactured from nickel or titanium. it's also important to save you any heat being transferred to the encompassing plane structure. that is executed by using passing ventilating air around the jet pipe, or by lagging the section of the exhaust machine with an insulating blanket (fig. 6-6). each blanket has an inner layer of fibrous insulating cloth contained by means of an outer pores and skin of thin stainless-steel, that is dimpled to growth its power. further, acoustically absorbent materials are from time to time carried out to the exhaust gadget to lessen engine noise (part 19). 14. when the fuel temperature may be very high (for example, when afterburning is employed), the complete jet pipe is usually of double-wall creation (part sixteen) with an annular area between the two partitions. the new gases leaving the propelling nozzle induce, by way of ejector action, a go with the flow of air via the annular area of the engine nacelle. This go with the flow of air cools the inner wall of the jet pipe and acts as an insulating blanket by lowering the switch of warmth from the inner to the outer wall. 15. The cone and streamline fairings within the exhaust unit are subjected to the pressure of the exhaust gases; therefore, to save you any distortion, vent holes are supplied to gain a pressure balance. sixteen. The mixer unit used in low with the aid of-skip ratio engines includes some of chutes thru which the pass air flows into the exhaust gases. A bonded honeycomb structure is used for the incorporated nozzle meeting of high through-skip ratio engines to give lightweight electricity to this huge element. 17. because of the extensive variations of temperature to which the exhaust system is subjected, it ought to be mounted and have its

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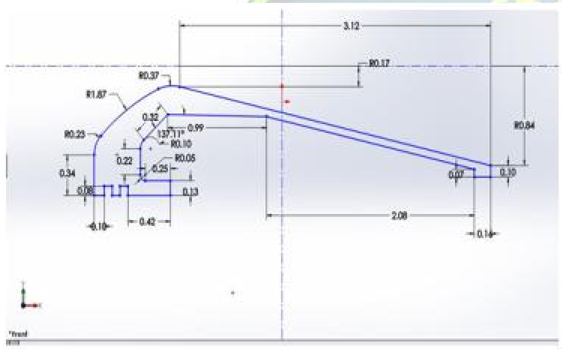
sections joined collectively in this sort of way as to allow for enlargement and contraction with out distortion or harm.

SOLID WORKS

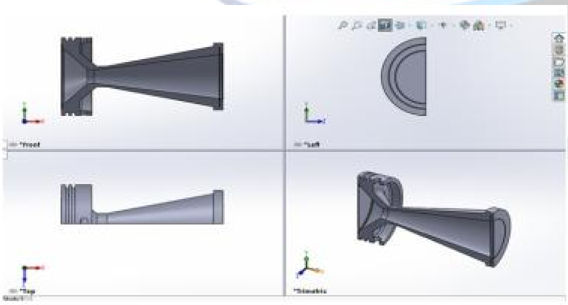
Solid works is mechanical design automation software that takes advantage of the familiar Microsoft windows graphical user interface.

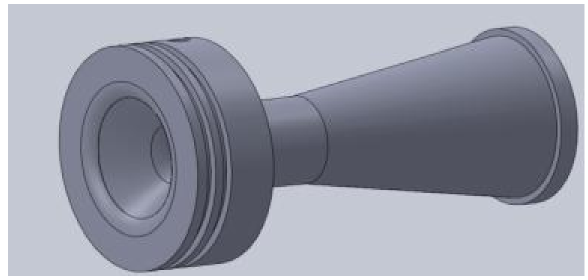
It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

Modeling of jet nozzle



By revolving the above sketch we get the model of jet nozzle





FLOW SIMULATION

Solid Works Flow Simulation 2010 is a fluid flow analysis add-in package that is available for SolidWorks in order to obtain solutions to the full Navier-Stokes equations that govern the motion of fluids. Other packages that can be added to SolidWorks include SolidWorks Motion and SolidWorks Simulation. A fluid flow analysis using Flow Simulation involves a number of basic steps that are shown in the following flowchart in figure.

