

DESIGN AND FABRICATION OF JET ENGINE USING RECYCLED TURBOCHARGER PARTS

A project report submitted in partial fulfillment of the requirement for the award of the
degree of

BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

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**SANGIVALASA, VISAKHAPATNAM – 531162
2019**

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CERTIFICATE

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ABSTRACT

This is a capstone project that describes the idea on how to design and fabrication of a Model Turbojet Engine from scrap and recycled parts of an old turbocharger from an old truck. The main motto of the project is to build a working model turbojet engine from scrap which is reliable and cheap.

A turbine jet engine comprises of four main parts, which are a compressor, a combustion chamber, a turbine and an exhaust nozzle. Turbine jet engine operates at an open cycle called a jet propulsion cycle. A small-scale turbine jet engine comprises of the same element as the gas-turbine engine but in a smaller scale. Both engines differ in utilization and purpose of its production. Turbine jet engines were constructed mainly for air transportation while the small-scale turbine jet engines are developed for a wider purpose, ranging for research activity to hobbyist enthusiastic. Hence, this thesis encompasses the design, fabrication, and testing a small-scale turbine jet engine. The engine was derived from an automobile turbocharger, which provided the turbine and compressor component. A combustion chamber was design and fabricated. Engine support system comprised of ignition, lubrication and fuel delivery system were installed at the engine. The engine assembly was mounted in a test setup.

This project is replica of actual working of the jet engine on a small scale level. The turbocharger serves as an integrated compressor & turbine assembly which is suitably manipulated (carefully converted) in to an open cycle constant pressure gas turbine. The project mainly involves complex modeling, designing and analysis of combustion chamber using software packages like mat lab, ANSYS and other related soft wares like AutoCAD, solid works etc.; and then complete fabrication of the same completely by us.

Contents

1.2.1	Sir Frank Whittle's Turbojet Concept.....	3
1.4.1.	Introduction.....	8
1.4.2.	Brayton cycle	8
1.4.3.	Simple jet engine cycle	9
1.	Design procedure for Model jet engine	22
1.1.	Preliminary equipment and materials	22
1.1.1.	Material selection.....	22
1.1.2.	Tools and Equipment's used.....	23
1.1.3.	List of Materials:	31
1.2.	Design Calculations.....	32
1.2.1.	Jet Engine Cycle calculations	32
1.3.	CAD Modelling.....	37
1.3.1.	Introduction to Solid Works.....	37
.....	40
1.3.2.	Engine part design using solid works:.....	41
1.4.	Fabrication of engine.....	65
1.4.1.	Shaft.....	65
1.4.2.	Shaft Housing.....	67
1.4.3.	compressor and turbine	68
1.4.4.	Diffuser blade	70
1.4.5.	Ignition pipe.....	71
1.4.6.	Combustion chamber	72
1.4.7.	Outer casing.....	73
1.4.8.	Compressor and Turbine casings.....	74
1.5.	Assembly of the Engine	76
1.5.1.	Connecting shaft and the housing.....	76
1.5.2.	Connecting turbine and the compressor.....	76
1.5.3.	Connecting diffuser and the nozzle guide vanes.....	77
1.5.4.	Connecting combustion chamber and the ignition pipe onto the housing.....	77
1.5.5.	Inserting into the outer casing.....	77
1.5.6.	Fixing compressor and turbine casing.....	78
1.5.7.	Connecting model to the platform	79
1.6.	Applications and Further study	80
1.7.	Conclusion:.....	82
1.8.	References	82

NOMENCLATURE

E Young's Modulus of Elasticity (MPa)

Λ Degree of Reaction

\dot{m} Mass flow rate (kg/s)

C_p Specific Heat of at constant pressure (J/kg K)

γ_R Loss Co-efficient

Greek Letters

ρ Density of Gas/Air (kg/m^3)

α_1, β_1 Nozzle blade angles

α_2, β_2 Rotor blade angles

u Flow Co-efficient

ψ Temperature Drop Co-efficient

k Ratio of Specific Heats

σ Slip Factor

CHAPTER I

AIR BREATHING ENGINES

1.1 Introduction

The invention of the gas turbines around twentieth century during the era of Second World War led to a major breakthrough in the field of prime movers. The absence of the reciprocating and rubbing members, few balancing problems, exceptionally low lubricating oil consumption coupled with high power to weight ratio made gas turbines highly reliable. These inherent advantages of the gas turbines were realized when they were first used for aircraft propulsion around mid-twentieth century; and ever since gas turbines have received a special attention by potential mass of engineers and scientists all around the globe. The gas turbines have been used as the source of power for variety of application most of which includes stationary power plant application, as propulsion device for marine, locomotives etc. but the vast portion of the application of gas turbines is found in aircraft industries. The introduction of the gas turbine as propulsion device in the airplanes have made air ways highly reliable source of transportation. It is not just the engineers and scientists who are thrilled by this new highly emerging and developing prime mover but it has also attracted the attention of the general public who are fascinated by its inherent advantages, simplicity of construction and high reliability.

A jet propulsion mechanism was conceptualized long before the jet plane was ever manufactured. As early as 150 BC, the Egyptian philosopher Hero visualized a cauldron-shaped machine that would convert steam pressure into a jet force. He called it the Aeropile. About 300 years ago, Sir Isaac Newton's third law of motion further developed the concept of jet force propulsion by explaining that "for every action there is an equal and opposite reaction." He proposed the idea of a horseless vehicle called the Newton Steam Engine that would use jet propulsion to move.

The development of the jet engine made a drastic leap when, in 1928, Sir Frank Whittle offered the first real practical idea which could be effectively used in an aircraft. By 1930, the idea of the jet engine is patented, but it was not until 1937 that the idea took off. Then, in April of 1941, an aircraft called the Gloster E.28 powered by a W1X engine was tested. Only a month late, the same aircraft was flown with a W1 engine. The results provided undeniable proof that Sir Frank Whittle had invented a first-class power unit for aircraft propulsion.

The development of the gas turbine engine as an aircraft power plant has been so rapid that it is difficult to appreciate that prior to the 1950s very few people had heard of this method of aircraft propulsion. The possibility of using a reaction jet had interested aircraft designers for a long time, but initially the low speeds of early aircraft and the unsuitability of a piston engine for producing the large high velocity airflow necessary for the jet presented many obstacles.

A French engineer, René Lorin, patented a jet propulsion engine (fig. 1-1) in 1913, but this was an athodyd (para. 11) and was at that period impossible to manufacture or use, since suitable heat resisting materials had not then been developed and, in the second place, jet propulsion would have been extremely inefficient at the low speeds of the aircraft of those days. However, today the modern ram jet is very similar to Lorin's conception.

In 1930 Frank Whittle was granted his first patent for using a gas turbine to produce a propulsive jet,

But it was eleven years before his engine completed its first flight. The Whittle engine formed the basis of the modern gas turbine engine, and from it was developed the Rolls-Royce Welland, Derwent, Nene and Dart engines. 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 prop fan, these are inevitable developments of Whittle's early engine.

1.2 History

Although the invention of the jet engine can be traced back to the aeolipile made around 150 B.C., Dr. Hans von Ohain and Sir Frank Whittle are both recognized as being the co-inventors of the jet engine as we know it today, even though each worked separately and knew nothing of the other's work.

Jet propulsion is defined simply as any forward movement caused by the backward ejection of a high-speed jet of gas or liquid. In the case of air travel and engines, jet propulsion means that the machine itself is powered by jet fuel.

While Von Ohain is considered the designer of the first operational turbojet engine, Whittle was first to register a patent for his schematics of a prototype, in 1930. Von Ohain obtained a patent for his prototype in 1936, and his jet was the first to fly in 1939. Whittle's took off for the first time in 1941.

While von Ohain and Whittle may be the acknowledged fathers of modern jet engine, many grandfathers came before them, guiding them as they paved the way for the jet engines of today.

The aeolipile of 150 B.C. was created as a curiosity and never used for any practical mechanical purpose. In fact, it wouldn't be until the invention of the fireworks rocket in the 13th century by Chinese artists that a practical use for jet propulsion was first implemented.

In 1633, Ottoman Lagari Hasan Çelebi used a cone-shaped rocket powered by jet propulsion to fly up into the air and a set of wings to glide it back to a successful landing. However, because rockets are inefficient at low speeds for general aviation, this use of jet propulsion was essentially a one-time stunt. In any event, his effort was rewarded with a position in the Ottoman Army.

Between the 1600s and World War II, many scientists experimented with hybrid engines to propel aircraft. Many used one of the piston engine's forms—including air-cooled and liquid-cooled inline and rotary and static radial engines—as the power source for aircraft.

1.2.1 Sir Frank Whittle's Turbojet Concept

Sir Frank Whittle was an English aviation engineer and pilot who joined the Royal Air Force as an apprentice, later becoming a test pilot in 1931.

Whittle was only 22 when he first thought to use a gas turbine engine to power an airplane. The young officer tried unsuccessfully to obtain official support for study and development of his ideas but was ultimately forced to pursue his research on his own initiative.

He received his first patent on turbojet propulsion in January 1930.

Armed with this patent, Whittle again sought funding to develop a prototype; this time successfully. He began construction of his first engine in 1935 -- a single-stage centrifugal compressor coupled to a single-stage turbine. What was meant to be only a laboratory test rig was successfully bench-tested in April 1937, effectively demonstrating the feasibility of the turbojet concept.

Power Jets Ltd. -- the firm with which Whittle was associated -- received a contract for a Whittle engine known as the W1 on July 7, 1939. In February 1940, the Gloster Aircraft Company was chosen to develop the Pioneer, the small engine aircraft the W1 engine was earmarked to power; the historic first flight of the Pioneer took place on May 15, 1941.

The modern turbojet engine used today in many British and American aircraft is based on the prototype invented by Whittle.

1.2.2 Timeline

1: Before the first century

The Aeolipile was created by Hero of Alexandria.

It is the first known jet engine.

2: 1791

First gas powered jet engine.

Made in Germany

3: 1930

Frank Whittle submitted his own patent for an aircraft engine. This is the design for the modern turbojet.

4: 1932

Frank Whittles Patent was granted.

5: 1935

Hans Von Ohain started working on similar designs as Frank Whittle

6: 1937

Hans Von Ohain had his first engine running properly

7: 1937

Frank Whittle has his first working engine.

8: 1939

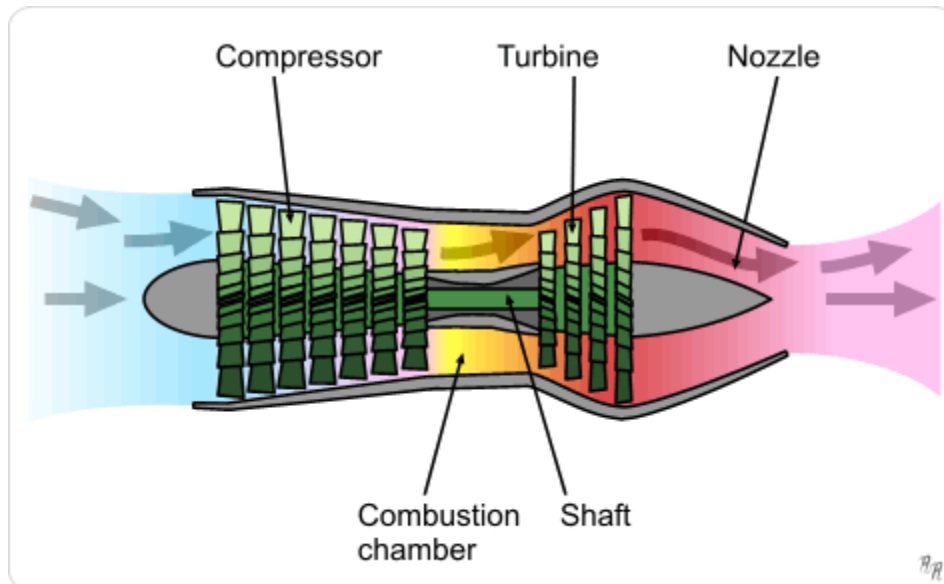
The jet arrived when Erich Warsitz flew a turbojet aircraft across the Atlantic.

9: 1947

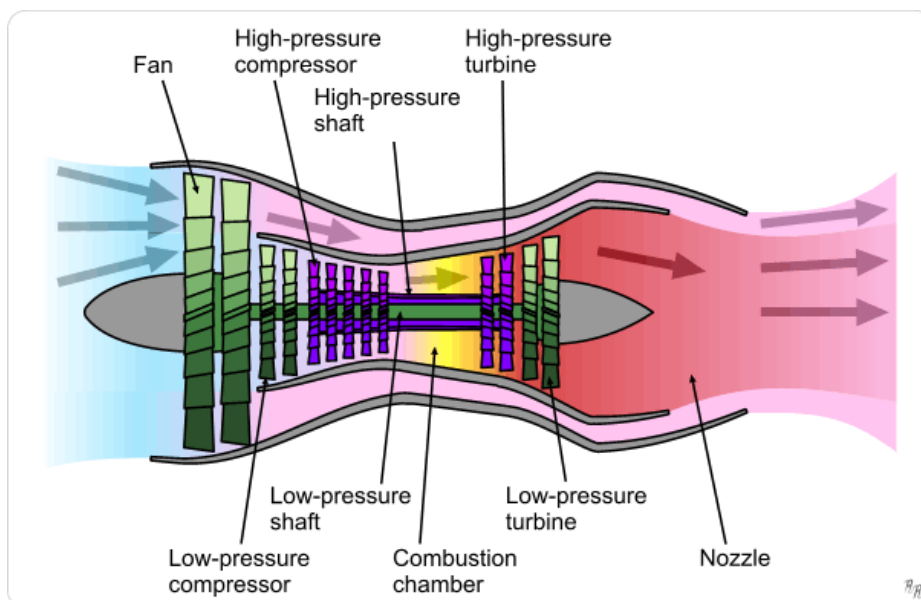
A Bell 1 rocket plane reached 964 Mile per Hour. (Mach 1.06) It is the first aircraft to reach Mach 1

1.3 Evolution of Jet Engines

The early days of jets were marked by loud, screaming engines that literally blew your ears out when one flew past, which is in great contrast to the low rumble or mechanical whine you hear today. This is because the fundamental design has changed drastically over the past six decades.

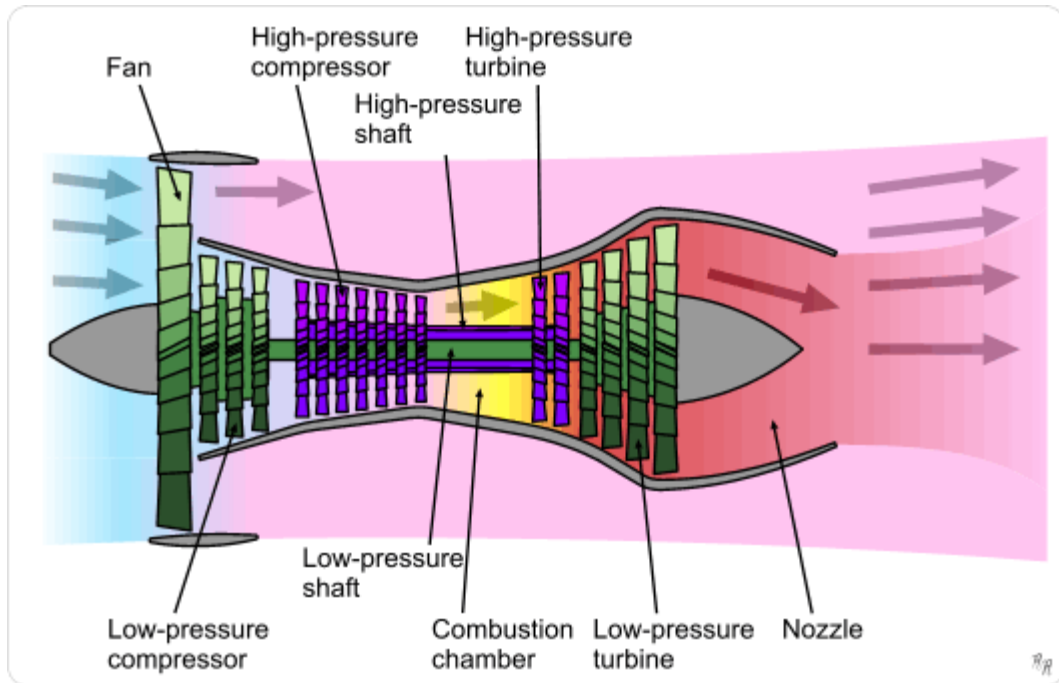


The diagram illustrates the traditional jet engine, a turbojet, where air is sucked in through the compressor, gets combusted, and then exits the engine through the turbine, which also powers the compressor. There were two main problems with this design. The first was the noise; they literally screeched and screamed as the hot exhaust mixed with cold atmospheric air. The second was the efficiency. These jets were gas-guzzlers because all the air that would be used to produce thrust first needed to be combusted with fuel in the combustion chamber.



Before long, someone realized that not all the air was needed to power a jet engine, and thus the idea of bypass jet engines appeared. As this diagram shows, not all the air is combusted; some of it travels around the “core”, instead traveling around it. This solved the two problems with turbojets. Fuel efficiency greatly improved because only part of the air inducted by the fan needed to be mixed with fuel and combusted, and noise was also significantly reduced thanks to

a layer of cool bypass air surrounding the hot air coming out of the turbines. Because of later developments, these engines are called low bypass ratio turbofans.



As demand for thrust increased, bypass ratios grew. The engines you see on the majority of commercial airliners today are of the type illustrated to the left. They have a huge fan at the front of the engine, with most of the air bypassing the core. These are high bypass ratio turbofans. The common bypass ratio used to differentiate this type of engine from the type above is a bypass ratio of 3:1, which means three times the volume of air bypasses the core compared to the volume of air that travels through the core.

1.3.1 Types of Jets

A. Turboprop Jet Engine

A turboprop engine is a jet engine attached to a propeller. The turbine at the back is turned by the hot gasses, and this turns a shaft that drives the propeller. Some small airliners and transport aircraft are powered by turboprops.

Like the turbojet, the turboprop engine consists of a compressor, combustion chamber, and turbine, the air and gas pressure is used to run the turbine, which then creates power to drive the compressor. Compared with a turbojet engine, the turboprop has better propulsion efficiency at flight speeds below about 500 miles per hour. Modern turboprop engines are equipped with propellers that have a smaller diameter but a larger number of blades for efficient operation at much higher flight speeds. To accommodate the higher flight speeds, the blades are scimitar-

shaped with swept-back leading edges at the blade tips. Engines featuring such propellers are called prop fans.

Hungarian, Gyorgy Jendrassik who worked for the Ganz wagon works in Budapest designed the very first working turboprop engine in 1938. Called the Cs-1, Jendrassik's engine was first tested in August of 1940; the Cs-1 was abandoned in 1941 without going into production due to the War. Max Mueller designed the first turboprop engine that went into production in 1942.

B. Turbofan Jet

A turbofan engine has a large fan at the front, which sucks in air. Most of the airflow around the outside of the engine, making it quieter and giving more thrust at low speeds. Most of today's airliners are powered by turbofans. In a turbojet, all the air entering the intake passes through the gas generator, which is composed of the compressor, combustion chamber, and turbine. In a turbofan engine, only a portion of the incoming air goes into the combustion chamber.

The remainder passes through a fan, or low-pressure compressor, and is ejected directly as a "cold" jet or mixed with the gas-generator exhaust to produce a "hot" jet. The objective of this sort of bypass system is to increase thrust without increasing fuel consumption. It achieves this by increasing the total air-mass flow and reducing the velocity within the same total energy supply.

C. Turbo Shaft Engines

This is another form of gas-turbine engine that operates much like a turboprop system. It does not drive a propeller. Instead, it provides power for a helicopter rotor. The turboshaft engine is designed so that the speed of the helicopter rotor is independent of the rotating speed of the gas generator. This permits the rotor speed to be kept constant even when the speed of the generator is varied to modulate the amount of power produced.

D. Ramjets

The simplest jet engine has no moving parts. The speed of the jet "rams" or forces air into the engine. It is essentially a turbojet in which rotating machinery has been omitted. Its application is restricted by the fact that its compression ratio depends wholly on forward speed. The ramjet develops no static thrust and very little thrust in general below the speed of sound. As a consequence, a ramjet vehicle requires some form of assisted takeoff, such as another aircraft. It has been used primarily in guided-missile systems. Space vehicles use this type of jet.

1.4 Turbo Machinery

1.4.1. Introduction

A turbomachine is a device in which energy transfer occurs between a flowing fluid and a rotating element due to dynamic action, and results in a change in pressure and momentum of the fluid. Mechanical energy transfer occurs inside or outside of the turbomachine, usually in a steady-flow process. Turbomachines include all those machines that produce power, such as turbines, as well as those types that produce a head or pressure, such as centrifugal pumps and compressors. The turbomachine extracts energy from or imparts energy to a continuously moving stream of fluid.

However, in a positive displacement machine, it is intermittent. The turbomachine as described above covers a wide range of machines, such as gas turbines, steam turbines, centrifugal pumps, centrifugal and axial flow compressors, windmills, water wheels, and hydraulic turbines. In this text, we shall deal with incompressible and compressible fluid flow machines.

Turbomachines in which fluid moves through the rotating member in axial direction with no radial movement of the streamlines. Such machines are called axial flow machines whereas if the flow is essentially radial, it is called a radial flow or centrifugal flow machine.

1.4.2. Brayton cycle

The Brayton cycle is a thermodynamic cycle named after George Brayton that describes the workings of a constant-pressure heat engine. The original Brayton engines used a piston compressor and piston expander, but more modern gas turbine engines and airbreathing jet engines also follow the Brayton cycle. Although the cycle is usually run as an open system (and indeed must be run as such if internal combustion is used), it is conventionally assumed for the purposes of thermodynamic analysis that the exhaust gases are reused in the intake, enabling analysis as a closed system.

The engine cycle is named after George Brayton (1830–1892), the American engineer who developed it originally for use in piston engines, although it was originally proposed and patented by Englishman John Barber in 1791. It is also sometimes known as the Joule cycle. The reversed Joule cycle uses an external heat source and incorporates the use of a regenerator. One type of Brayton cycle is open to the atmosphere and uses an internal combustion chamber; and another type is closed and uses a heat exchanger.

A Brayton-type engine consists of three components: a compressor, a mixing chamber, and an expander.

Modern Brayton engines are almost always a turbine type, although Brayton only made piston engines. In the original 19th-century Brayton engine, ambient air is drawn into a piston compressor, where it is compressed; ideally an isentropic process. The compressed air then runs through a mixing chamber where fuel is added, an isobaric process. The pressurized air and fuel mixture is then ignited in an expansion cylinder and energy is released, causing the heated air and combustion products to expand through a piston/cylinder, another ideally isentropic process. Some of the work extracted by the piston/cylinder is used to drive the compressor through a crankshaft arrangement.

Gas turbines are also Brayton engines. This also has three components: a gas compressor, a burner (or combustion chamber), and an expansion turbine.

Ideal Brayton cycle:

Isentropic process – ambient air is drawn into the compressor, where it is pressurized.

Isobaric process – the compressed air then runs through a combustion chamber, where fuel is burned, heating that air—a constant-pressure process, since the chamber is open to flow in and out.

Isentropic process – the heated, pressurized air then gives up its energy, expanding through a turbine (or series of turbines). Some of the work extracted by the turbine is used to drive the compressor.

Isobaric process – heat rejection (in the atmosphere).

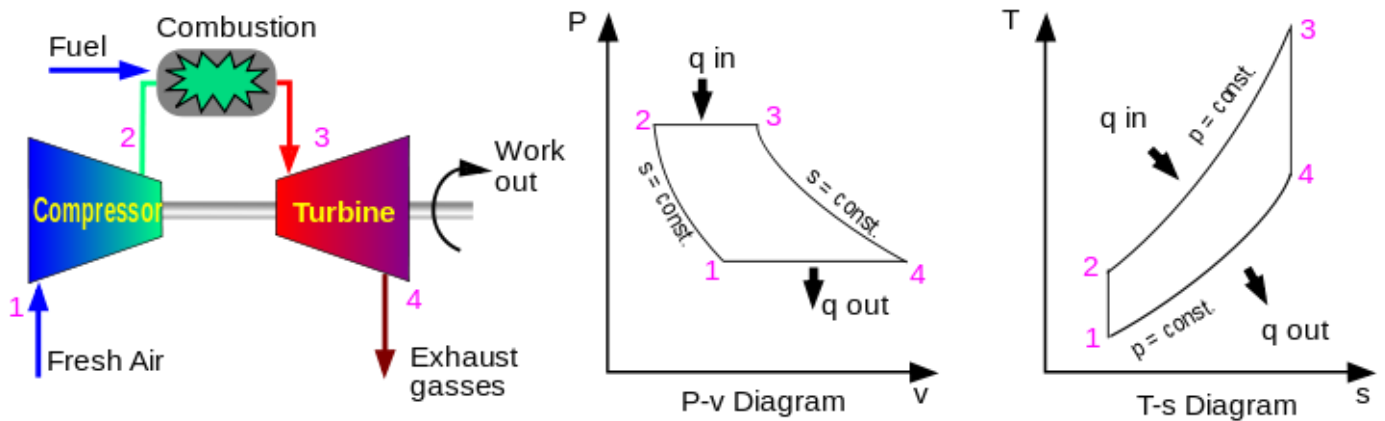
Actual Brayton cycle:

adiabatic process – compression

isobaric process – heat addition

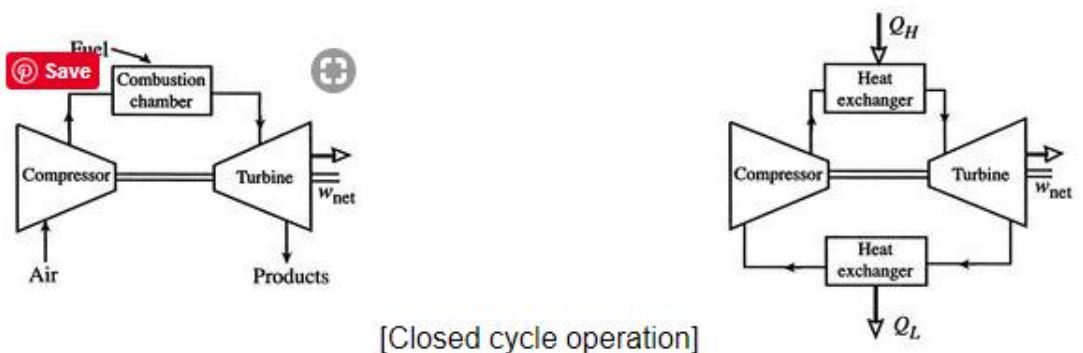
adiabatic process – expansion

isobaric process – heat rejection



1.4.3. Simple jet engine cycle

They are two types of jet engine cycles:



Adding a compressor to a ramjet powered by a turbine in the exhaust allows increased combustor inlet temperature, and a consequent increase in possible thermal efficiency. The turbine however is limited in the temperature it can handle, so maximum power is also limited.

In the T-S diagram below the presence of the compressor allows us to raise the combustor inlet temperature. The raising of the combustor segment increases the cycle area and the thermal efficiency.

1.5 Model Jet Engine to Date

These are some of the present model jet engines:

1) PBS TJ150

The PBS TJ150 jet engine was developed for unmanned vehicles, training targets and missiles.

Its advantage is its compact design, low weight with a thrust of up to 1,500 N, and low fuel consumption in the given power category. The generator output is 750 W. One of the PBS TJ150 engine versions enables landing on water. The PBS TJ150 engine is a single-shaft jet engine consisting of a radial compressor, radial and axial diffuser, annular combustion chamber, axial turbine and a fixed outlet nozzle.

Standard accessories: included: control system (FADEC), ignition, connecting cable

Optional accessories: electromagnetic fuel valve, fuel filter, control lever, signaling panel, boost pump, reduction valve, converter CAN, converter CAN-USB, user software.



2) PBS TJ40-G1

It is a turbojet engine designed for UAV systems, such as target drones and decoy drones, in order to confuse enemy air defenses and small reconnaissance drones. It has the advantage of having a weight of only 7.16 lb. (3.25 kg) and a thrust of 88.8 lbf (395 N).



3) KJ-66

The KJ-66 engine around a KKK turbocharger compressor No 2018. This has 2 advantages, the compressor is readily available in reasonably well balanced condition and it can withstand higher rpm than it will encounter in the engine.

This engine represents major advance over the FD3 64 and has been further developed to produce 50 Newtonthrust (11 lbs). It will run reliably with the revised chamber at a temperature of 550 deg C or cooler.



CHAPTER II

LITERATURE REVIEW

- 1) Onkar Patel: “A REVIEW ON TURBO JET ENGINE” In this review paper describe the turbo jet engine’s his working and device use in turbo jet engine twine spool turbo jet engine factor affecting thrust. Air velocity air temperature system component energy balance.
- 2) Patrick Hendrick: “RESEARCH ON SMALL TURBOJET ENGINES AT THE ROYALMILITARY ACADEMY OF BELGIUM” High speed and high-altitude UAV and MAV flight requires certain qualities of the installed engine(s). The use of turbojets for this purpose is justified, though, the engines can lack performance, which might be countered with inlet precooling. This paper describes the research done at the RMA on inlet precooling. Mainly the influence of the precooling on the thrust and the TSFC of the SR-30mini turbojet are covered. Here, the precooling is obtained through injection of liquid nitrogen in the engine inlet. Theory and experiments are compared and the influence of icing on the performance of the engine is discussed.
- 3) Edwin Cyril: “A Study on Mini Jet Engine” The use of Mini Jet Engines in the present scenario is very limited. They provide many advantages over conventional reciprocating engines such as high power to weight ratio, cleaner combustion, a smaller number of moving parts etc. These advantages along with their Smaller Size and Lower Weight they present themselves as the ideal alternative to reciprocating engines in hybrid vehicles. The features of the engine are studied in detail and brought forth in this project wherein a mini jet engine is designed, fabricated, assembled and run at operating speeds.
- 4) Jassem M.: “Contribution in Development of Design and Performance of Turbine Jet Engine” A turbine jet engine has four main parts, they are compressor, combustion chamber, turbine and exhaust nozzle. Turbine jet engine operates at an open cycle called a jet propulsion cycle. A small-scale turbine jet engine comprises of the same element as the gas-turbine engine but in a small scale. Turbine jet engines are constructed mainly for air transportation while the turbine jet engines are developed for a wider purpose, ranging for research activity to hobbyist enthusiastic. Hence, this paper encompasses the design, fabrication, and testing a turbine jet engine. The engine is derived from an automobile turbocharger, which provided the turbine and compressor component. A combustion chamber is design and fabricated. Engine support system comprised of ignition, lubrication and fuel delivery system are installed at the engine. Thermocouple K-type are installed at four different stations on the engine flow path to measure the temperature. Fuel regulators are utilized to measure the fuel flow rate. The design of the combustion chamber is developed to make primary and secondary air takes paths to allow a series of combustion processes that help to increase the speed of a jet engine.
- 5) Prabodh Singh Virdi1: “Design and Fabrication of Major Components of Turbojet Engine”. In this work, a centrifugal type impeller has been designed using Ansys software to develop a pressure of 2.9 bar at the mass flow rate of 0.6 kg/s and suitable diffuser has been designed to guide the air flow in required direction using the same software. According to the pressure and mass flow rate available annular type of combustion chamber has been designed to produce suitable temperature. The turbine rotor, having reaction 0.4974 has been designed to produce the power required to run the impeller and the accessories in a single stage utilizing the pressure and temperature available which has greatly reduced the cost of manufacturing. Aerofoil shape required for blade has been developed using Bludgeon tool of Ansys software. Impeller and diffuser have been produced using Aluminium by CNC machining. To endure the high temperatures developed, Stainless Steel is used for combustion chamber and produced using basic machining processes. Oil hardened Nickel steel is the material used to manufacture the stator and rotor of a turbine section and it is done using CNC machining process. All the above components have been successfully assembled.

- 6) Nick Strahan: A turbocharger jet engine combines knowledge of fluid mechanics, thermodynamics, heat transfer, machine elements and jet propulsion. This paper describes how we built a jet engine using a truck turbocharger. We review the history of jet engines, types of jet engines, how we built our jet engine and the engineering analysis behind it. We calculated specific thrust, specific fuel consumption, and the adiabatic flame temperature using concepts we learned from jet propulsion and thermodynamics classes. We machined an air handling system out of stainless steel and built a fuel system, cooling oil system and ignition system to run the engine.

CHAPTER III

TURBOCHARGERS

3.0 Introduction

A turbocharger is a centrifugal compressor powered by a turbine that is driven by an engine's exhaust gases. A turbocharger's purpose is to compress the oxygen entering a car's engine, increasing the amount of oxygen that enters and thereby increasing the power output. The turbocharger is powered by the car's own exhaust gases. In other words, a turbocharger takes a by-product of the engine that would otherwise be useless, and uses it to increase the car's horsepower.

Turbocharger compressor: Turbocharger compressors are generally centrifugal compressors consisting of three essential components: compressor wheel, diffuser, and housing. With the rotational speed of the wheel, air is drawn in axially, accelerated to high velocity and then expelled in a radial direction.

Turbocharger turbine: The turbocharger turbine, which consists of a turbine wheel and turbine housing, converts the engine exhaust gas into mechanical energy to drive the compressor. The gas, which is restricted by the turbine's flow cross-sectional area, results in a pressure and temperature drop between the inlet and outlet. This pressure drop is converted by the turbine into kinetic energy to drive the turbine wheel.

The turbojet engine makes use of a large diesel truck turbocharger; this is simply because the turbocharger serves as an integrated compressor and turbine assembly. Thus eliminating to construct or separately search for the individual compressor and turbine units. This reduces a great deal of task as far as making of the project is concerned. The construction of the turbocharger has already been explained in the component description, it resembles very much like an actual gas turbine with centrifugal compressor coupled to the radial turbine, supported by a hydrodynamic bearing system. The combustion chamber is not present in turbocharger. The working cycle of the turbocharger matches with that of the simple gas turbine. Thus the

functional working of the turbocharger at least for this project is same as that of the simple gas turbine. The working of the turbocharger is explained below.

3.2 Working of Turbocharger

Working of turbocharger:

1. Through the air inlet the ambient air enters the compressor of the turbo.
2. The air is then compressed to increased density (mass/unit volume flow). Air enters the compressor at a temperature equivalent to atmosphere, but as compression causes the temperature to rise, it leaves the compressor at temperatures of 200 degrees C and more at high boost applications.
3. Sometimes a charge air cooler (intercooler) is employed after compressor unit that cools the compressed air to further increase its density and thus the amount of oxygen in same volume of air charge.
4. After passing through the outlet of the compressor, the air enters the combustion chamber where the air is mixed with the fuel to form a combustible air fuel mixture which is then burned.
5. After the air fuel mixture is burned in the combustion chamber it then flows into the turbine housing.
6. The high temperature gases then continue on to the radial turbine blades. The turbine rotates due to the impulse action of the high temperature high pressure gases.
7. A pressure and temperature drop occurs (heat expansion) across the turbine, which harnesses the exhaust gas energy to provide the power necessary to drive the compressor.
8. Not all the power produced by the turbocharger turbine is used to drive the compressor, part of the energy of the hot gases is used to drive the compressor and part is exhausted to the atmosphere.
9. In order to make some use of these exhausting hot gases which is otherwise wasted, we make use of an exhaust nozzle. The exhaust nozzle is a convergent nozzle which adiabatically converts

the pressure energy of the exhaust gases in to kinetic energy. This kinetic energy is used to get the useful thrust which can be suitably used for propulsive application.

3.3 Selection of Turbocharger

There are a number of factors, such as turbo lag, boost threshold, heat, back-pressure, low-end torque, and top-end power, that must be taken into account when selecting a turbo. A large turbo will suffer from turbo lag and won't produce much low-end torque but it also won't put too much heat to the intake charge, won't have much back-pressure, and will produce loads of top-end power. A small turbo, on the other hand, won't have much turbo lag and will produce loads of low-end torque but will also have lots of back-pressure and will add lots of heat to the intake charge. The turbocharger selection based on the operating characteristics of the compressor and turbine is widely used for the selection of turbocharger for passenger cars. For the turbojet engine application the turbocharger is selected on the basis of the compressor and turbine maps.

Operating characteristics of Compressor:

The compressor operating behavior is generally defined by maps showing the relationship between pressure ratio and volume or mass flow rate. The useable section of the map relating to centrifugal compressor is limited by the surge and choke lines and the maximum permissible compressor speed.

Surge line

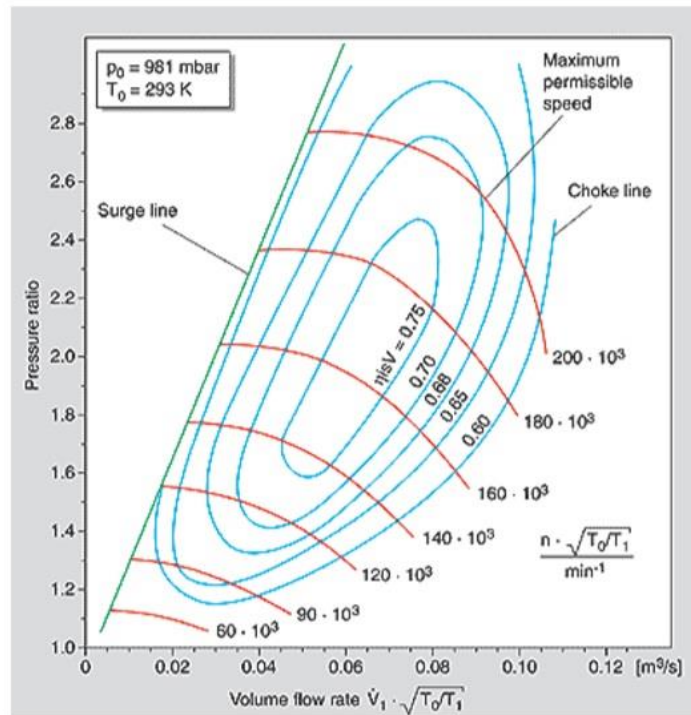


Fig: Compressor map of a turbocharger for passenger car applications

The map width is limited on the left by the surge line. This is basically "stalling" of the air flow at the compressor inlet. With too small a volume flow and too high a pressure ratio, the flow can no longer adhere to the suction side of the blades, with the result that the discharge process is interrupted. The air flow through the compressor is reversed until a stable pressure ratio with positive volume flow rate is reached, the pressure builds up again and the cycle repeats. This flow instability continues at a fixed frequency and the resultant noise is known as "surging".

Choke line

The maximum centrifugal compressor volume flow rate is normally limited by the cross-section at the compressor inlet. When the flow at the wheel inlet reaches sonic velocity, no further flow rate increase is possible. The choke line can be recognized by the steeply descending speed lines at the right on the compressor map.

Operating characteristics Turbine

The turbine's characteristic behavior is determined by the specific flow cross-section, the throat cross-section, in the transition area of the inlet channel to the volute. By reducing this throat cross-section, more exhaust gas is dammed upstream of the turbine and the turbine performance increases as a result of the higher pressure ratio. A smaller flow cross-section therefore results in

higher boost pressures. The turbine's flow cross-sectional area can be easily varied by changing the turbine housing.

Besides the turbine housing flow cross-sectional area, the exit area at the wheel inlet also influences the turbine's mass flow capacity.

The operating characteristics of exhaust gas turbocharger turbines are described by maps showing the flow parameters plotted against the turbine pressure ratio. The turbine map shows the mass flow curves and the turbine efficiency for various speeds. To simplify the map, the mass flow curves, as well as the efficiency, can be shown by a mean curve

For high overall turbocharger efficiency, the co-ordination of compressor and turbine wheel diameters is of vital importance. The position of the operating point on the compressor map determines the turbocharger speed. The turbine wheel diameter has to be such that the turbine efficiency is maximized in this operating range.

Requirements of Turbocharger:

1. It should be a diesel truck turbocharger.
2. It should be sturdy and robust to withstand high speeds, stresses and forces.
3. Compressor pressure ratio should be around 2.5.
4. Operating speed of the turbocharger must be greater than 70,000 rpm.
5. Turbine pressure ratio/Boost pressure should be high around 2.
6. Individual efficiencies of the compressor and turbine should be high.
7. Turbocharger should be able to withstand high dynamic vibrations.
8. Turbo lag should be minimum
9. Back pressure should be minimum
10. Turbo bearing must be hydrodynamic bearing with forced lubrication mechanism.
11. The lubrication system should be simple and easy to maintain.
12. The turbo lubricant should be easily available and cheap.
13. Operating temperatures of turbine should be high around 1000 degree Celsius.
14. High reliability at top speeds.

15. Overall maintenance of the turbocharger should be easy; turbocharger parts should be easily available.

CHAPTER IV

COMPONENTS OF MODEL JET ENGINE

4.1 Compressor

The chosen compressor was a radial compressor, taken from a turbocharger used in an automotive engine. This was seen as the easiest way to get a compressor without building one. But after further work and study on the subject it became clear that the compressor used was insufficient for the design made. As can be seen in fig 30 the compressor's intended range of operation is at very high speeds, and even then the pressure ratio is not particularly high, there is not even any data for the speeds we could hope to achieve. We made the conclusion that this turbo was made with high efficiency rather than high pressures in mind. The compressor had backwards curved vanes, which gives a lesser flow rate than one of radial vanes but instead it has a higher efficiency. The assumption that it would be too hard to make a compressor, may have been wrong. After being in the workshop, and later noticing the insufficient compressor, the idea of making a compressor did not seem so distant anymore. It would be possible to make a compressor with radial vanes, which is not as efficient as backwards curved vanes but airflow and compression is higher, and the operating range of the compressor could be made to fit the rest of the engine.

4.2 Diffuser

The compressor on the turbocharger serves the same function as the compressor on the turbojet engine. It is used to compress a large amount of air into a small space and increase pressure. The compressor wheel turns at a very high speed; usually between 45,000 and 1,25,000 rpm. the larger truck turbochargers turn about 75,000 rpm. The compressor wheel is usually made from an aluminum alloy. It does not run at a high temperature so aluminum works fine. The compressed air exits the compressor into a diffuser. This is usually a casting that increases in area so that the air will be slowed down and the pressure will increase. The compressor end contains the impeller. It is usually an investment casting of aluminum alloy. The blades near the center are called the inducer vanes and are used to draw the air into the compressor where the radial blades accelerate it. The air then passes into the snail shaped housing called the diffuser.

4.3 Combustion chamber

The chosen combustion chamber was of annular type. Compared to the other can and can-annular, the annular type is of a more solid and simple construction and has the possibility to give the most efficient combustion. It is structurally the easiest to build, and is great for a simple construction. A disadvantage of the annular combustion chamber is that replacement will require an engine disassembly, which is expensive and time consuming, for us this is not an issue.

4.4 Turbine

The turbine was of axial type, which is the most common turbine type. It was made from a steel hub, and was planned to have turbine blades welded to the hub. Due to an undersized compressor, work was aborted on the engine, and the turbine was left unfinished.

4.5 Drive Shaft and Bearings

The shaft was made out of a steel rod to create a solid structure, with the bearings connecting the shaft to the engine. The turbine drives the compressor by means of a drive shaft, usually a very short, small diameter shaft that is friction welded to the turbine wheel and bolted to the compressor. The shaft runs through an aluminum bearing

The maximum allowed speed of the bearings was listed at 50,000 rpm. Another factor in how fast we could make the engine spin is balancing of all the rotating parts, which is a complicated process, requiring a lot of precision and patience. This caused some problems with the compressor, as these speeds would not be sufficient to achieve compression ratios needed for a self-sustaining cycle. Most modern turbochargers use hydrodynamic bearings. This is an alloy sleeve bearing with design tolerances that allow a layer of oil between the shaft and the bearing. When the turbocharger is running, the oil supply is under pressure and the shaft rides on a layer of oil and does not touch the alloy bearing. The shaft is suspended on a layer of oil. The trust bearing on the turbine end rides on a layer of oil and is cooled by oil. The turbine end bearing runs extremely hot, usually about 1,800 deg. F. Large quantities of oil must be circulated to provide adequate cooling.

1. Design procedure for Model jet engine

1.1. Preliminary equipment and materials

1.1.1. Material selection

The materials require to model a turbo jet engine are quite available in the local scrap iron and steel stores. The selection of the materials is done based on the engineering standards, type of purpose and the environment in which they were used.

the material specification is done based on the engineering and the construction parameters. Most of the parts and the materials are bought form the scrap and from the unused components so that we could achieve a less budget in fabrication of this engine. The list of components with their respective materials can be found in the table 1.1.

most of the materials are of high grade materials because in building an machine like jet engine one should be very careful while judging the material of purpose because these engines can produce a quite number of dynamic forces while running so, one should be quite aware with the properties of the material such as with which metal and the temperature with which these can be withstand and the strength ,durability, deformability and the stress generated along with their behavior with respect to temperature change. Since, there engines operate on high temperatures which can be vary from hundreds to thousands of degrees which is so high that a specific material could for a specific task.

These engines are continuous energy generating engines, so the energy is liberated continuously due to this these engines rotates at high speeds which are far greater that the conventional speed of sound. So, the speed of them are measure in terms of “Mach number.” For this reason, the materials which bear a large amount of torsional stress and the centrifugal force should be considered.

One should be through with the properties and the applications of these materials so that I the case if the desired material is unavailable the modeler should choose a best suitable alternative material

The material used mostly are ferrous (MS, SS, CI etc....) and the other materials such as aluminum alloys for compressors and the Ni-Cr steel for the turbine because it should withstand high thermal stress and high speeds. The casings of the jet engine model are made from Mild steel material and the shaft and the housing are made from the high-quality Stainless-Steel material. other components like the combustion chamber which is made from the SS sheet and the components which produce high heats are made from the copper material such as ignition pipe and the nozzle guide vanes.

1.1.2. Tools and Equipment's used

There are various tools with which one can build the model but the following are the mostly used and are also found frequently in the workshops and at engineering works.