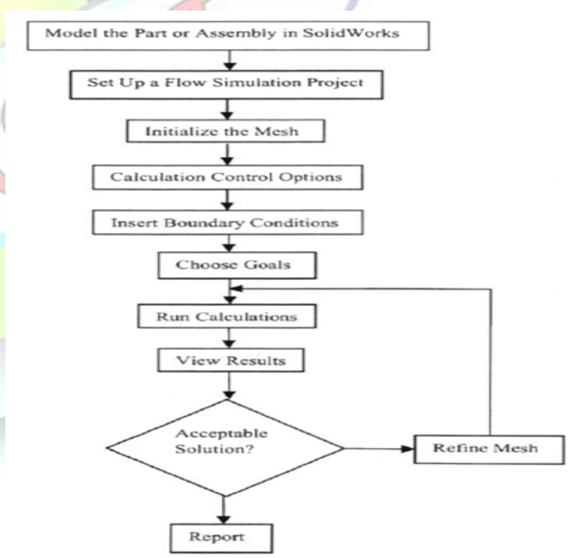


Figure: Flowchart for fluid flow analysis using Solid works Flow Simulation

Advantages of Flow Simulation

Low Cost:

Speed

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Complete information

Ability to stimulate Realistic Conditions

Reduction of Failure risks

Applications of Flow Simulation

Automobile and Engine Applications

Industrial Manufacturing Applications

Civil engineering Applications

Environmental Engineering Applications

Product design

Product improvement:

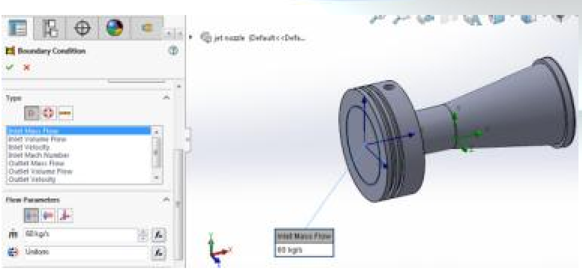
Bio medical engineering

CFD ANALYSIS

Boundary condition at “0” meters (ground) altitude.