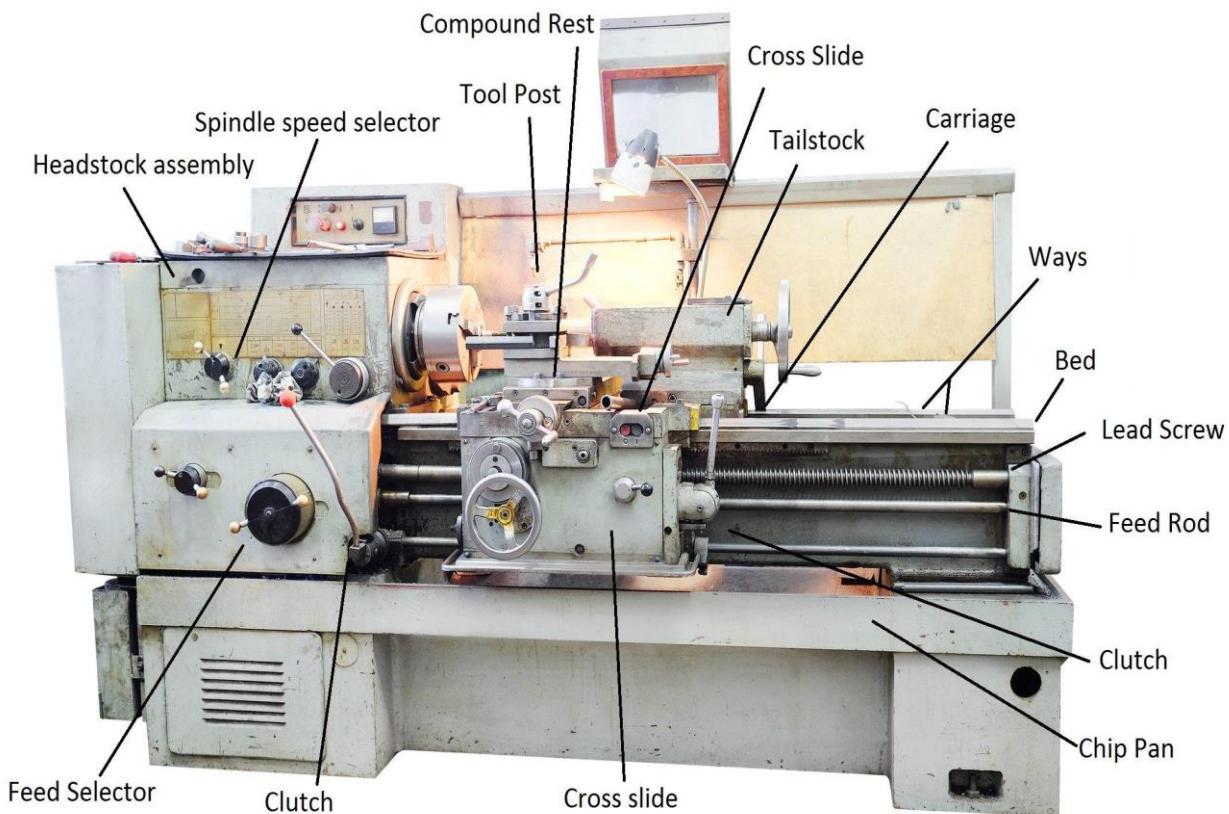
The following are the list of tools and equipment's used for the fabrication of the model jet engine :

1. Lathe Machine
2. CNC machine
3. Radial drilling machine
4. Arc Welding machine
5. Sheet Rolling machine
6. Oxy-fuel welding and cutting
7. Miscellaneous tools such as hand drill, Angle grinder

1. Lathe machine

Lathe is a machine that helps in shaping several material pieces in the desired shapes. A lathe is a machine that rotates the piece on the axis in order to perform various operations like cutting, facing, knurling, threading and more. Metal spinning, thermal spraying, woodturning and metalworking are the common operations performed with a lathe machine. One can even shape pottery with this working wonder. Whatever material used in lathe machine whether metal or wood is molded first.

The wood piece is placed in between the headstock and the tailstock of the lathe. Clamping is also used to work the piece about the axis of rotation with the help of a faceplate, clamps/dogs or collet/chuck. The products produced with the help of the lathe machine are cue sticks, musical instruments, candlestick holders, table legs, baseball bats, gun barrels, camshafts, bowls, crankshafts and much more. There are plenty of lathe that vary in sizes and shapes according to the work to be done



2. CNC Machine

CNC machines are computer-controlled machine tools. With CNC, a computer controls servo that operate the machine. NC, and later CNC, allowed for tremendous increases in productivity for machine tools because the machines could be run automatically without requiring constant attention from their operator.

The taper attachments available for many manual lathes are not unlike the hydraulic tracer capability, it's just that the tracer is capable of more elaborate templates than simple tapers. But the advent of first NC and then later CNC radically increased the amount of automation that was possible. CNC Machining is dominant method of machining materials these days, though manual machining is still quite common as well for one-offs, repair, and prototyping work.

The individuals that run CNC Machines on Shop Floors are called "CNC Operators," while those that write the programs to automate production are "CNC Programmers."

CNC Machines execute what are called "Part Programs" which are written in a special language called "G-Code." A g-code part program may either be directly coded, or CAM Software may be used to convert a CAD drawing of the part into g-code.



3. Radial drilling machine

The machine consists of a heavy, round, vertical column mounted on a large base. The column supports a radial arm which can be raised and lowered to accommodate work pieces of different height. The arm may be swung around at any position over the work bed. The drill head containing mechanism for rotating and feeding the drill is mounted on a radial arm and can be moved horizontally on the guide ways and can be clamped at any desired position. These three movements in a radial drilling machine can be combined to permit the drill to be located at any desired point on the work piece for drilling the hole. When several holes are drilled on a large work piece, the position of the arm and drill head is altered so that the drill spindle may be moved from one position to the other after drilling the hole without altering the setting of the work. This versatility of the machine allows it to work on large work pieces. The work may be mounted on the table or when the job is large it may be placed on the floor or in a pit.



4. Arc Welding machine

Arc welding is one of several fusion processes for joining metals. By applying intense heat, metal at the joint between two parts is melted and caused to intermix - directly, or more commonly, with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts. This is in sharp contrast to non-fusion processes of joining (i.e. soldering, brazing etc.) in which the mechanical and physical properties of the base materials cannot be duplicated at the joint.

In arc welding, the intense heat needed to melt metal is produced by an electric arc. The arc is formed between the actual work and an electrode (stick or wire) that is manually or mechanically guided along the joint. The electrode can either be a rod with the purpose of simply carrying the current between the tip and the work. Or, it may be a specially prepared rod or wire that not only conducts the current but also melts and supplies filler metal to the joint. Most welding in the manufacture of steel products uses the second type of electrode.

An arc is created across the gap when the energized circuit and the electrode tip touches the workpiece and is withdrawn, yet still with in close contact.

The arc produces a temperature of about 6500°F at the tip. This heat melts both the base metal and the electrode, producing a pool of molten metal sometimes called a "crater." The crater solidifies behind the electrode as it is moved along the joint. The result is a fusion bond.



5. Sheet Rolling machine

Metal rolling is one of the most important manufacturing processes in the modern world. Most of all metal products produced today are subject to metal rolling at one point in their manufacture. Metal rolling is often the first step in creating raw metal forms. The ingot or continuous casting is hot rolled into a bloom or a slab, these are the basic structures for the creation of a wide range of manufactured forms. Blooms typically have a square cross section of greater than 6x6 inches. Slabs are rectangular and are usually greater than 10 inches in width and more than 1.5 inches in thickness. Rolling is most often, (particularly in the case of the conversion of an ingot or continuous casting), performed hot.

At a rolling mill, blooms and slabs are further rolled down to intermediate parts such as plate, sheet, strip, coil, billets, bars and rods. Many of these products will be the starting material for subsequent manufacturing operations such as forging, sheet metal working, wire drawing, extrusion, and machining. Blooms are often rolled directly into I beams, H beams, channel beams, and T sections for structural applications. Rolled bar, of various shapes and special cross sections, is used in the machine building industry, as well as for construction. Rails, to produce railroad track, are rolled directly from blooms. Plates and sheets are rolled from slabs and are extremely important in the production of a wide range of manufactured items. Plates are generally considered to be over 1/4", (6mm), in thickness. Plates are used in heavy applications like boilers, bridges, nuclear vessels, large machines, tanks, and ships. Sheet is used to produce car bodies, buses, train cars, airplane fuselages, refrigerators, washers, dryers, other household appliances, office equipment, containers, and beverage cans, to name a few. It is important to understand the significance of metal rolling in industry today, as well as its integration with other manufacturing processes.



6. Oxy-fuel welding and cutting

Gas welding is a fusion welding process in which the heat for welding is obtained by the combustion of oxygen and fuel gas. The fuel gas may be acetylene, hydrogen, propane or butane. An intense gas flame is thus produced which melts the edges of the parts to be welded. The molten metal is allowed to flow to Solidify together and continuous joint is obtained.

The gas welding is particularly suitable for joining metal sheets and plates having thickness of 2 to 50 mm. An additional metal called filler material is used for thickness more than 15mm. This filler metal is used in the form of welding rod. The Composition of filler rod is usually same as that of base metal. The filler metal is used to fill up the cavity made during edge preparation. A flux material is also used during welding to remove impurities and oxides present on the metal surfaces to be joined.

Different combinations of gases are used to produce hot gas flame, e.g., Oxygen and acetylene, oxygen and hydrogen, oxygen and propane, air and acetylene etc. The combination of oxygen and acetylene is most widely used. This combination burns to produce a highest flame temperature of about 3200°C. Such a flame produced is known as Oxy-acetylene flame.



7. Miscellaneous tools such as hand drill, Angle grinder

Hand drill

In the workshop you probably use a 'hand drill' and a 'ratchet brace' as part of practical work. These are used for drilling a range of sizes of hole and they are very useful especially if machine drills are not available. The hand drill generally holds drill sizes from 1mm to 9mm whilst the brace will hold larger drill bits called 'forester bits' and 'auger bits.' These larger bits can be used to drill 'blind holes' (holes that do not go the entire way through material).



Angle Grinder

An angle grinder, also known as a side grinder or disc grinder, is a handheld power tool used for grinding (abrasive cutting) and polishing. Although developed originally as tools for rigid abrasive discs, the availability of an interchangeable power source has encouraged their use with a wide variety of cutters and attachments.



1.1.3. List of Materials:

ITEM NO.	PARTS	MATERIAL	DIMENSIONS/NOTES
1	shaft	SS-304	Turned
2	housing	SS-316	Turned
3	bearing	High Carbon Chrome Steel	Radial/Deep Groove Ball Bearing
4	compressor	Al-Si alloy	Holset(hx40) Ready made
5	diffuser	Al-6061	Milling
6	Compressor cover	Mild steel, Grade EN-8	Turned
7	Turbine cover	Mild steel, Grade EN-8	Turned
8	nozzle vane guide modified	SS-304	Milling
9	combustion chamber modified	SS-304, Sheet	Bending, Brazing
10	ignition pipe modified	Copper	Sheet Rolling, 2mm
11	pipe 140mm	Mild steel	Ø140mm ID, Ø 155 OD
12	turbine wheel	Ni-Cr Steel	K418 Turbo Turbine Wheel, Ø 75.45 ready made

Table – 1.1

- Various other small parts such as screws, nuts and clips not listed individually

1.2. Design Calculations

1.2.1. Jet Engine Cycle calculations

The calculation of a Model jet engine will be started by determining pressures and temperatures at different stages. The corresponding cycle is of Brayton cycle, calculations are the basis for designing the different stages of the model turbojet engine, here we will input the desired thrust and the initial conditions which are ambient, and the outlet temperature is taken by the operating conditions of similar systems.

$$T_a = 288.15\text{k}$$

$$P_a = 1.01325\text{bar}$$

$$T_3 = 873\text{k}$$

$$C_a = 340.29 \text{ m/s}$$

These parameters are assumed at this stage, these efficiencies are to be calculated at the later stages of the project calculations.

$$\text{Compressor Ratio: } 1.023$$

Isentropic Efficiency

$$1. \text{ Compressor Efficiency} = \eta_c = 0.74$$

$$2. \text{ Turbine Efficiency} = \eta_t = 0.75$$

$$3. \text{ Intake} = \eta_i = 0.90$$

$$4. \text{ Nozzle} = \eta_j = 0.95$$

$$5. \text{ Mechanical Efficiency} = \eta_m = 0.99$$

$$6. \text{ Combustion Efficiency} = \eta_b = 0.98$$

$$7. \text{ combustion pressure loss} = \Delta P_b = 0.06$$

As we have different pressure and temperature conditions, so we will use the temperature difference equation to determine the temperatures of inlet and outlet at different stages.

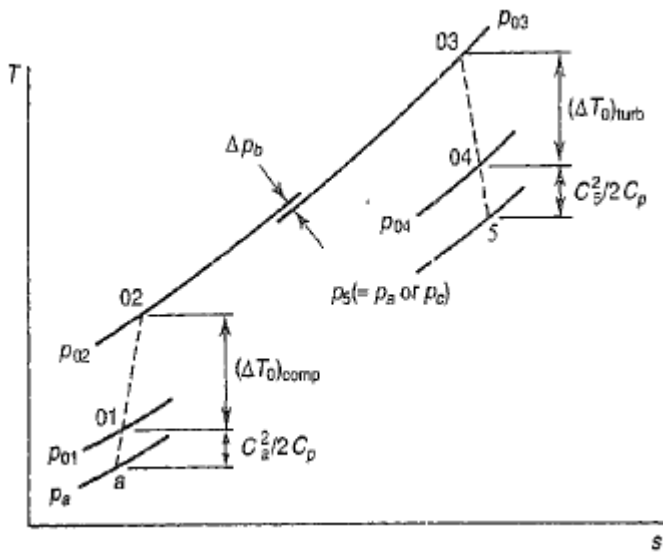


Fig 3: The Simple Turbojet Cycle Initial Conditions:

The stagnation conditions after the intake may be obtained as follows:

$$\frac{C_a^2}{2C_p} = 57.61K$$

$$T_{01} = T_{0a} + \frac{C_a^2}{2C_p} = 345.76K$$

Pressure ratio:

$$\frac{P_{01}}{P_a} = \left[1 + n_i \left(\frac{C_a^2}{2C_p} \right) \right]^{k/k-1} = 1.7844$$

$$P_{01} = 1.80811bar$$

At outlet from the compressor,

$$P_{02} = \frac{P_{02}}{P_{01}} \times P_{01} = 1.8496bar$$

$$T_{02} - T_{01} = \frac{T_{01}}{n_c} \left[\left(\frac{P_{02}}{P_{01}} \right)^{\frac{k-1}{k}} - 1 \right] = 3.045K$$

$$T_{02} = 345.76 + 3.045 = 348.805K$$

Work done by the compressor:

$$\frac{W_c}{\dot{m}} = C_{pa} (T_{02} - T_{01}) = 3.060W$$

Work done by the turbine:

$$\frac{W_t}{\dot{m}} = \frac{\frac{W_c}{\dot{m}}}{n_m} = 3.0911 \text{W}$$

The stagnation conditions at combustion chamber:

$$T_{03} - T_{04} = \frac{C_{pa} (T_{02} - T_{01})}{C_{pg} n_m} = 26.94 \text{K}$$

$$T_{04} = 846.06 \text{K (Turbine outlet temperature)}$$

$$P_{03} = P_{02} \left(1 - \frac{\Delta P_b}{P_{02}} \right) = 1.775616 \text{bar}$$

The actual temperature is given as

$$T'_{04} = T_{03} - \frac{1}{n_t} (T_{04} - T_{03}) = 837.08 \text{K}$$

$$P_{04} = P_{03} \left(\frac{T'_{04}}{T_{03}} \right)^{\frac{K}{k-1}} = 1.532 \text{bar} \quad (\text{here , } K = 1.333)$$

The nozzle pressure ratio is therefore,

$$\frac{P_{04}}{P_a} = 1.512657 \text{bar}$$

The critical pressure ratio

$$\frac{P_{04}}{P_c} = \frac{1}{\left(1 - \frac{1}{n_j} \left(\frac{k-1}{k} \right) \right)^{\frac{k}{k-1}}} = 1.9179 \text{bar}$$

Since, here $\frac{P_{04}}{P_c} > \frac{P_{04}}{P_a}$ the nozzle is unchoked

$$T_{05} = T_c = \left(\frac{2}{k+1} \right) T_{04} = 725.2046 \text{K}$$

$$P_{05} = P_c = P_{04} \times \frac{1}{\frac{P_{04}}{P_c}} = 0.7991 \text{bar}$$

$$\rho_{05} = \frac{P_c}{RT_c} = 0.3839 \frac{\text{kg}}{\text{m}^3}$$

$$C_5 = (kRT_c)^{0.5} = 526.72 \text{ m/s}$$

Mass flow rate at exit

$$\frac{A_{05}}{\dot{m}} = \frac{1}{\rho_{05} C_5} = 0.004945 \text{ m}^3/\text{kg}$$

The specific Thrust:

$$F_s = (C_{05} - C_{0a}) + \frac{A_5}{\dot{m}} (P_c - P_a) = 186.43 \text{ Ns/kg}$$

Specific fuel consumption

$$\text{Here, } T_{02} = 348.805\text{K}$$

$$T_{03} - T_{02} = 524.195\text{K}$$

To determine the theoretical fuel/air ratio, the value is obtained from the combustion temperature rise vs fuel/air ratio graph

From the given temperature we obtained fuel to air ratio is 0.0129

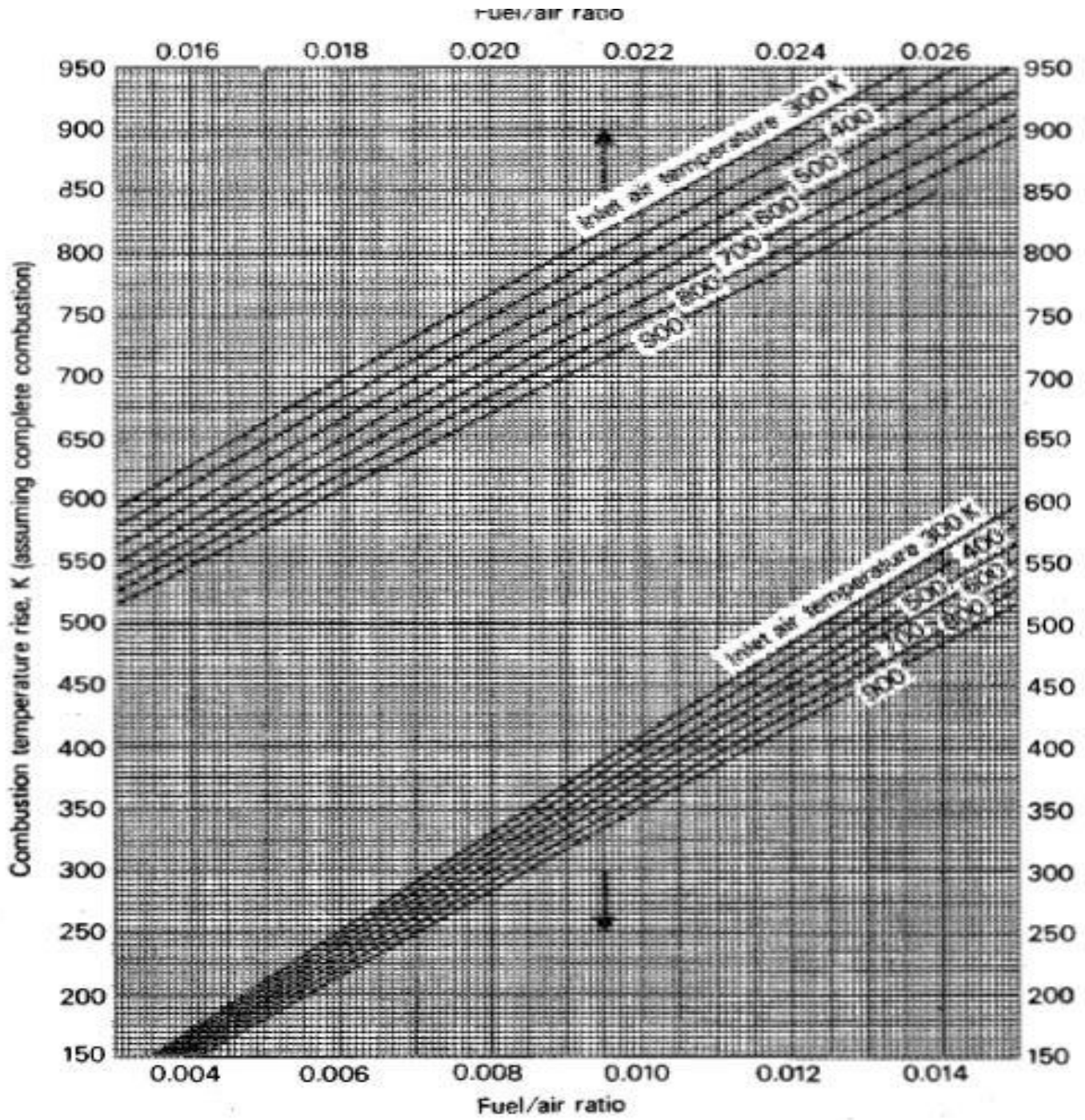
Then the actual fuel/air ratio is

$$f = \frac{\text{actual fuel/air ratio}}{\text{combustion efficiency}} = 0.013163$$

The specific fuel consumption (SFC):

$$\text{SFC} = \frac{f}{F_s} = 0.2541 \text{ kg/hN}$$

Table -1.2



1.3. CAD Modelling

1.3.1. Introduction to Solid Works

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows, Mac, Linux. SolidWorks is published by Dassault Systems. SolidWorks is a solid modeler and utilizes a parametric feature-based approach which was initially developed initially by PTC (Creo/Pro-Engineer) to create models and assemblies. The software is written on Parasolid-kernel.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other using relations, which allows them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface and will then honor their design intent no matter what height they later assign to the can.

Features refer to the building blocks of the part. They are the shapes and operations that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded or cut to add or remove material from the part. Operation-based features are not sketch-based, and include features such as fillets, chamfers, shells, applying draft to the faces of a part, etc.

SolidWorks files use the Microsoft Structured Storage file format. This means that there are various files embedded within each SLDDRW (drawing files), SLDPRT (part files), SLDASM (assembly files) file, including preview bitmaps and metadata sub-files. Various third-party tools (see COM Structured Storage) can be used to extract these sub-files, although the subfiles in many cases use proprietary binary file formats. Some of the packages offered by solid works are given below:

SOLIDWORKS Standard

- **3D Solid Modelling:** Accelerate your design, increase productivity, and reduce cost with 3D solid modelling with lifelike visualization and virtual testing before manufacturing.
- **Large Assembly Design:** Simplify design of large assemblies with easy-to-use tools to create, manage, and visualize large and complex designs that can contain more than 100,000 parts.
- **3D Animations and Basic Rendering:** Quickly and easily create powerful images and animations to communicate your design intent and functionality.
- First Pass Design Analysis: Verify operation and performance while creating your design with fully integrated wizard driven simulation and analysis tools.
- **Interference Check:** Verify that your parts and assemblies will fit, assemble, and operate correctly
- **2D Drawings:** Create production-ready 2D drawings that communicate how your design should be manufactured and assembled.
- **Sheet Metal Design:** Quickly and cost-effectively create a wide range of sheet metal part designs using a wide range of flexible tools to meet your specific needs.
- **Weldments:** Quickly create designs that have extrusions and easily generate cut lists and bills of materials to streamline design and manufacturing of welded structures, frames, and bases.
- **Mould Design:** Simplify mould design with fully integrated product design, mould design, and validation that updates all part files automatically to enable changes right up to final manufacturing.

- **CAD Import and Export:** Accelerate design, save time and development costs, and increase productivity by converting CAD data into a format that meets your design needs. You can also connect models from other CAD packages in SOLIDWORKS with [3D Interconnect](#).

SOLIDWORKS Professional Packages

- **File Management:** [SOLIDWORKS PDM Standard](#) helps individuals and small workgroups manage project data, control their design revisions, and control access to files, accelerating the design process and increasing productivity.
- **Manufacturing Cost Estimation & Quoting:** [SOLIDWORKS Costing](#) will save you time and development costs, avoid redesigns, and increase productivity by continuously checking your designs against cost targets with integrated cost estimation tools. On-line Cost Estimates via the [MySolidWorks Manufacturing Network](#). Get instant cost estimates from any manufacturer in the MySolidWorks Manufacturing Network.
- **ECAD/MCAD Data Sharing:** Share data between electrical CAD (ECAD) and mechanical CAD (MCAD) designers using the [Circuit Works](#) tool
- **Standards Checking:** [SOLIDWORKS Design Checker](#) allows you to establish design standards and easily check drawings (or models) to create uniform designs and related documentation, which speeds up product development, saves time, and increases productivity.
- **Design Collaboration:** Use powerful [e Drawings Professional](#) software to increase collaboration, accelerate your design process, and increase productivity by easily viewing and sharing SOLIDWORKS 3D models and 2D drawings in an email-ready format.
- **Task Scheduling:** [Task Scheduler](#), a software utility included with SOLIDWORKS Professional puts your system to work while you're away. It lets you run resource intensive processes (such as batch importing, exporting, and printing) when the computer is normally idle, freeing you to focus on more creative projects.
- **CAD Library:** [SOLIDWORKS Toolbox](#) provides libraries of prebuilt 3D CAD models and other CAD data that help accelerate the design process, save time and development costs, and increase productivity.
- **Tolerance Analysis:** Quickly and easily check dimensions and tolerances using SOLIDWORKS Professional [Tool Analyst software](#) to assess the manufacturability of your design long before reaching production. Check parts and assembly tolerances during design, accelerating the design process, saving time and development costs, and increasing productivity.
- **Advanced Photorealistic Rendering:** [SOLIDWORKS Visualize Standard](#) enables designers, engineers, and content creators across all industries to create compelling visual content of their designs with unparalleled ease and flexibility. By utilizing photo-quality content early in the design process, more informed design decisions can be made, as well as receiving useful early feedback from sales teams and potential customers.
- **Reverse Engineering:** [SOLIDWORKS ScanTo3D](#) will streamline the design process using SOLIDWORKS Professional to create new designs—or recreate existing designs—based on ones that already exist. Reverse engineering can accelerate product development and reduce risk, save time, and increase productivity.
- **Design for Manufacturability:** Check your design and verify manufacturability of your product early in the development process using SOLIDWORKS Professional, saving time and development costs, improving productivity, and accelerating your time-to-market.

SOLIDWORKS Premium Packages

- **Time Based Motion Analysis:** [SOLIDWORKS Motion](#) easily evaluates how your product will perform and move throughout its operational cycle with motion analysis. Visualize your product moving as it would in the real world and measure the forces and loads on your design.

- **Linear Stress Analysis:** Linear stress analysis enables designers and engineers to quickly and efficiently validate quality, performance, and safety—all while creating their design. Reduce the need for costly prototypes, eliminating rework, and save time and development costs.
- **Advanced Surface Flattening:** Often products like leather goods, sports equipment, footwear, and products made from composite materials, like carbon fibre and fiberglass, have complex shapes, but are manufactured from materials that start out as flat stock, such as cow hides, nylon, cloth, and flat composite sheet. With SOLIDWORKS Premium you can accurately determine or estimate the size and shape of surfaces in their flattened state in order to be able to cut the material from the flat sheet.
- **Piping and Tubing Design:** Accelerate the development process and save time by designing piping and tubing in 3D during system design with SOLIDWORKS Routing. By integrating piping and tubing during the design process, designers can help ensure efficient assembly, operation, and serviceability, avoiding rework, delays, and extra cost.
- **Electrical Cable Harness and Conduit Design:** Quickly design and route electrical wiring, harnessing, cabling, and conduit assemblies of products in 3D using the SOLIDWORKS Premium package. Integrating these systems during product design rather than adding them later accelerates your development process, saves time and rework costs, and helps to ensure efficient product assembly and serviceability.
- **Routing of Rectangular and Other Sections:** SOLIDWORKS Premium users can route rectangular and round sections to meet their design needs. Equipment designers, product designers, machine designers, facility designers and others all need rectangular section routing to complete their designs that include ducting, cable trays, conveyors, material handling chutes, and many other systems.

Simulation Standard

Simulation Professional

Simulation Premium

Statik für Baugruppen



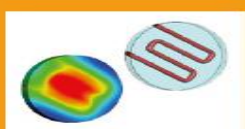
Motion



Frequenz



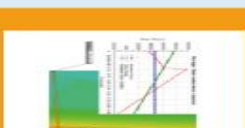
Thermisch



Event Based Motion



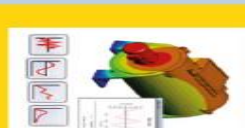
Druckbehälter



2D Vereinfachung



Lineare Dynamik



Faserverbund



Trenderfassung



Ermüdung



Falltest



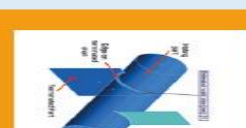
Knicken Beulen



Optimierung



Verbindungs-Überprüfung



Sub-Modellierung



Nichtlinear Dynamisch



Nichtlinear Statisch

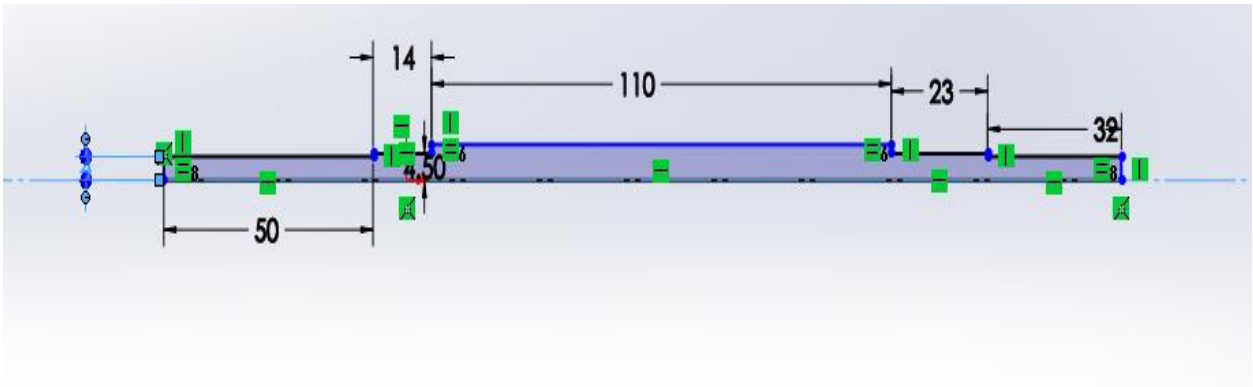


1.3.2. Engine part design using solid works:

Shaft :

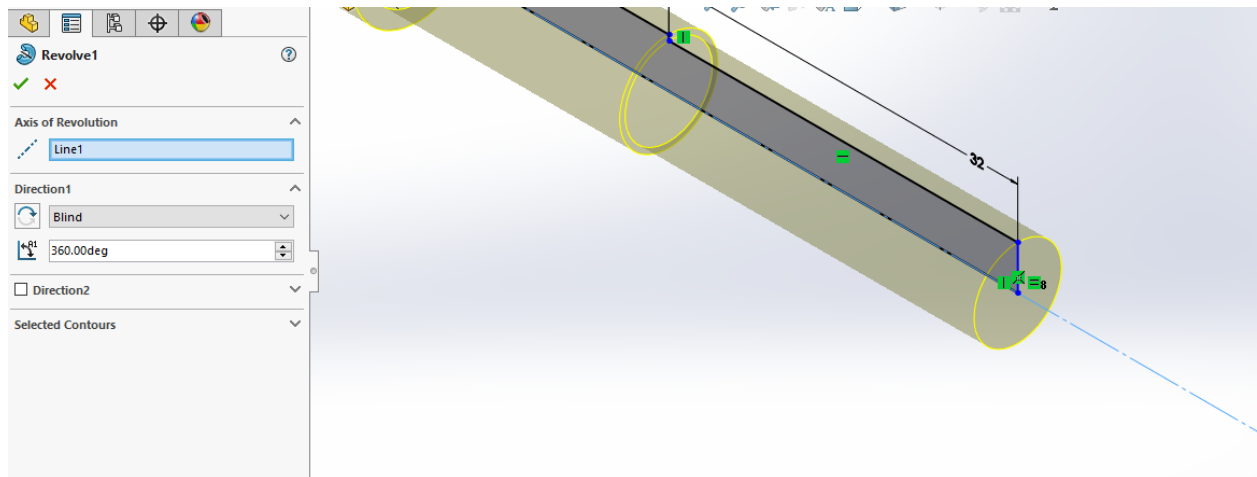
Step-1:

Select the sketch plane → then select sketch→ use line command the draw the periphery of the part with the required dimensions.



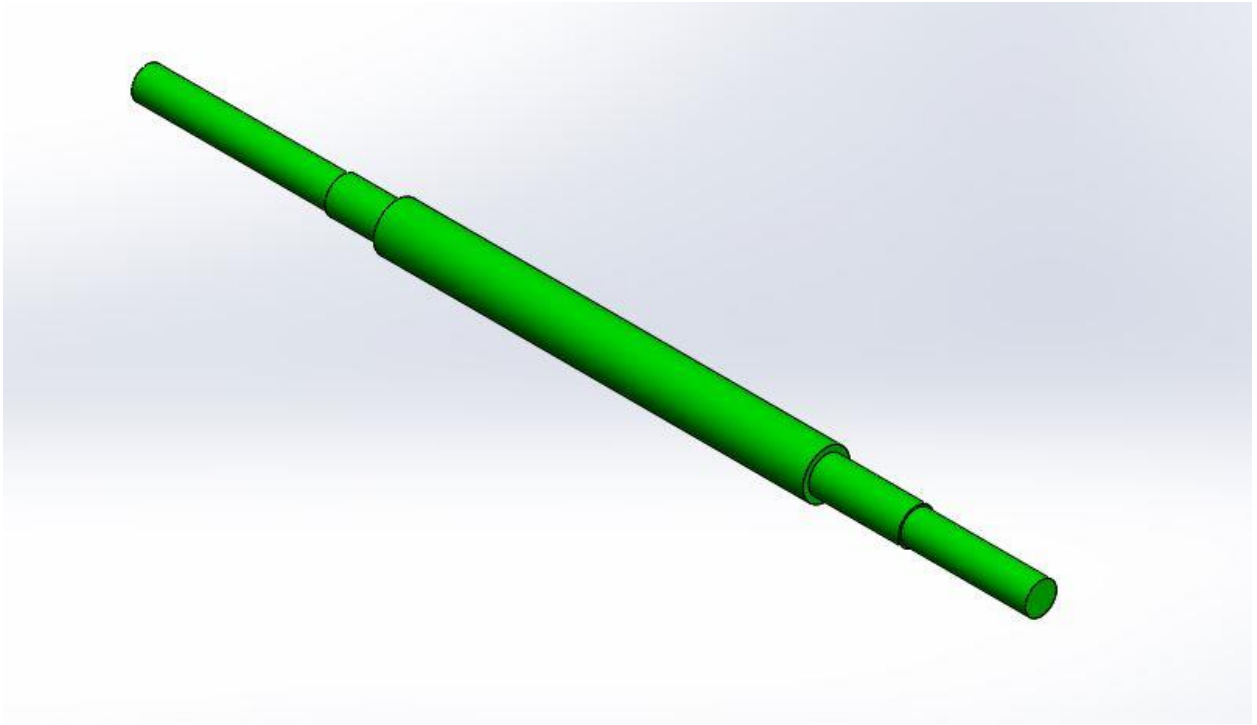
Step -2:

Open features tab→ select revolved boss/base feature→ then specify axis of revolution



Step -3:

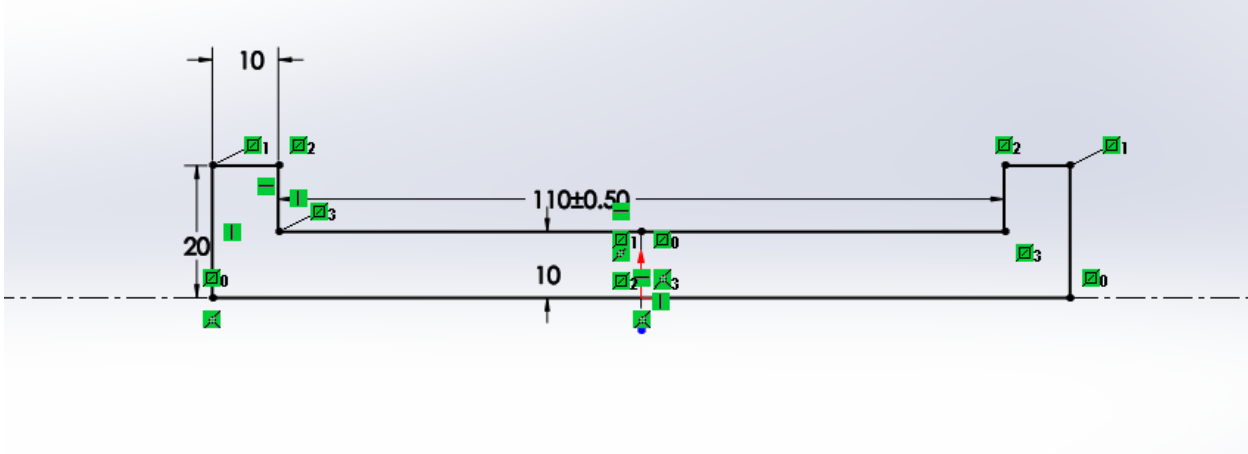
The final view of the 3D modeled shaft



Shaft housing :

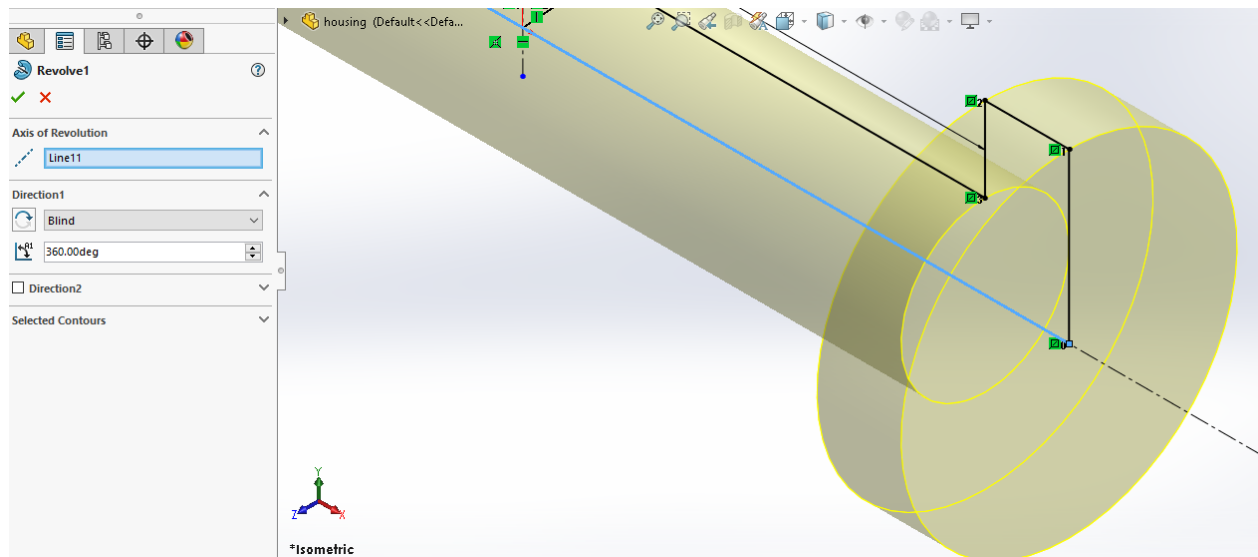
Step-1:

Select the front view plane → then select the sketch→ draw the outlet of the sketch using line command.



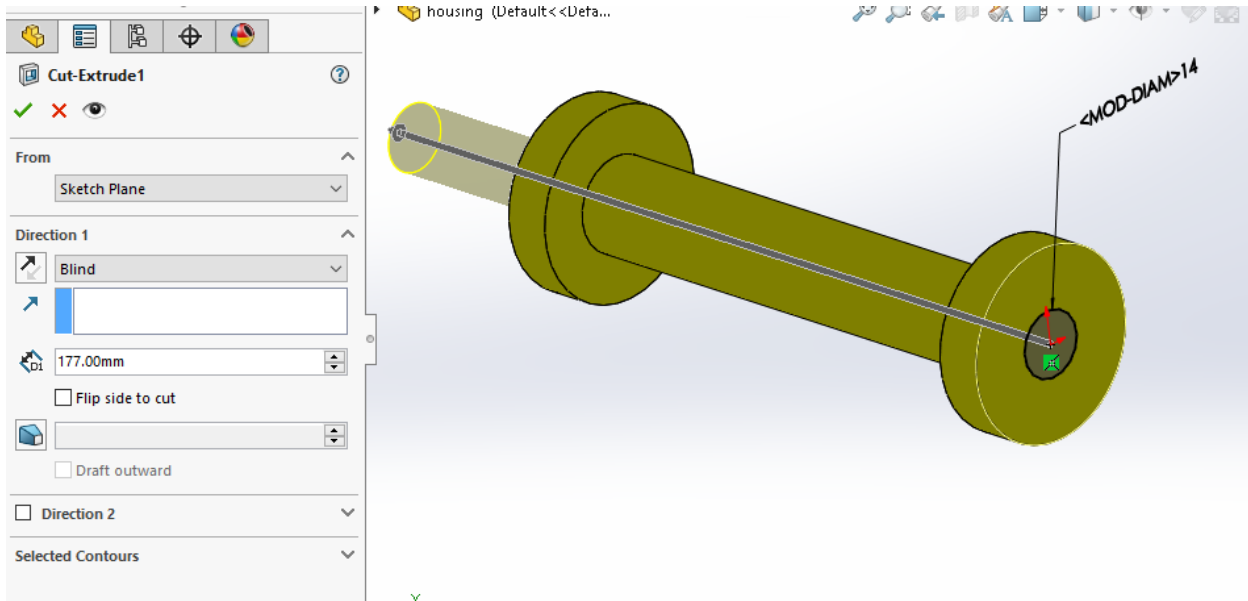
Step-2:
Open feature tab → select revolved boss / base command → specify

the axis of revolution



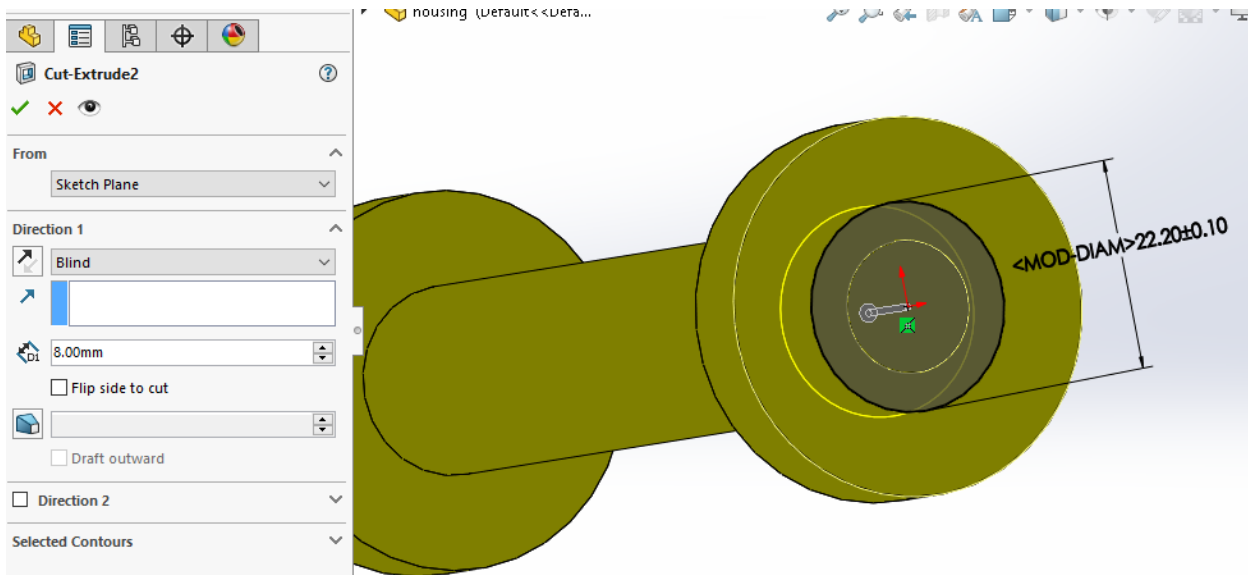
Step – 3:

Select the desired face to sketch → make a circle at the center of the origin and specify its dimension → use cut extrude feature then select the surface which to be cut



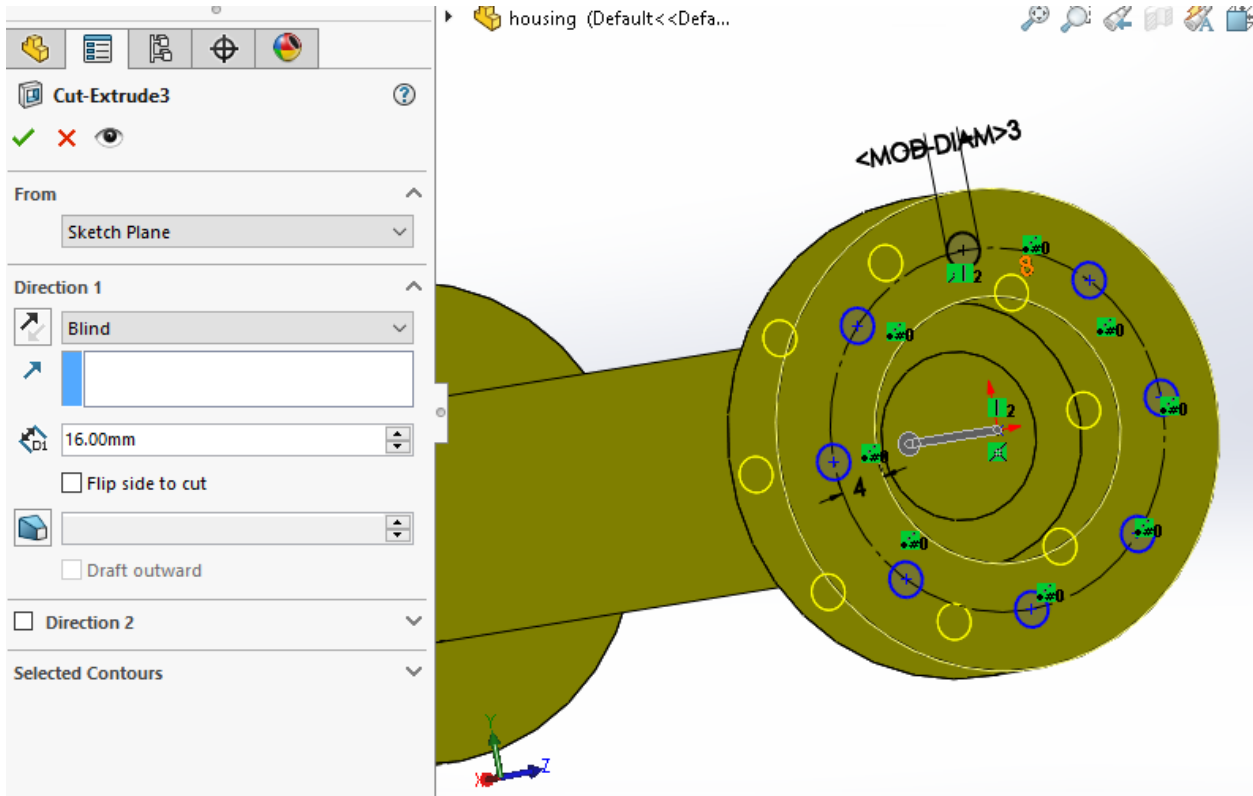
Step-4:

Select the same face for the sketch → now select another circle at the center and specify its dimension → then specify cut extrude feature and select the surface to be removed → the depth of cut is specified as 8mm