Air as fluid

Mass flow inlet 60kg/s

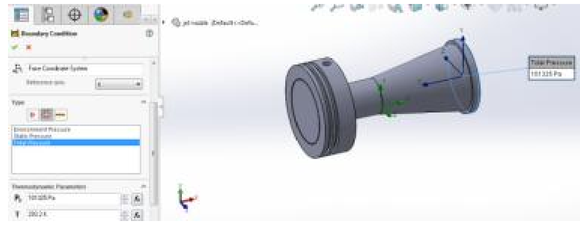


At “0’ meters altitude

Out let pressure is taken at 0 meters altitude

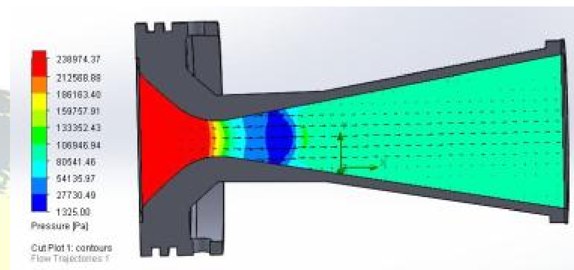
Pressure: 101325 Pa

Temperature 293.2 K

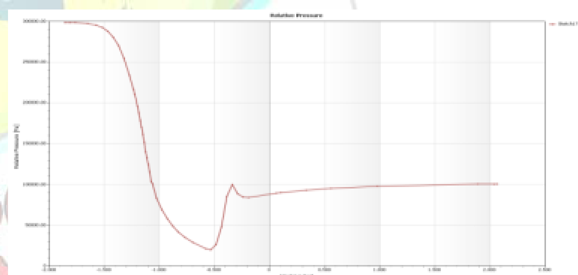


Results

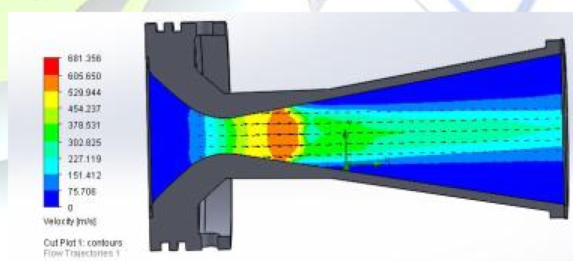
Pressure



Graph



Velocity



Graph

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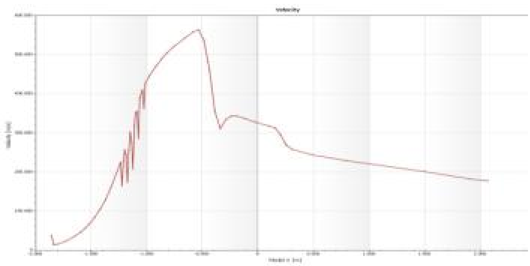
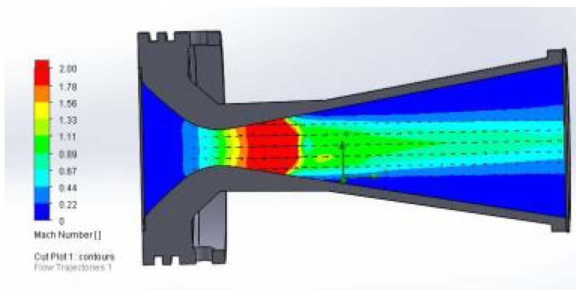


Mach number



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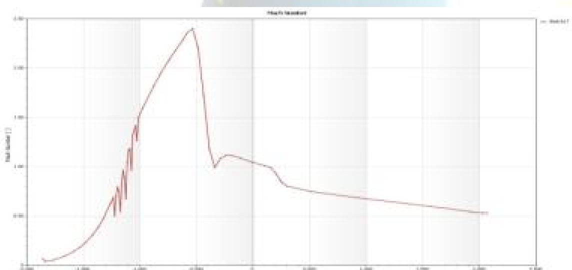
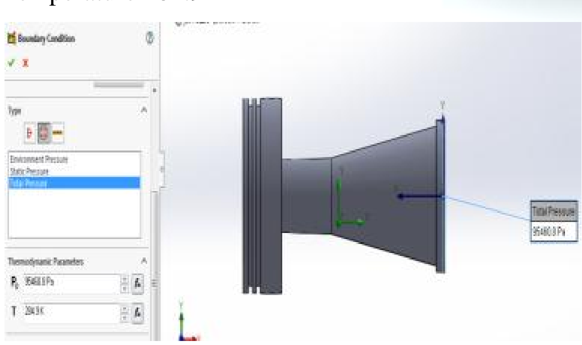


AT "500" METERS ALTITUDES

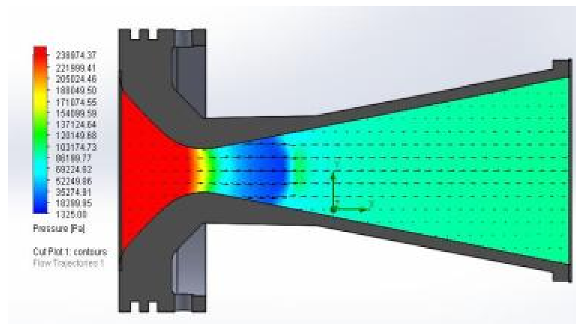
Out let pressure is taken at 500 m altitude