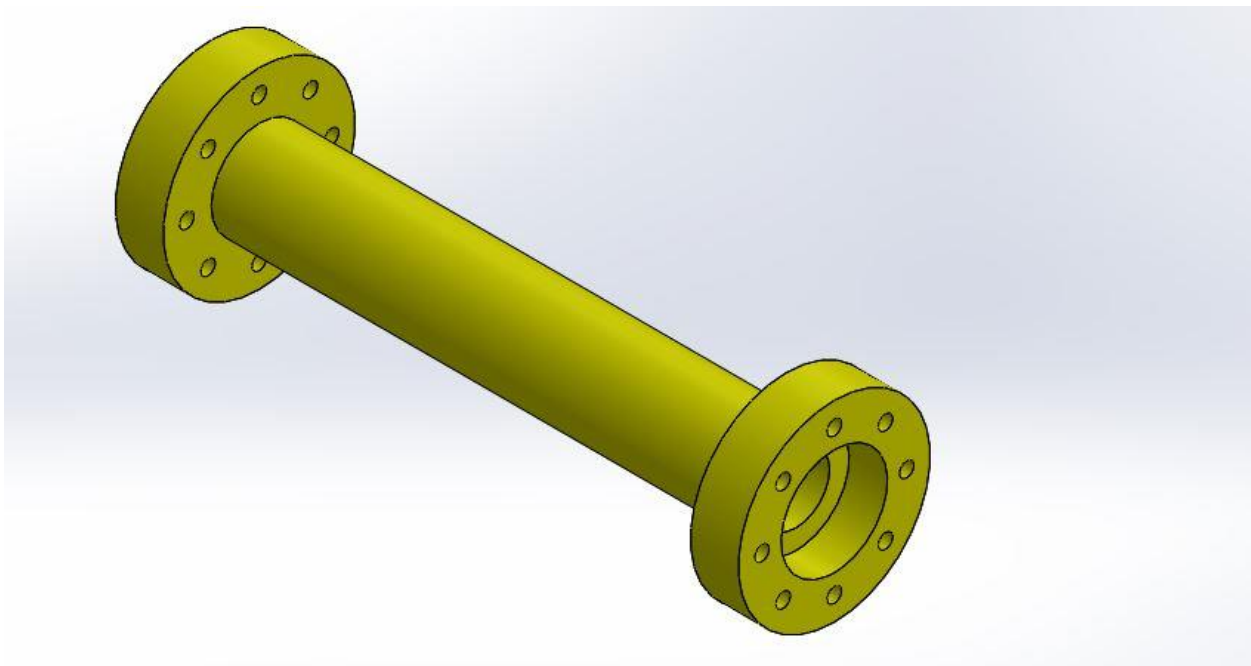
Step -5:

The same face is again selected → now draw a circle on top and pattern them using circular sketch pattern → use cut extrude feature for the selected faces



Step -6:

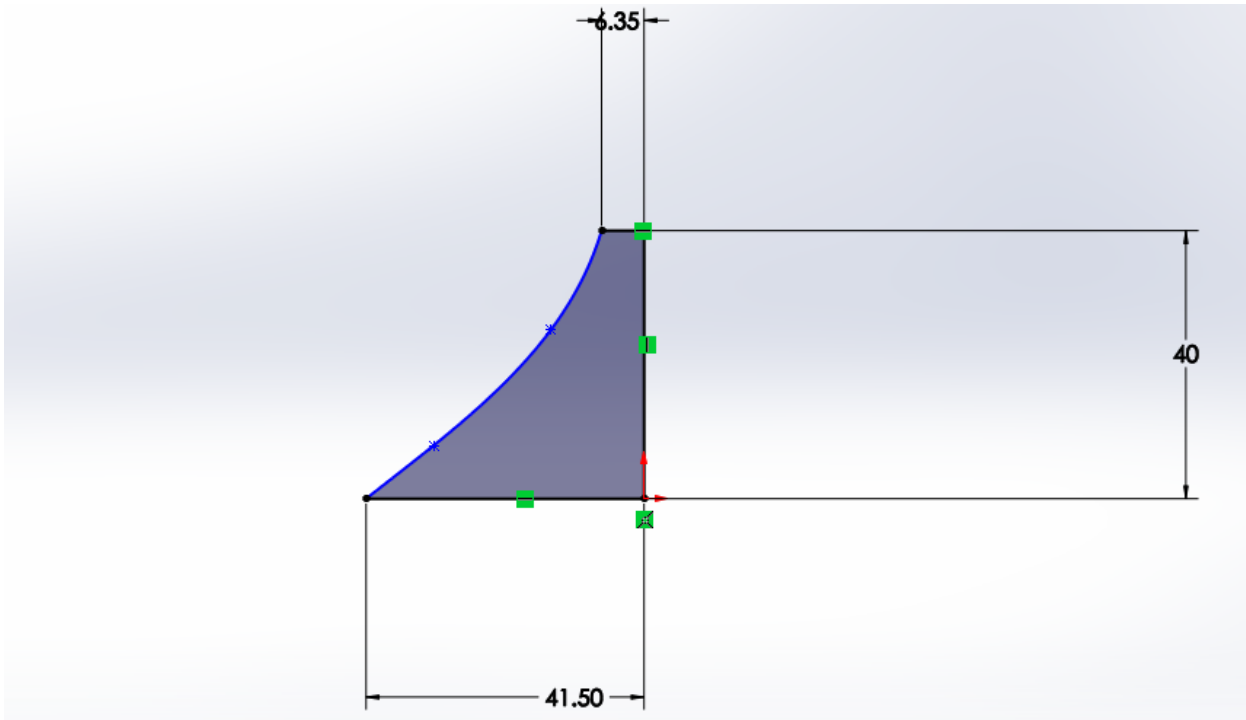
The final 3D model was prepared by mirror the given features to the respective alternative side



Design of Centrifugal Compressor:

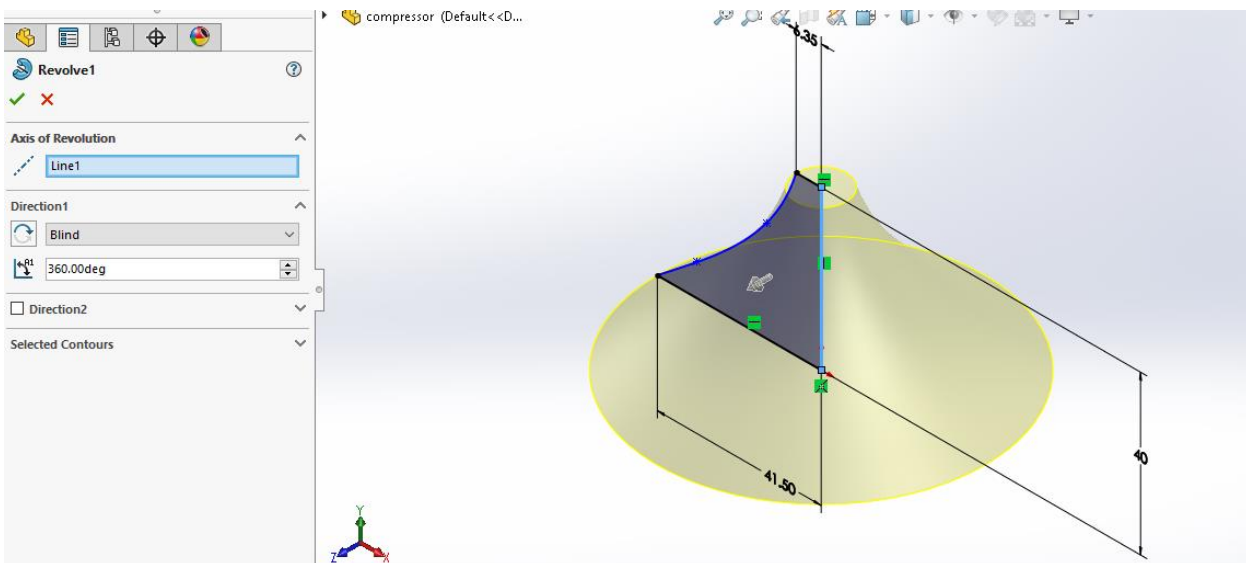
Step – 1:

Select the front plane to sketch→ use lines and curves to draw the periphery of the part



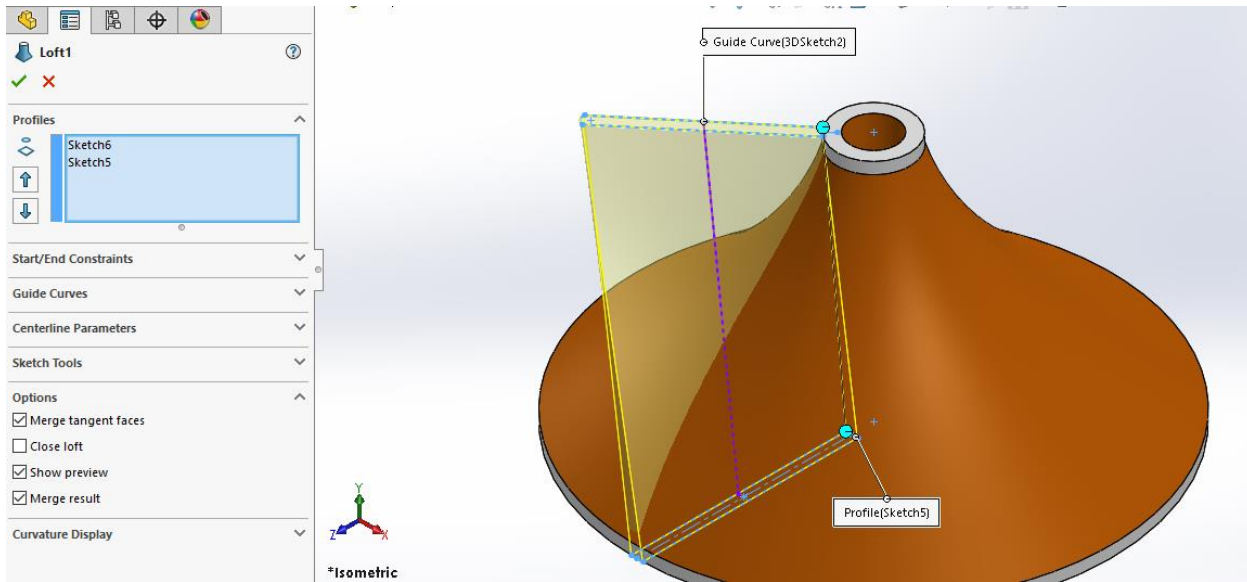
Step-2:

The model is converted from 2D to 3D by using revolved boss/base → by selecting the axis of rotation at required rotation



Step-3:

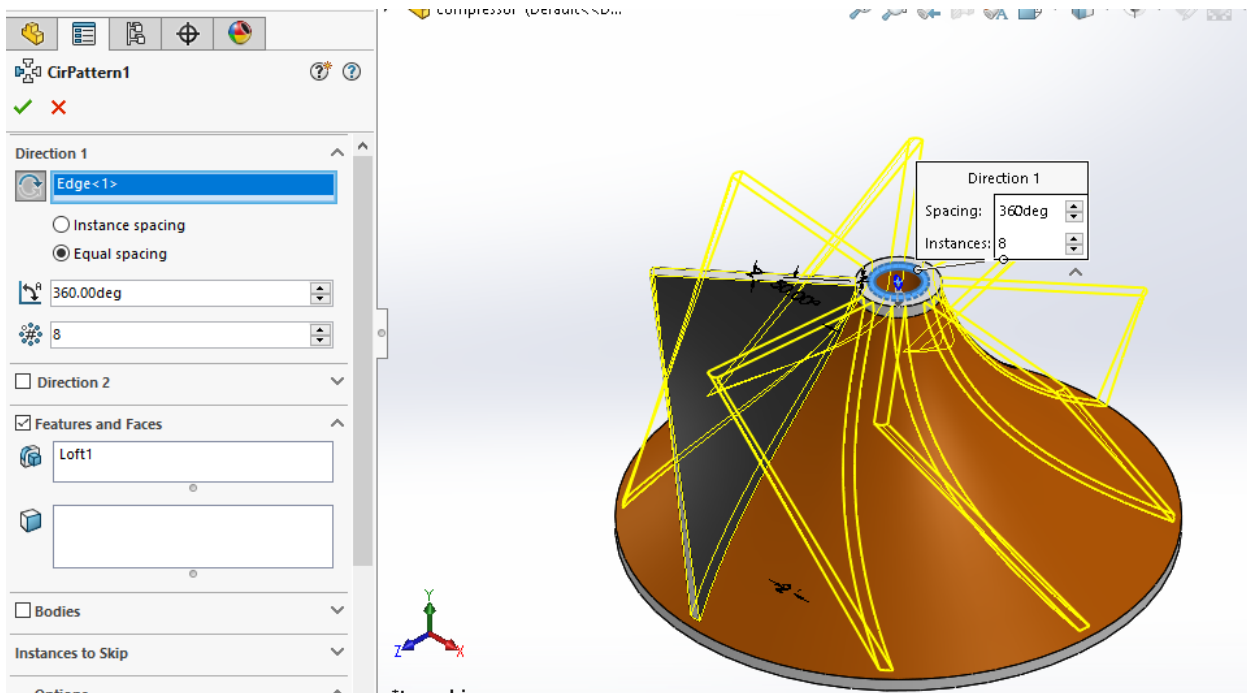
The blades of the compressor can be constructed by using reference planes → the respective sketching is done using 3D Sketch tool → the created sketch are then converted to solid using loft feature so, that the two faces merge to get a retro curved shape



Step-4:

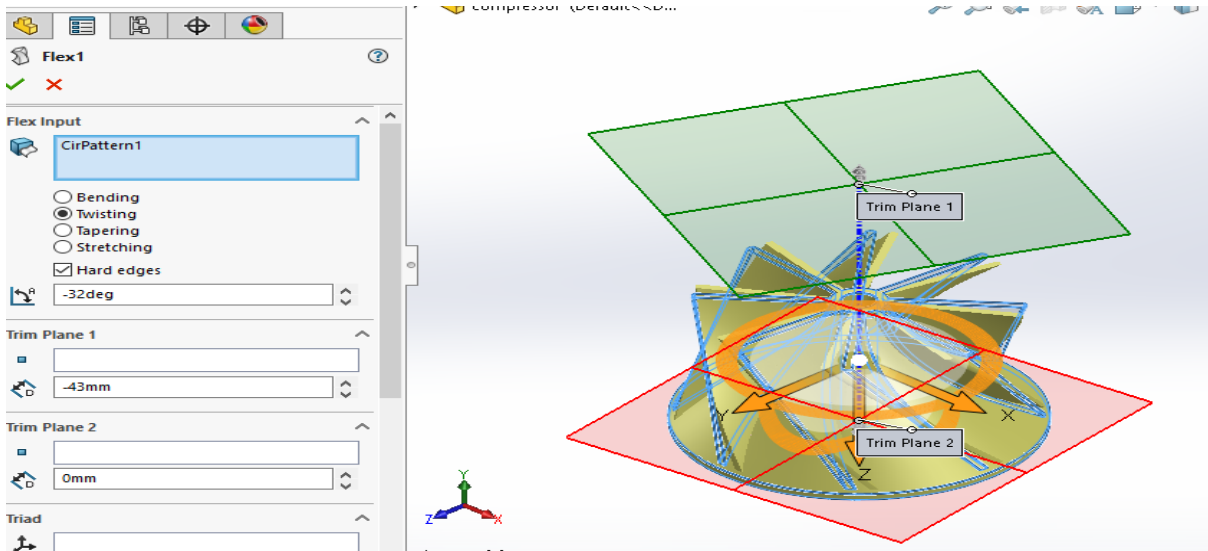
The desired number of blades are obtained from the circular pattern from the features tab →

Here the number of instances and the pattern axis is specified



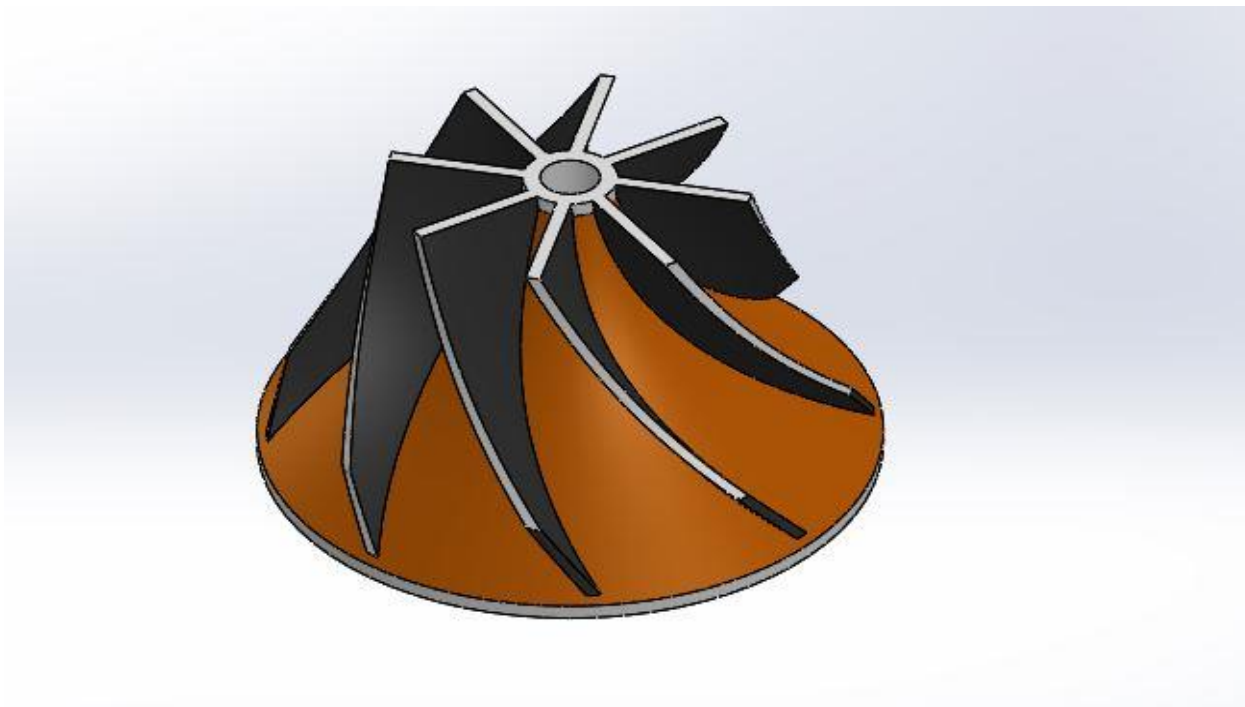
Step-5:

The blades are twisted by using a feature called flex → the desired trim planes are selected → then the twisting angle is specified.



Step-6:

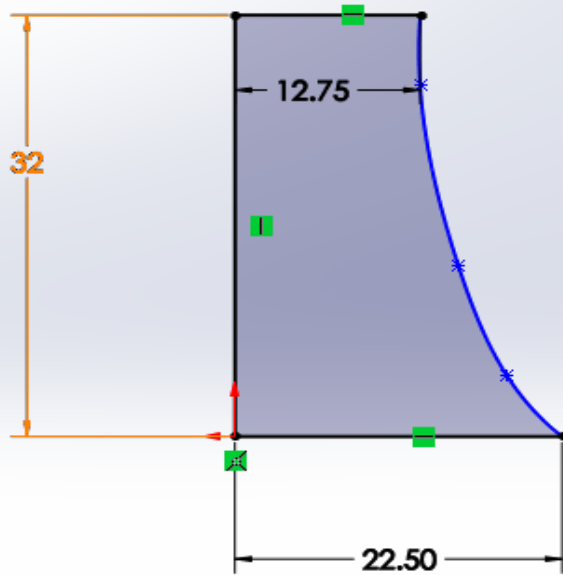
The excess blade material is removed by using the revolve cut extrude feature → the hole through the center is also made by the extrude cut feature → the final 3D model is generated



Design of Radial Turbine:

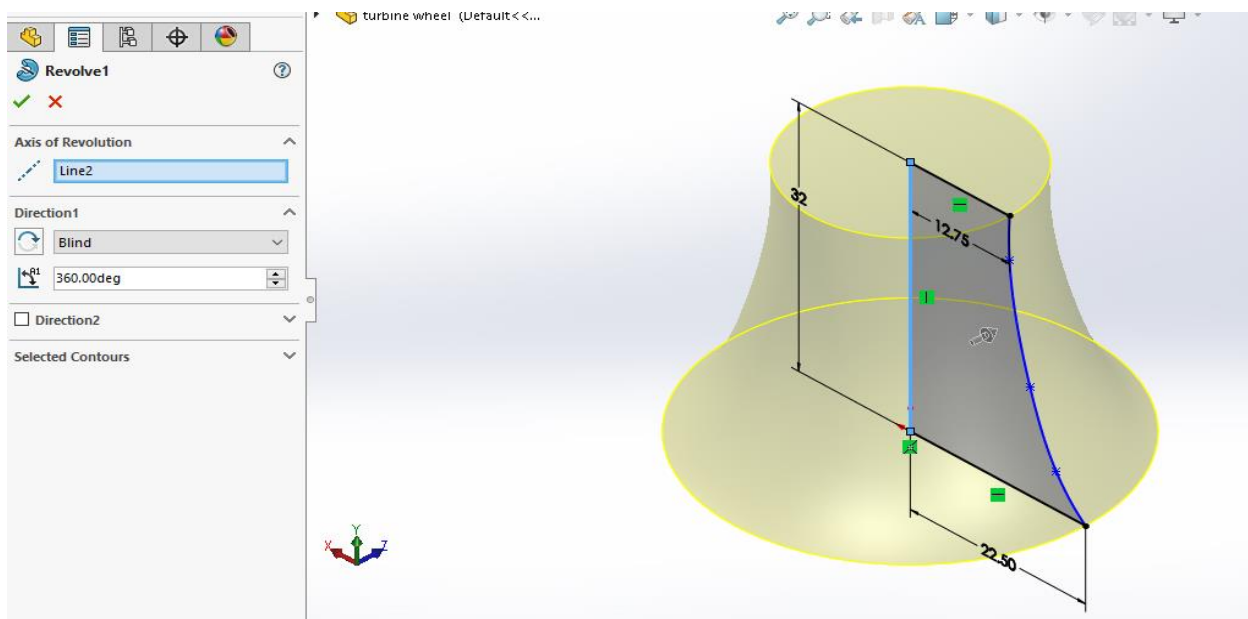
Step-1:

The front plane is selected for sketching → the lines and the cured lines are drawn on the sketch plane



Step -2:

The sketch is converted to 3D- model using revolved boss/base feature→ then select the rotational axis through which the model gets revolved

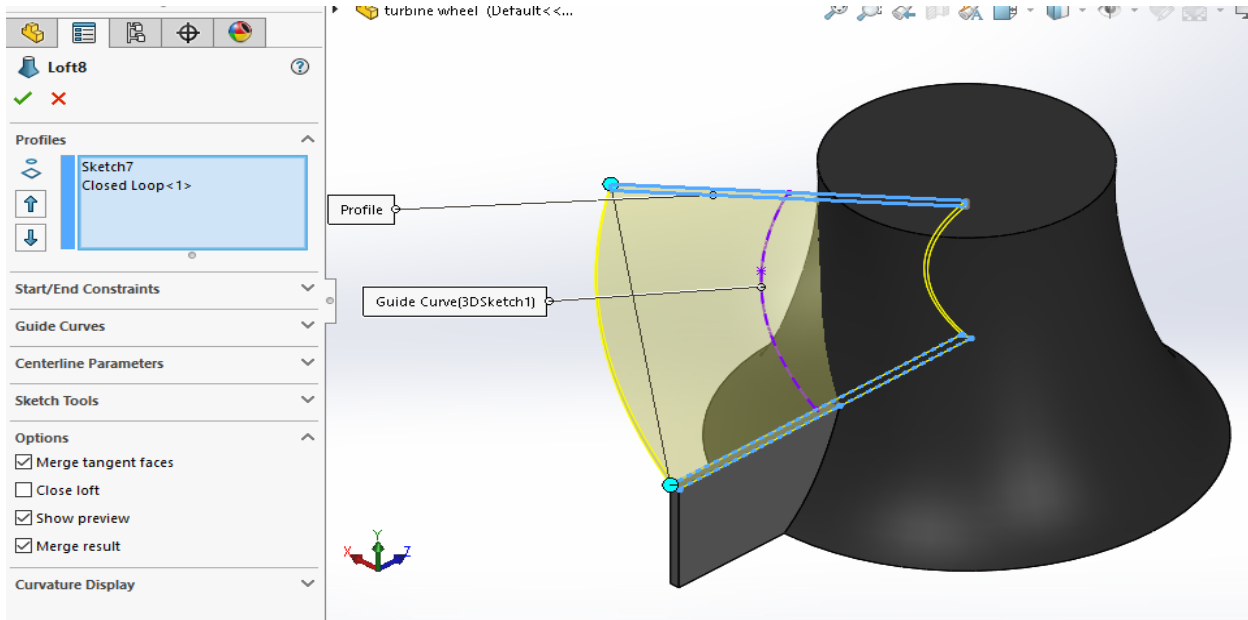


Step-3:

Select the reference planes at the location through which the blade sectional view can be drawn→

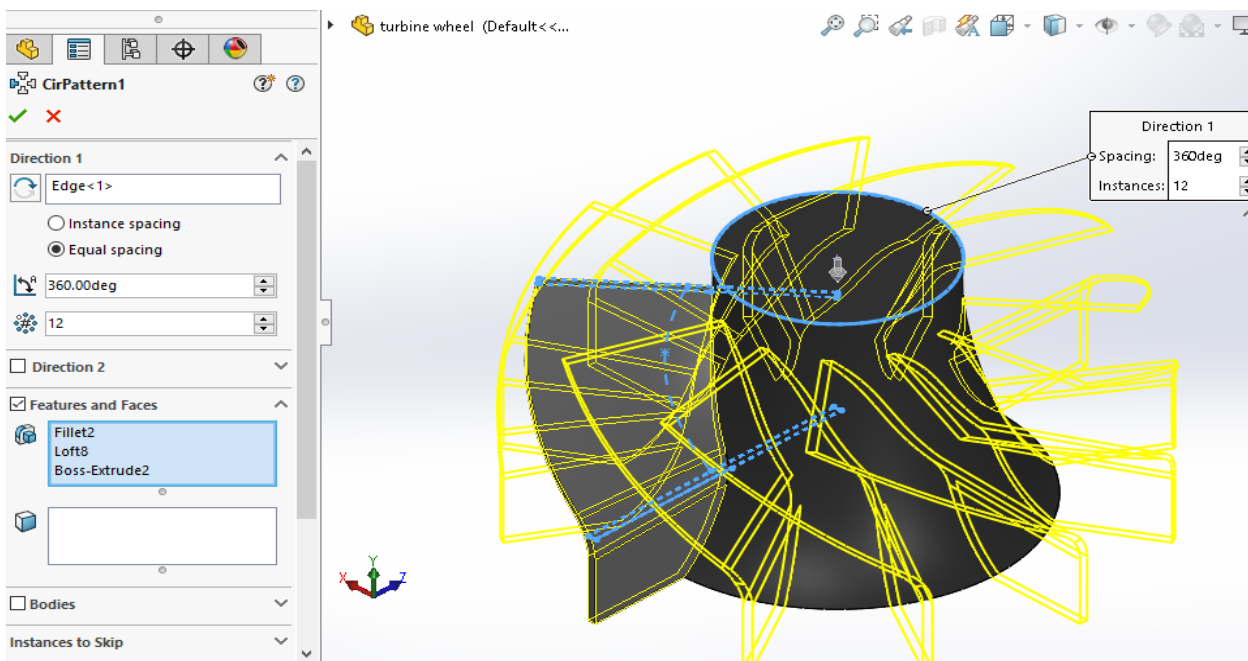
By using loft feature we can construct the solid blade of specified dimensions and thickness→

fillet is done accordingly with required radius



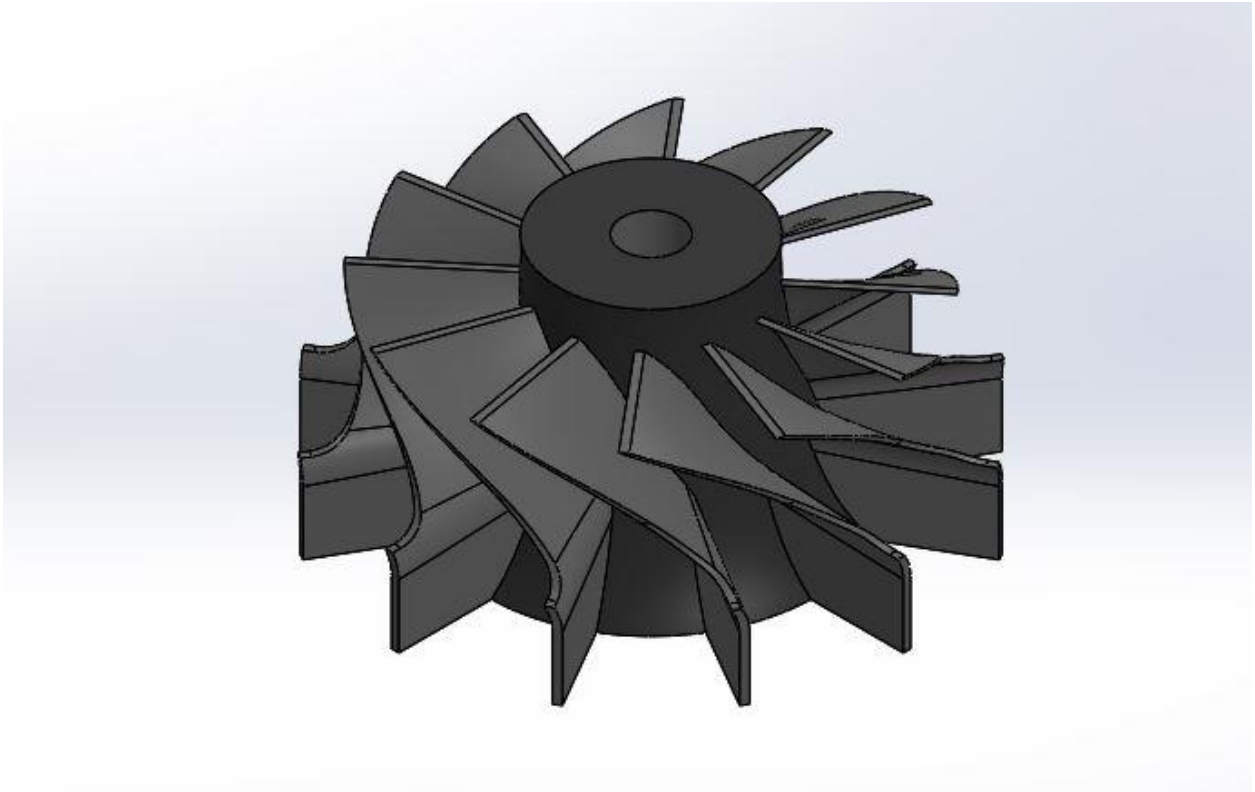
Step-4:

Using the circular pattern the required blades can be generated → the pattern axis is specified



Step-5:

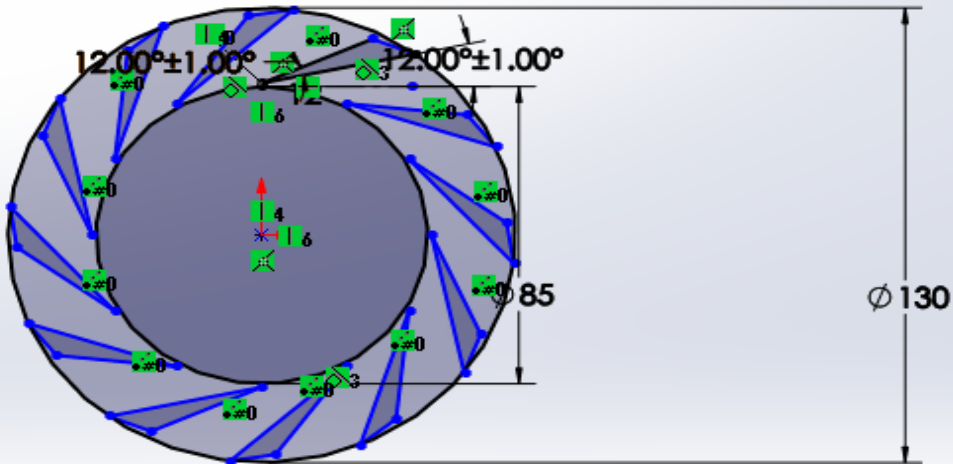
The necessary holes are done using cut extrude feature→ the final finished model is



Design of Diffuser system:

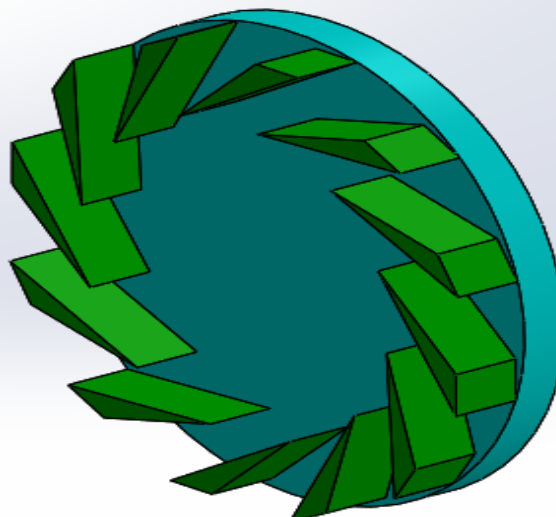
Step-1:

The initial drawing of the base of the diffuser system is generated → the sketch is then no converted to 3-D by using extrude feature



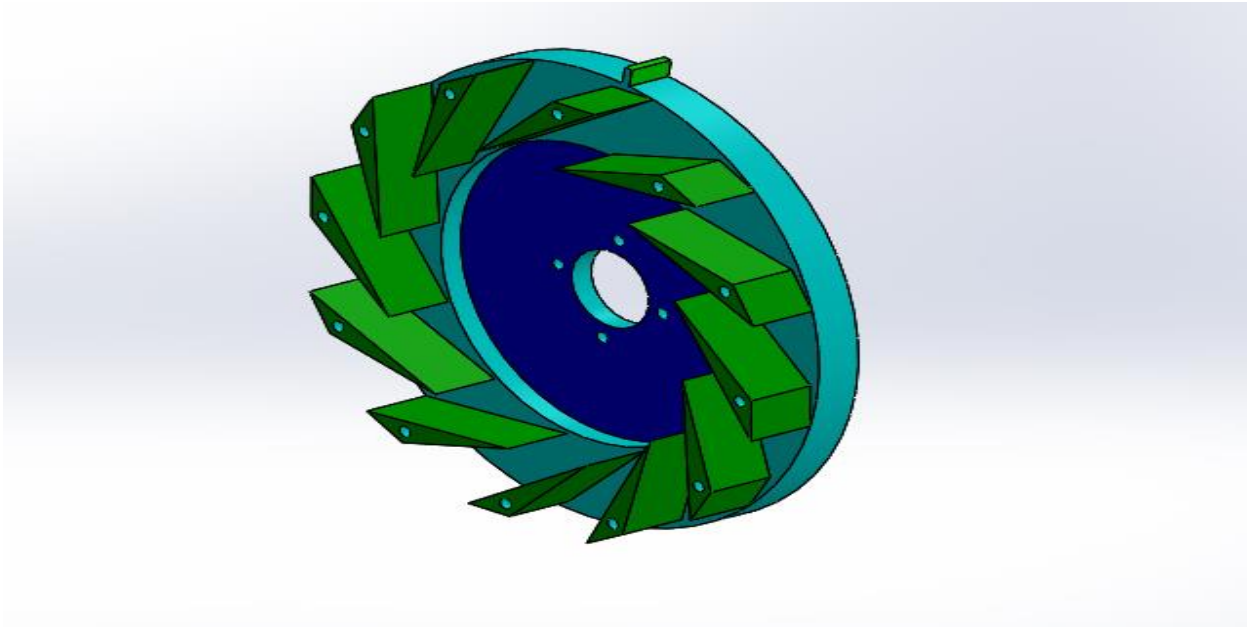
Step-2:

The respective face is selected for sketching for the design of blades → the diffuser constructed is a wedge shape diffuser



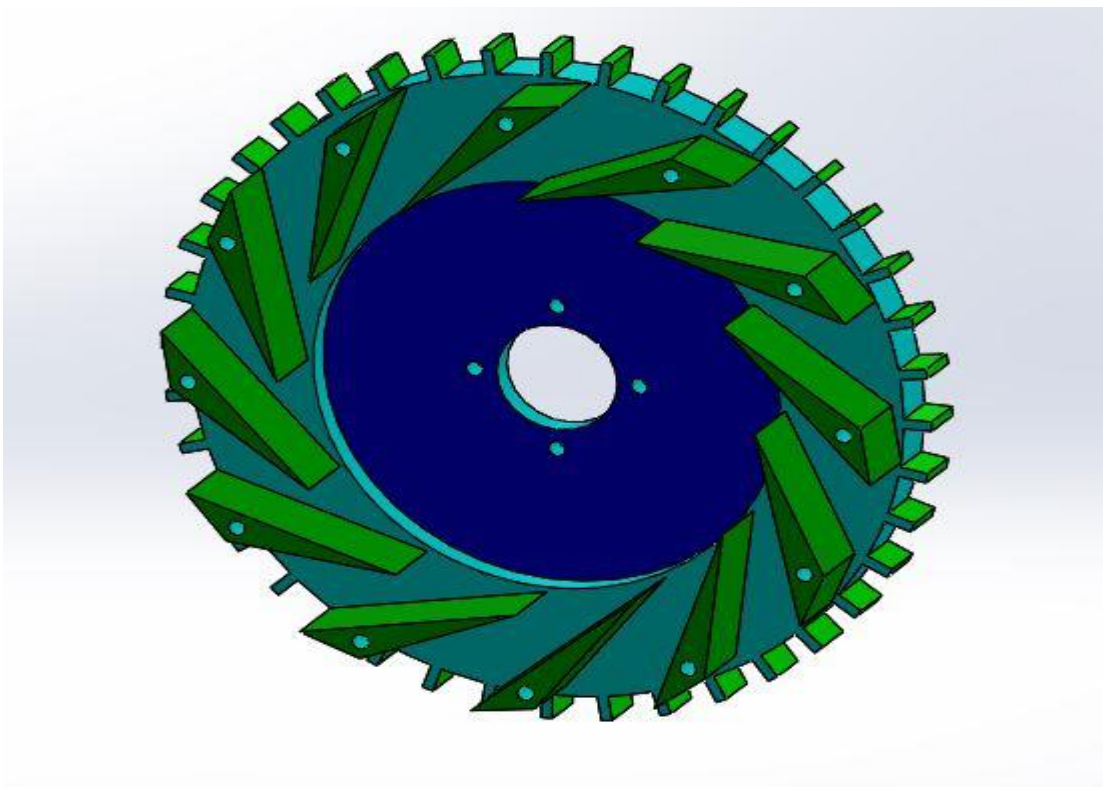
Step-3:

The following expansion angle of the blade the intertangle are also specified → the number of blades can be taken a required number and the axis of planner rotation is specified



Step-4:

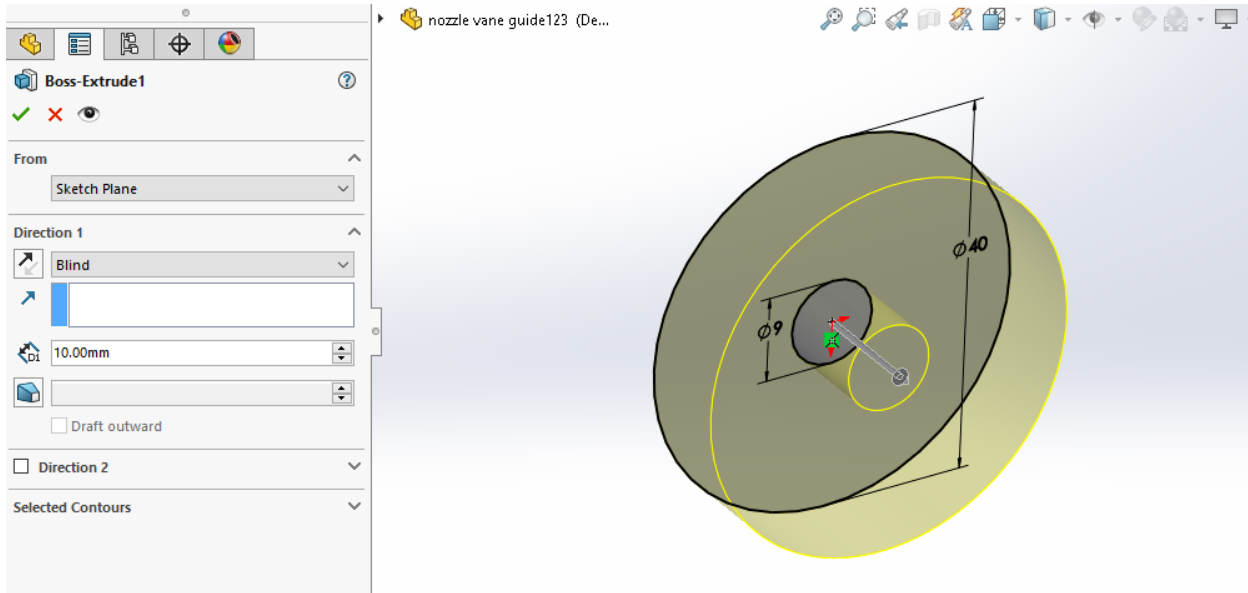
The grooves and the holes are done using cut extrude and whole wizard → cavity for the compressor mounting is done using cut extrude → the final figure is



Design of Nozzle Guide Vanes system:

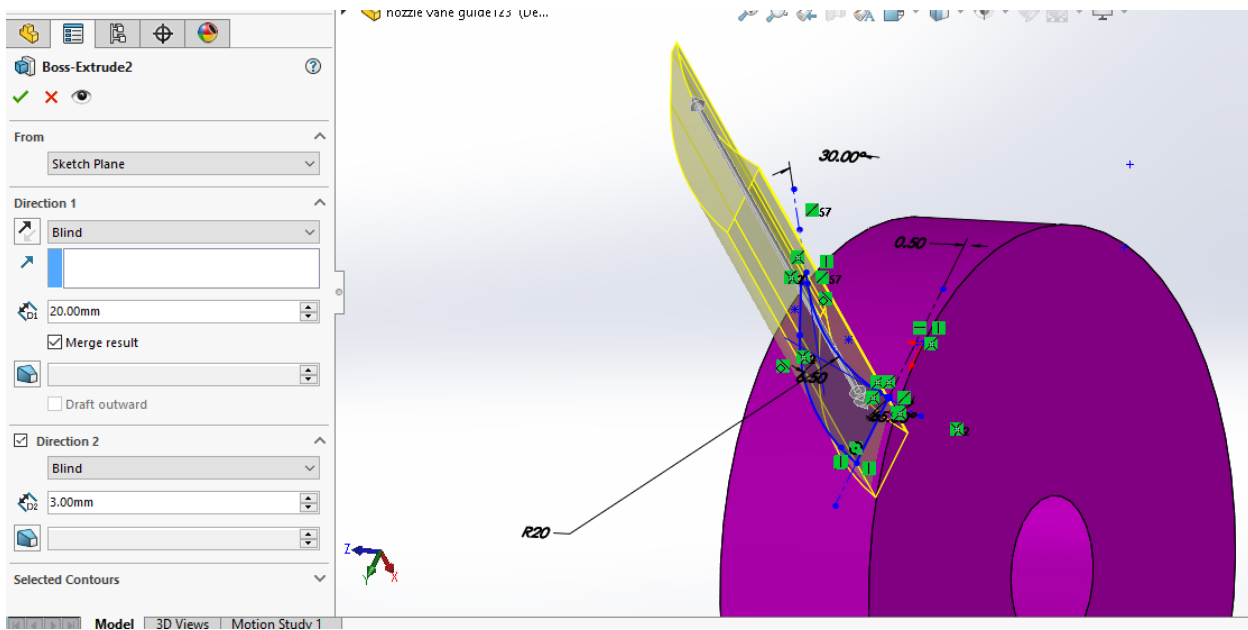
Step-1:

The view in which the sketch is produced → using circle construct a base → this base is then converted to 3-D by the selection of extrude boss/bass feature



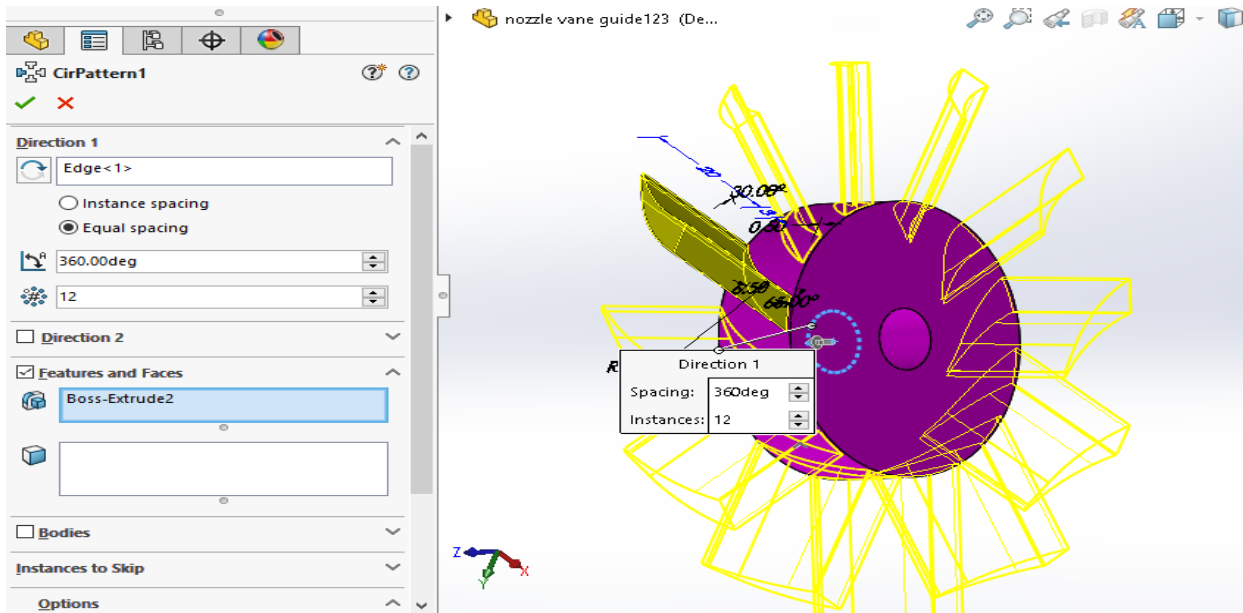
Step-2:

By considering the reference planes on to the circumference of the solid → the design is done based on the air foil with an inlet and exit angles of 30° and 65°