Pressure: 95460.8 Pa

Temperature 284.9 K



Pressure



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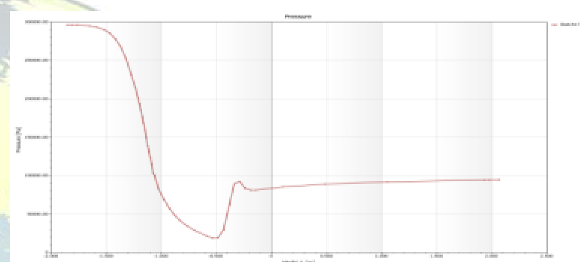
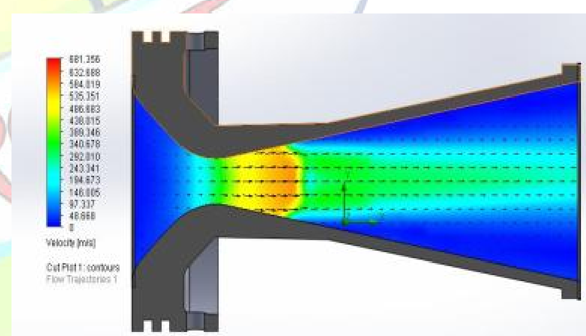


Velocity



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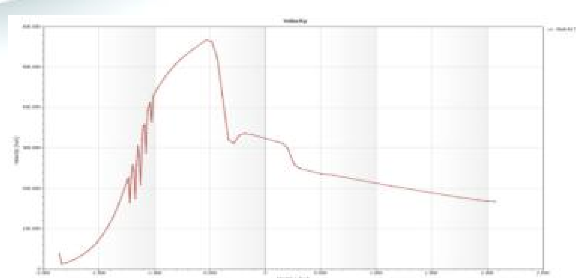

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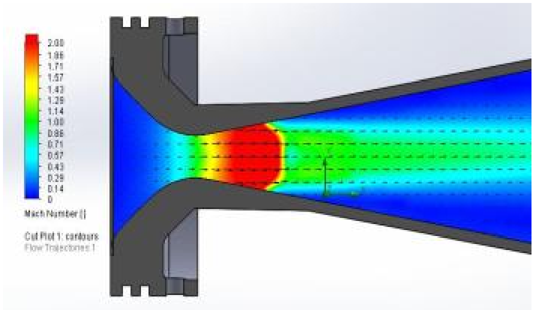

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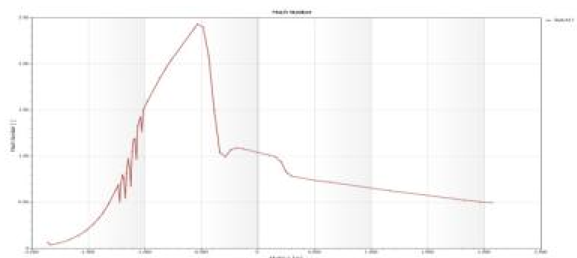

RESULT TABLE

"0" METERS ALTITUDE

PARAMETERS	MININMUM	MAXIMUM
Velocity (m/s)	574.91	589.763
Pressure (Pa)	306832	307824
Mach Number	2.50599	2.5972

"500" METERS ALTITUDE

PARAMETERS	MININMUM	MAXIMUM
Velocity (m/s)	581.298	596.86
Pressure (Pa)	301628	305615
Mach Number	2.56136	2.64964

Results and conclusion

1. Design and cfd analysis of jet nozzle is done in solid works.
2. Designing of jet nozzle is made in solid works
3. Analysis is performed on two deferent altitude that is ground level and 500 m altitude.
4. It is observed from the results that the maximum velocity is attained at throat area and divergent part of the nozzle.
5. The flow is reached up to max 2.64 mach number at convergent region on 500 m altitude
6. Pressure is decreased at convergent region due to sudden expansion of flue gasses.
7. Velocity is increasing at 500m altitude compare to ground level.
8. Shocks waves are detected in jet nozzle due to high Mach number of flue gasses.
9. Pressures of flue gasses are decreasing as the altitude increasing.
10. Mach number is increasing as the altitude increasing from ground level to 500 meters.

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