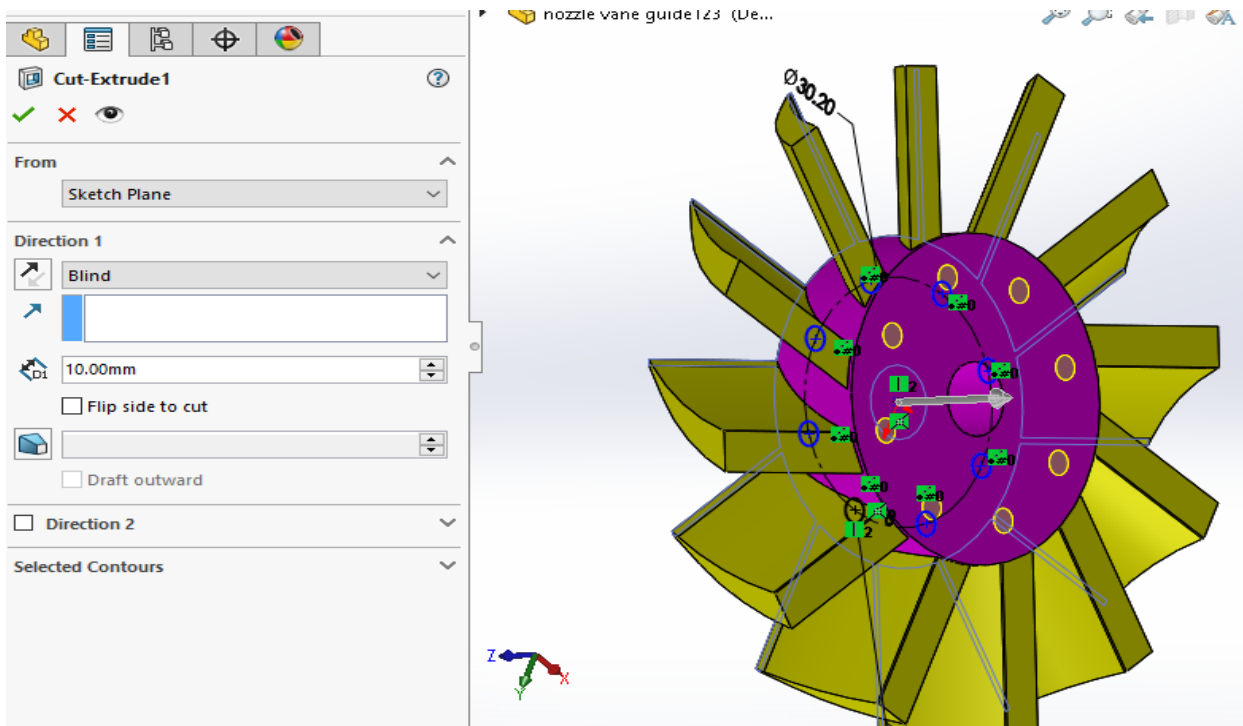
Step-3:

The number of blades are formed by using circular pattern → the pattern axis is specified → this respective pattern contain 12 blades in it



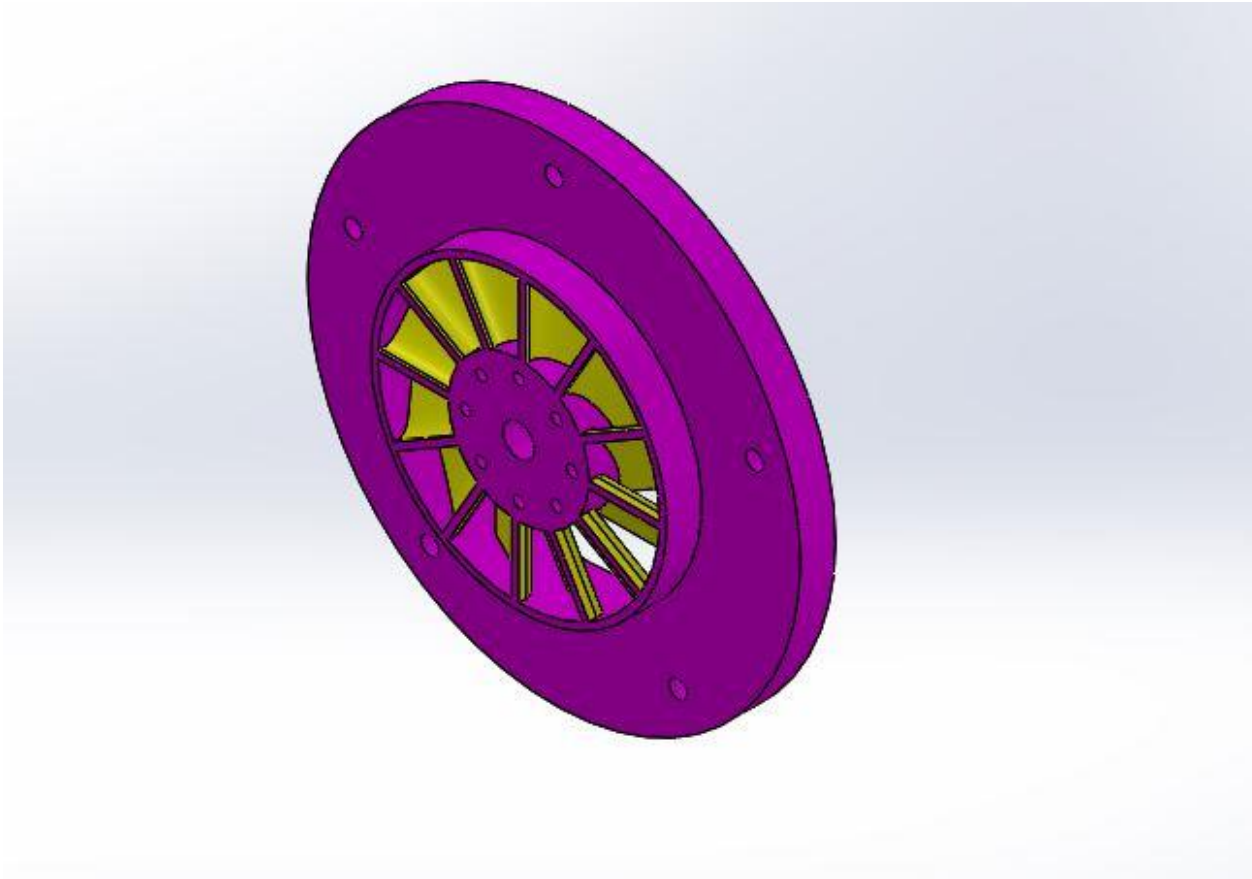
Step-4:

By selection of face the sketch of circle at the center and a series of holes at the periphery → the cutting is done using cut extrude and the desired surfaces are selected



Step-5:

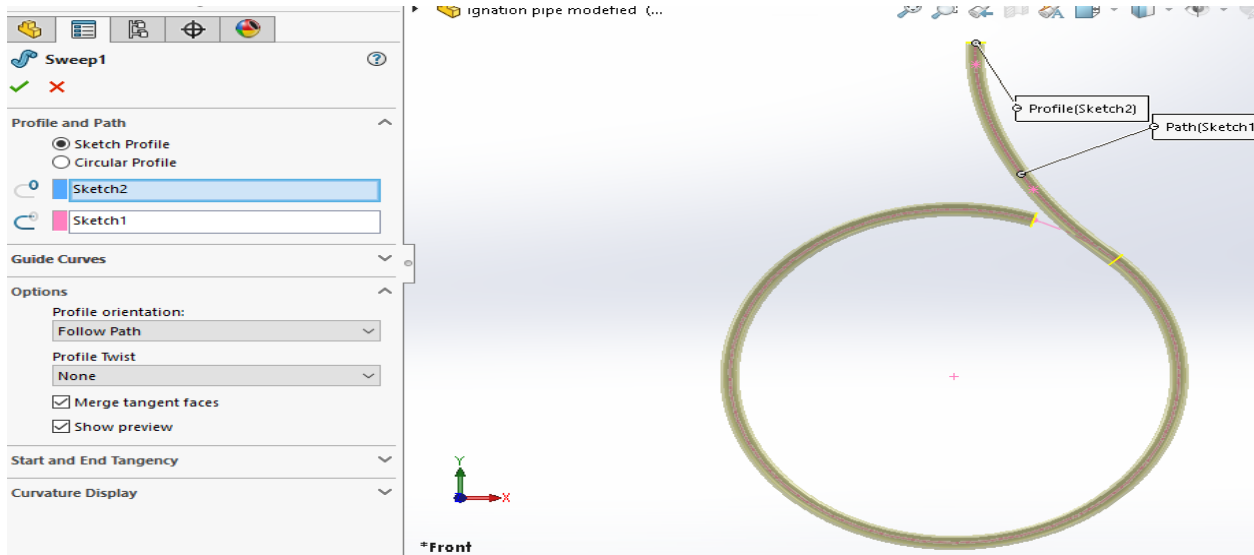
The outer casing is done by selecting one of the faces of the nozzle → sketching is done → the sketching is extruded by using extrude boss/base



Design of Ignition Pipe:

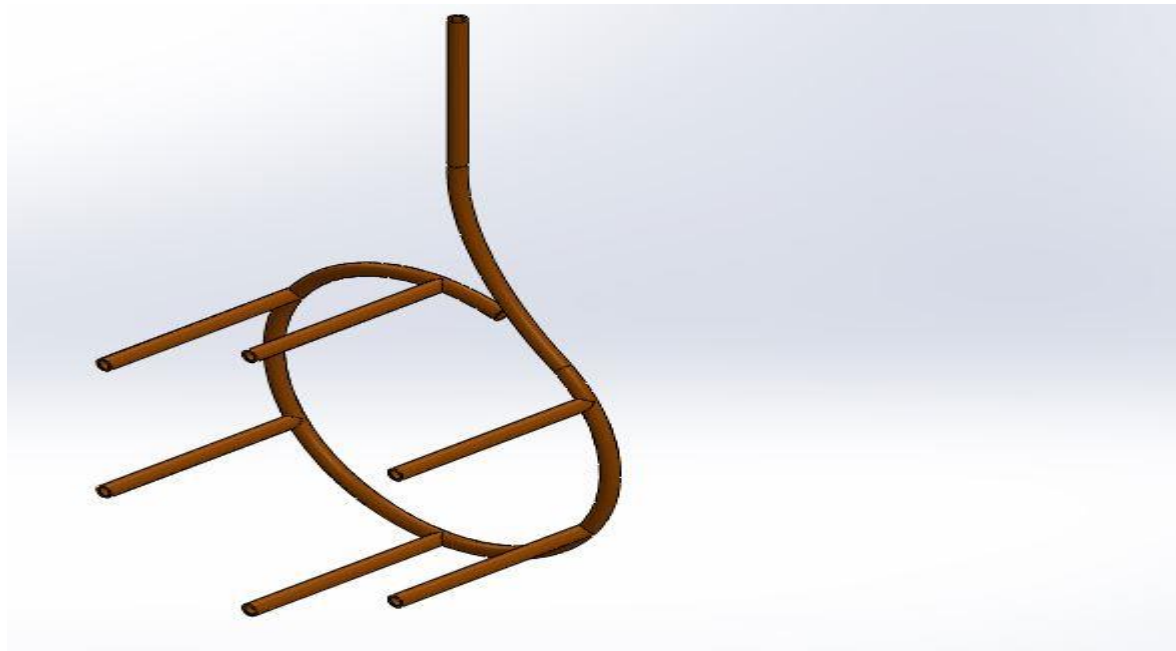
Step-1:

The plane is fixed for the sketching → the sketch is generated by the curves and the line and a circle is drawn at the starting point perpendicularly → By using swept boss/base the profile and the path are selected



Step-2:

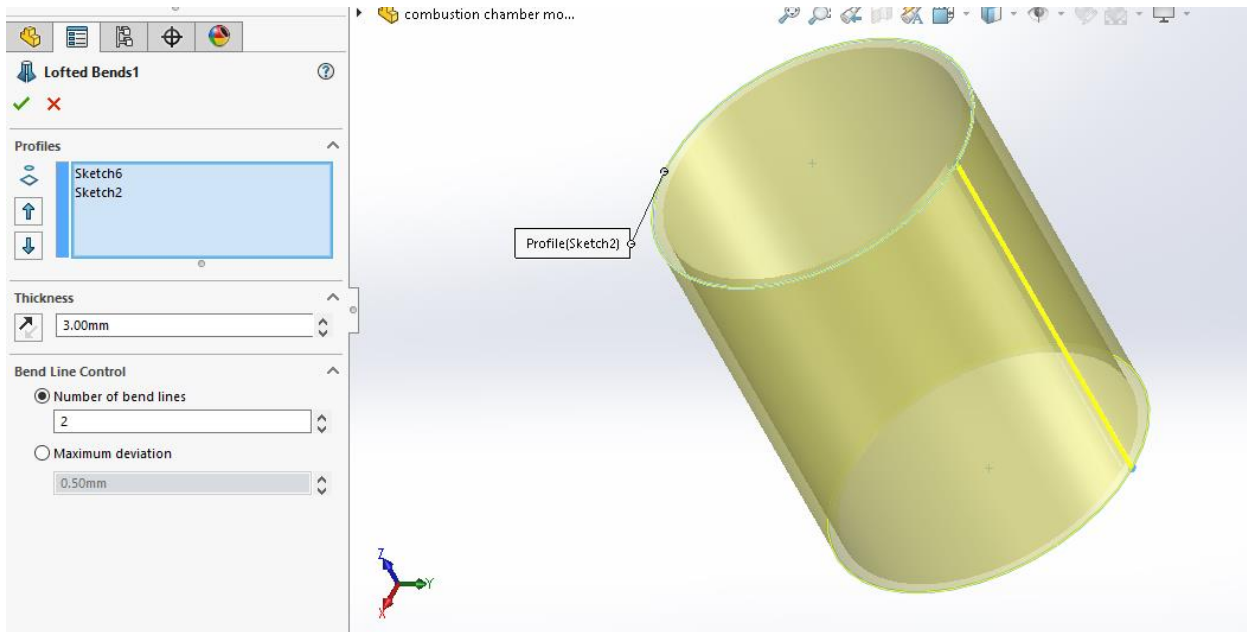
A reference plane is produced at the tip of the curve → the concentric circles are drawn on to the plane → these sketches are the extruded to a required length



Design of Combustion Chamber:

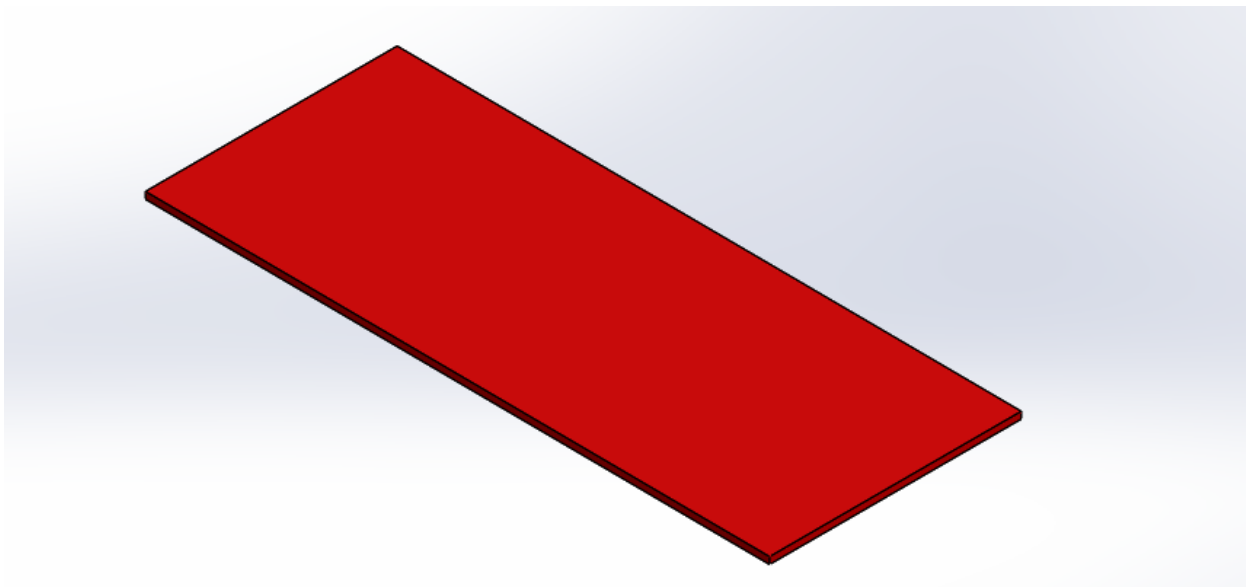
Step-1:

Sketching is done on to the defined plane→ open circle are drawn at the different places→ the loft bend feature operation is performed in sheet metal operation



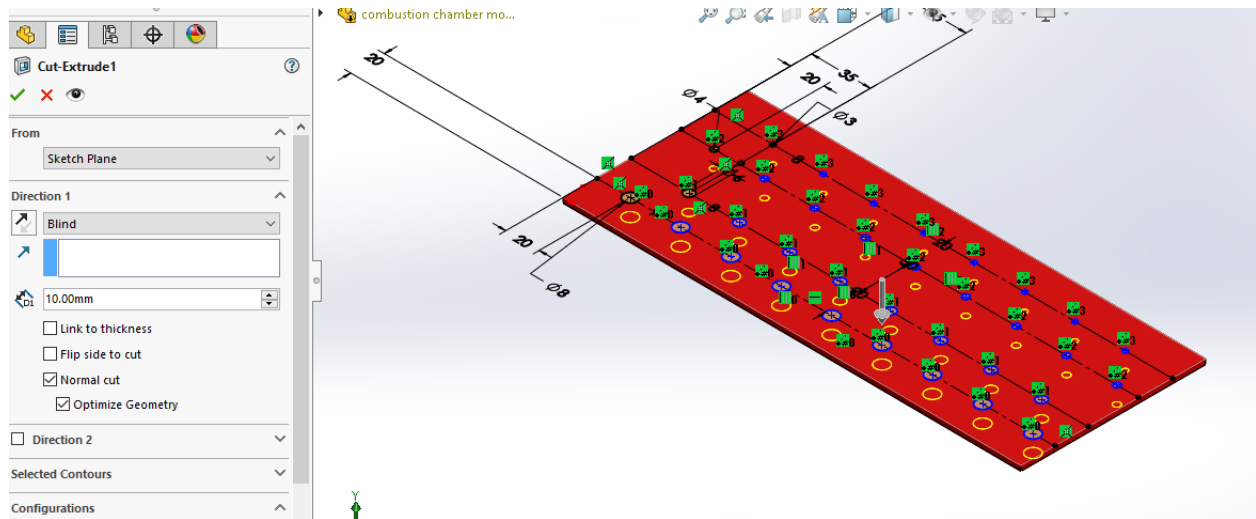
Step-2:

Unfold the model using by unfold feature in the sheet metal tab→ select the fixed edge and the surface to unfold



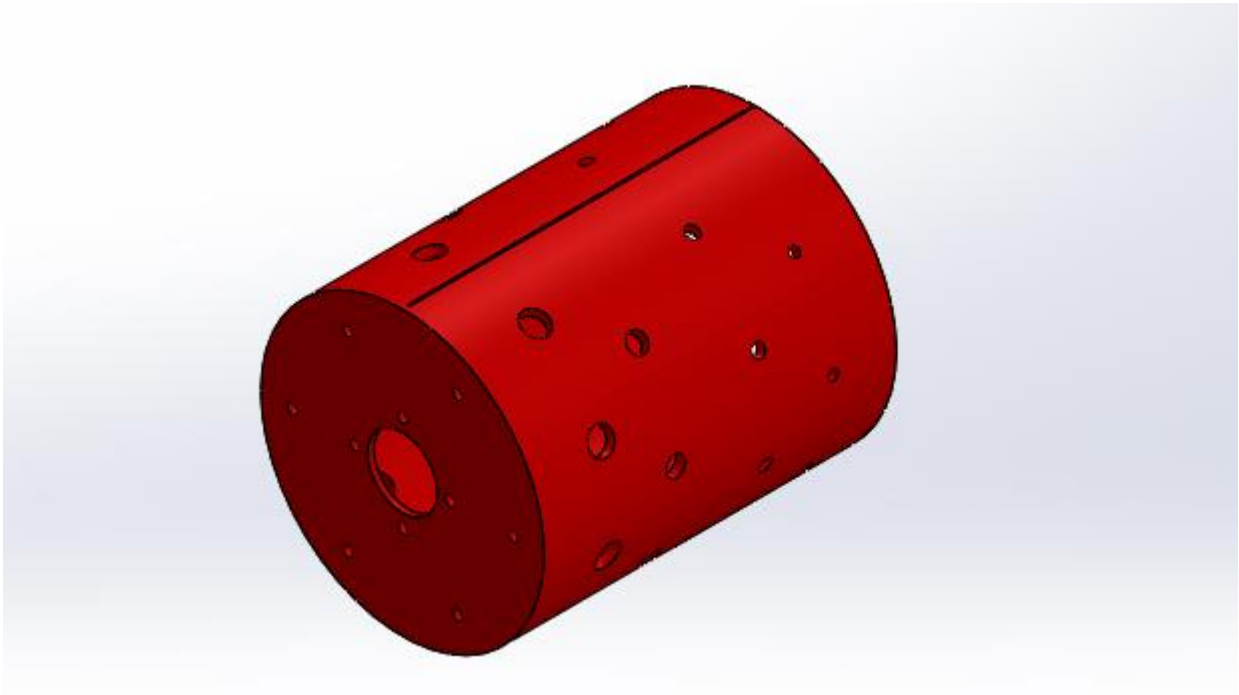
Step-3:

Make holes on the surface by selecting the face→ draw series of circles along its length→ select cut extrude feature for the respective circles to make holes



Step-4:

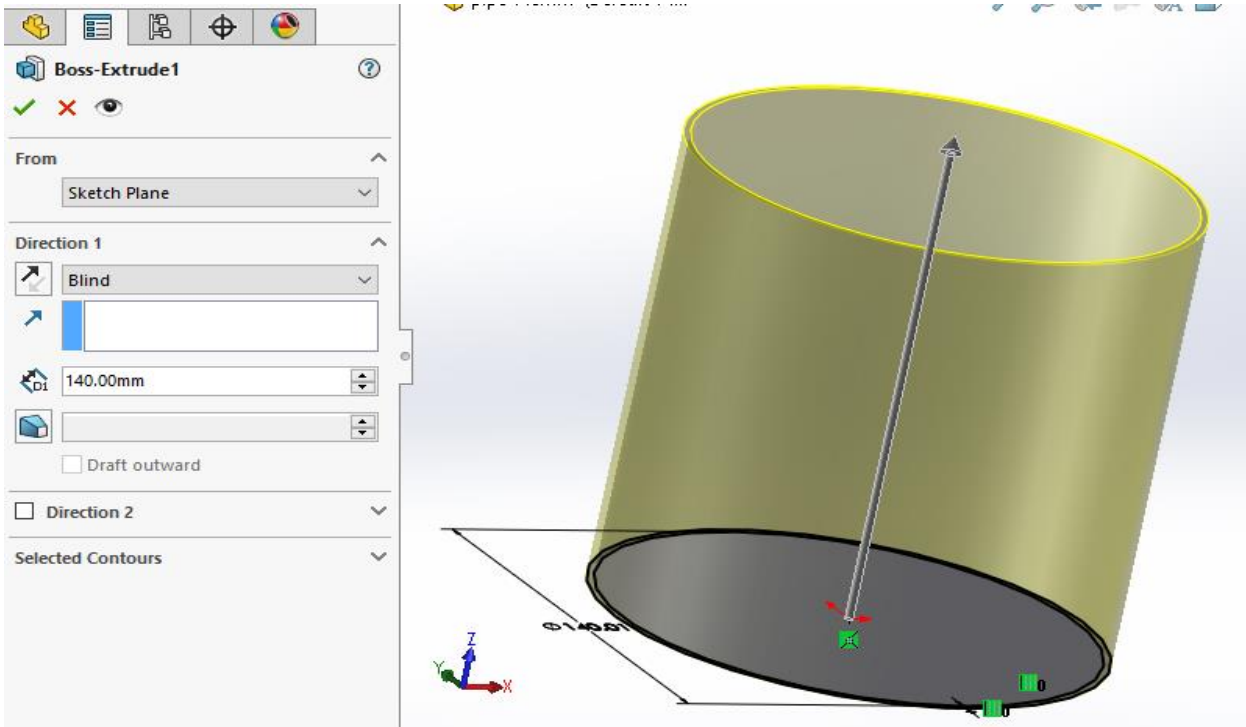
The faces are then folded using fold feature in the sheet metal operation → then the top side is selected for sketching → use circle to at the origin and use boss extrude to the desired thickness



Design of outer pipe:

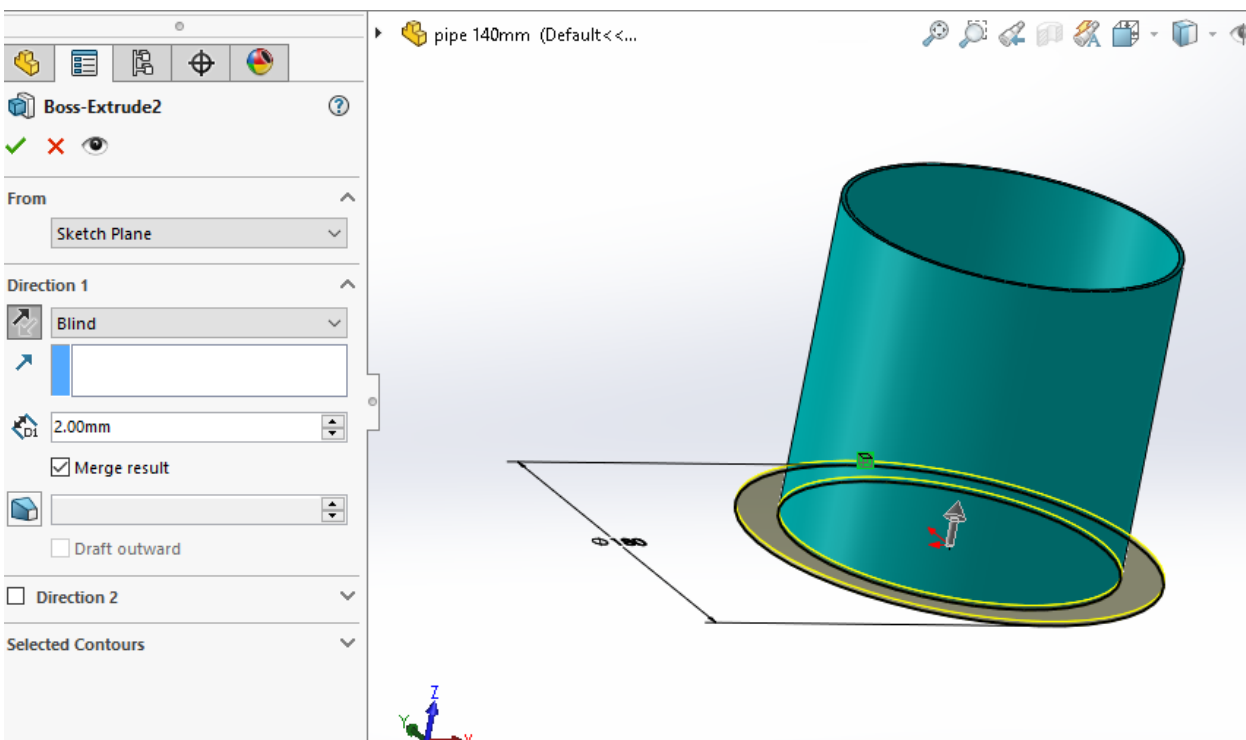
Step-1:

The sketch is drawn on the front plane → then use boss extrude to generate a 3-D part



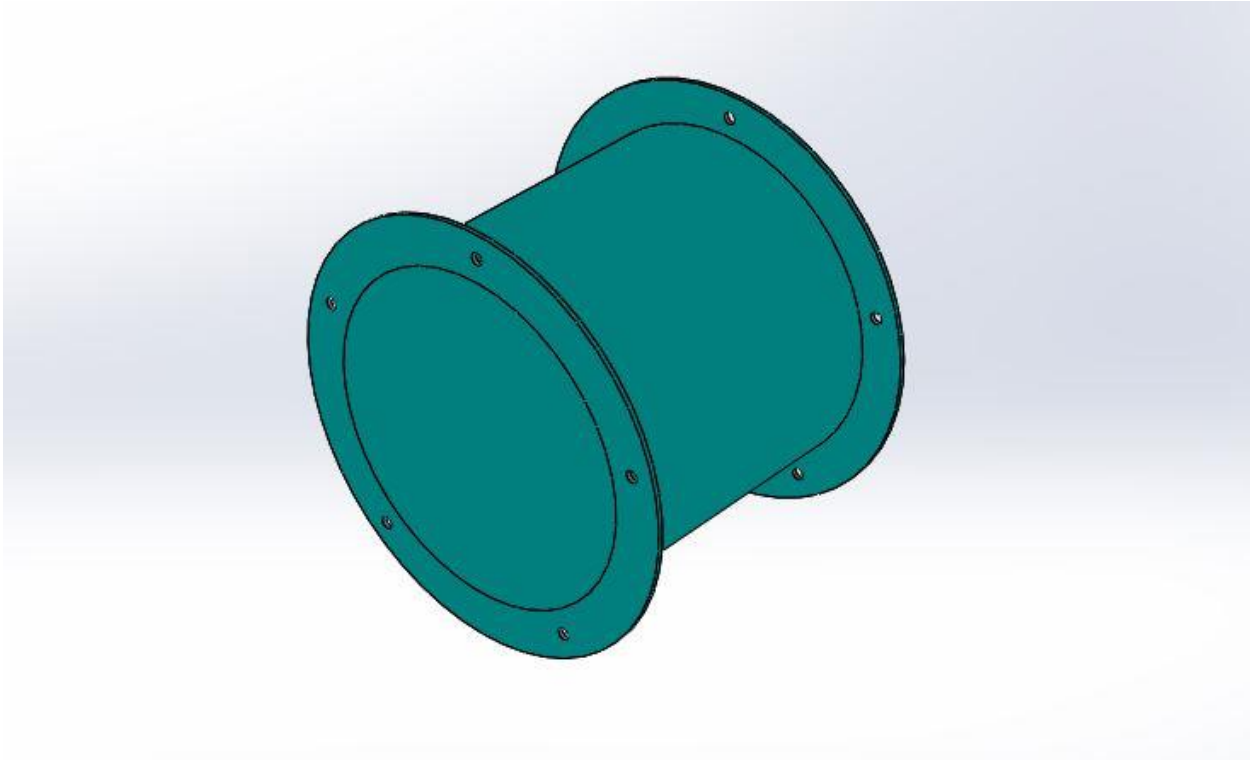
Step-2:

The flanges are drawn on the top surface and then are extruded to a required thickness



Step-3:

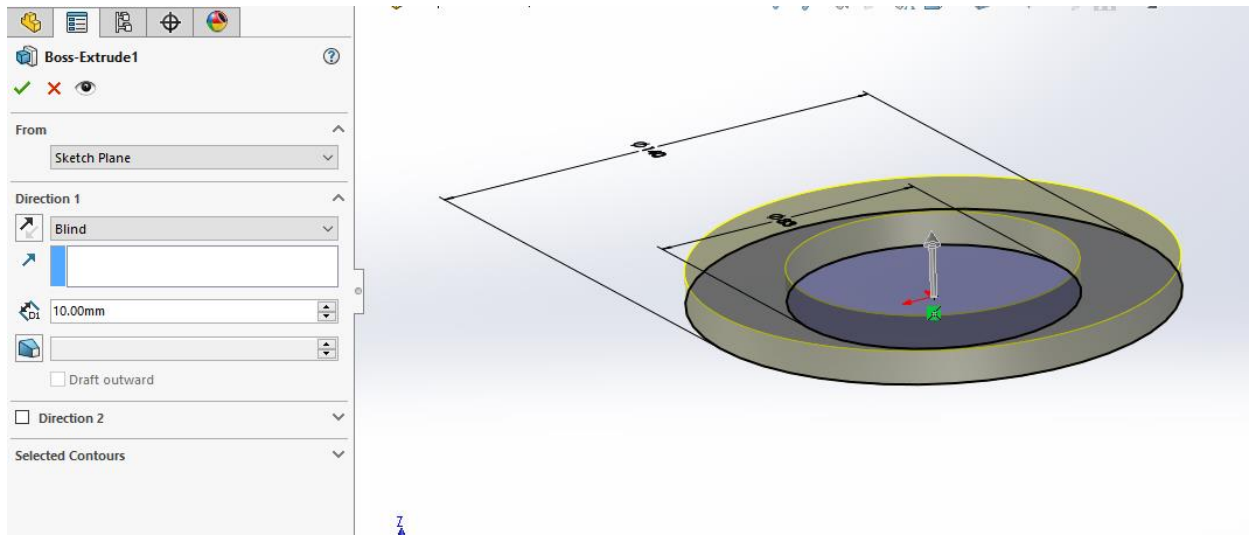
The hole are place on to the flanges by using cut extrude feature→ the part is then mirror to the alternative face



Design of compressor casing:

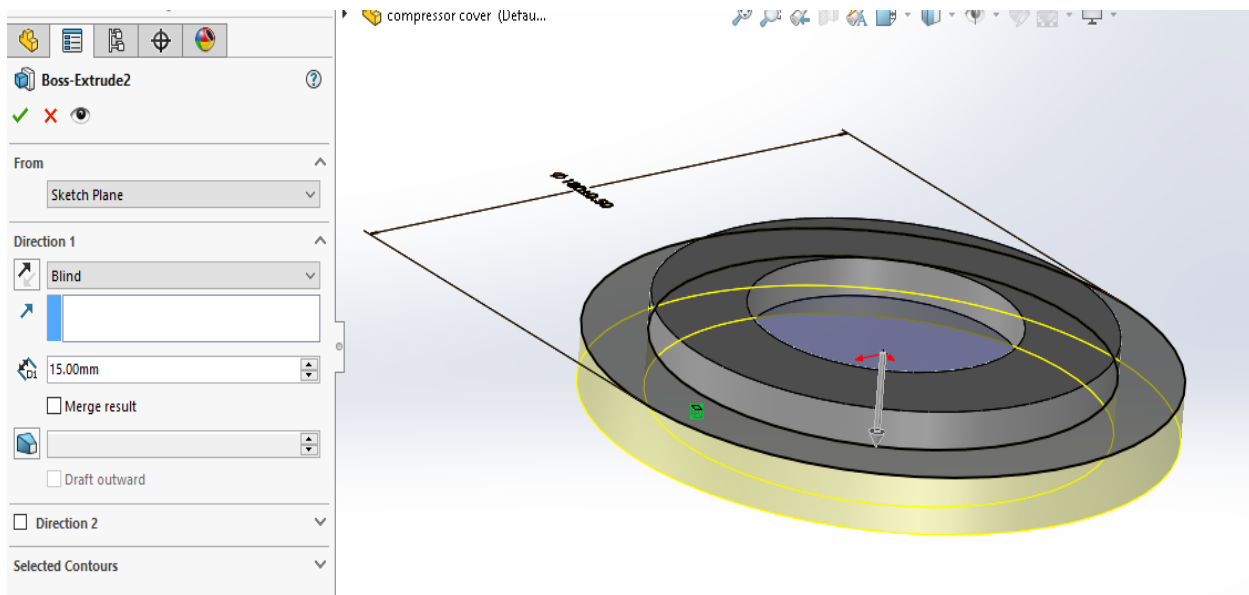
Step-1:

The initial sketch is drawn on to the front plane → then apply extrude Boss feature to the required thickness



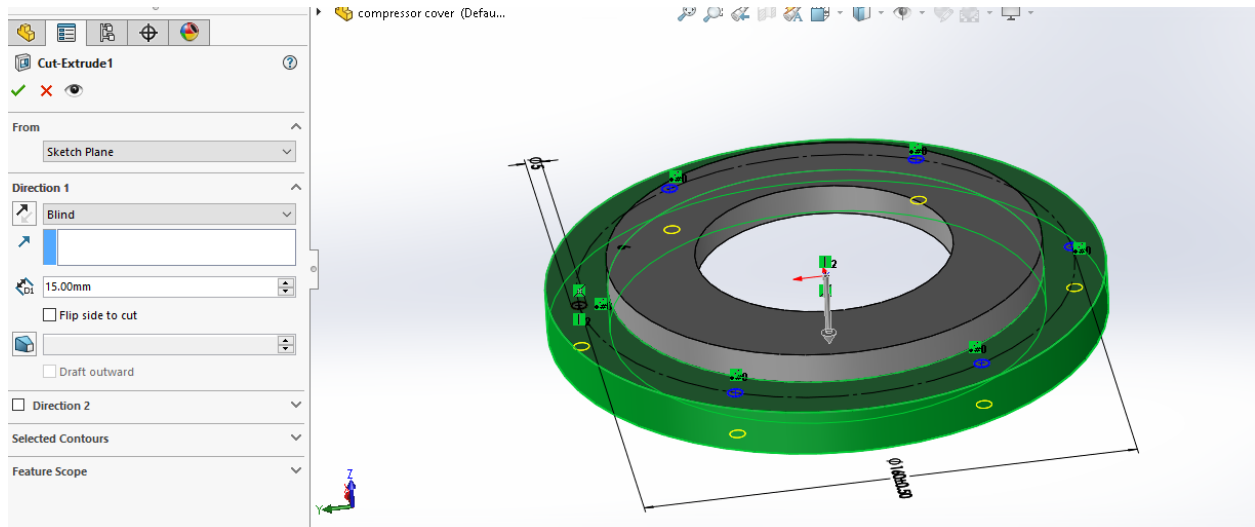
Step-2:

Select the top face to sketch and generate concentric circles → use the boss extrude feature up to the required thickness



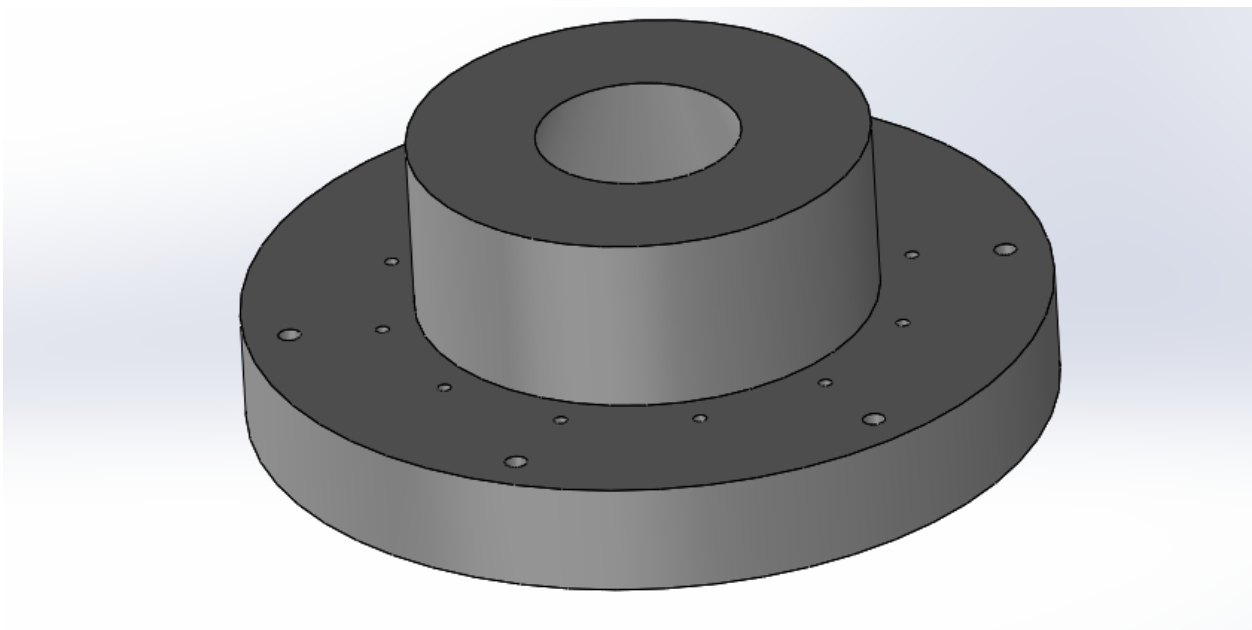
Step-3:

Use extrude cut feature for the given circles which are drawn on the face



Step-4:

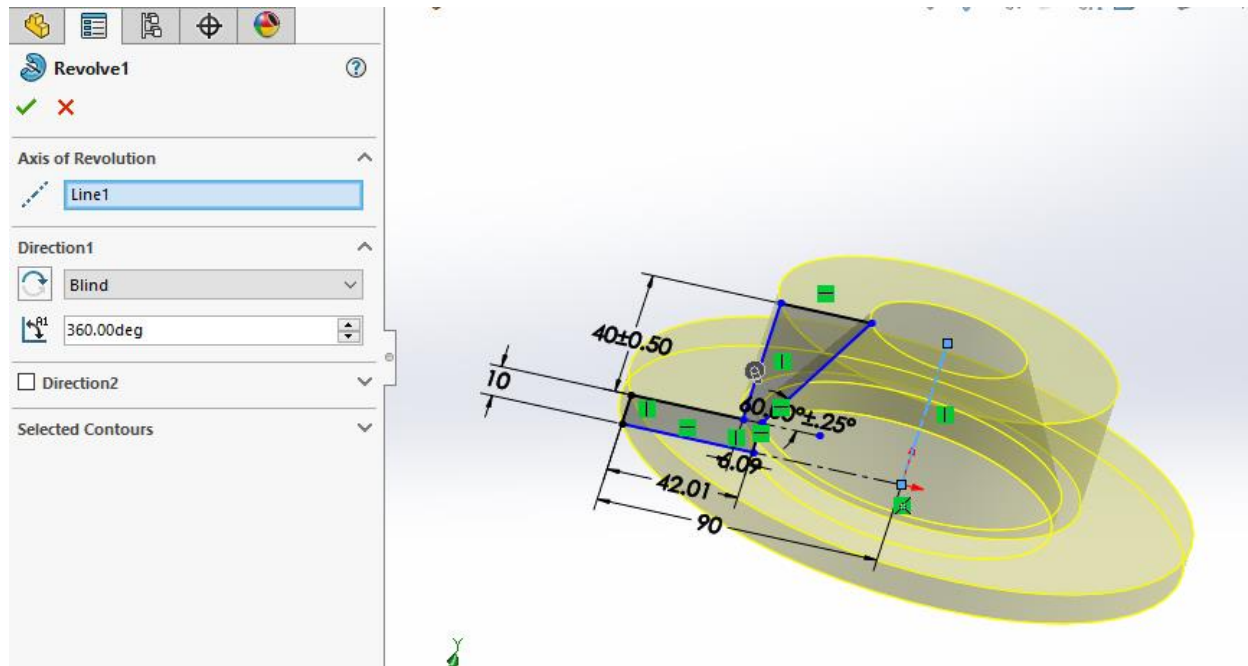
The taper truncated cone is generated inside the part using revolved cut



Design of turbine casing:

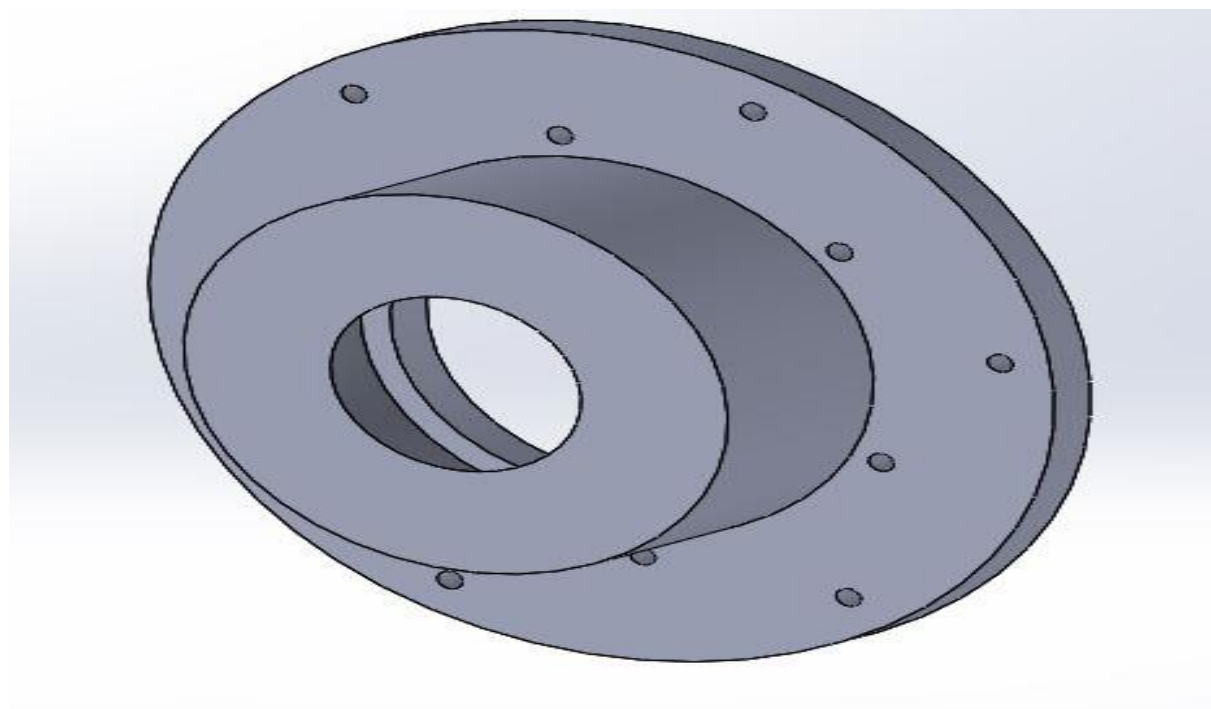
Step-1:

The initial sketch is drawn on to the front plane → use revolve extrude to make the solid part



Step-2:

Use cutting feature to get the required hole → the final part is done



1.4. Fabrication of engine

1.4.1. Shaft

The shaft was the basic component which connects the turbine and the compressor with in the housing . the shaft of over all length of 250mm should be made from the SS-304 material. We used scrap material to machine it, the following are the different process used to fabricate a shaft.

Machines used:

- 1) Lathe machine
- 2) Angle grinder

Following process are involved

- 1) Facing.
- 2) Turning.
- 3) Threading.
- 4) Cutting.

Material: Stainless Steel 304L

Cost: Rs.500 (Including material cost)

Time to complete: 43days





1.4.2. Shaft Housing

The housing is fitted with bearings and the lubrication system in which the shaft is placed and made to rotate. The housing is connected with the diffuser and the guide vane which in turn fitted inside the outer casing.

The fabrication of the housing is done with SS-316 which is high temperature resistant and good durability. The part is made from the scrap solid shaft and a pipe.

Machines used:

- 1) Lathe machine
- 2) Angle grinder

Following process are involved

- 1) Facing.
- 2) Turning.
- 3) Drilling.
- 4) Cutting.
- 5) welding

Material: Stainless Steel 316

Cost: Rs.600 (Including material cost)

Time to complete: 2 days



1.4.3. compressor and turbine

the compressor and the turbine are taken from an old turbocharger from the through research the material and the specification we known the compressor was made from the aluminum alloy 6061, and the turbine is made from the Ni-Cr steel alloy.

Cost: Rs.100 (Including including both turbine and compressor)

These are the part figure which are available for the turbocharger:

Specifications of compressor:

- 1) blade count – 8
- 2) maximum diameter- 83mm
- 3) minimum diameter-47.66mm
- 4) material – Aluminium 6061 alloy



Specification of turbine wheel:

- 1) blade count – 12
- 2) maximum diameter- 70.45mm
- 3) minimum diameter – 57mm
- 4) Hight – 32mm



1.4.4. Diffuser blade

The diffuser was to perform no rotation in the engine so the material selection for it was not a much-complicated task and we had to choose something that is light in weight. The design didn't have any curved surfaces, so it was easy to manufacture using a 3-axis CNC machine and the manufacturing.

Machines involved:

- 1) CNC 3 axis Milling machine
- 2) CNC Lathe machine

Following process are involved :

- 1) Turning
- 2) Cutting
- 3) Drilling
- 4) Machining

Material: Aluminium 6061

Cost: Rs. 6,000 (Material Cost)

Time to complete: 7 days



1.4.5. Ignition pipe

The ignition pipe is very important component of the combustion process as the gases flow from the tank to the pipe into the ignition pipe. The selection of material is very important because it should withstand high temperatures, so we choose copper as a best one because of its high heat resistance.

The pipes of copper is purchased of diameters 5mm , 3mm

Machines involved

- 1) Oxy-fuel welding and cutting
- 2) Angle grinder
- 3) Circular die

Following process are involved:

- 1) Brazing
- 2) Cutting
- 3) Grinding

Material: Aluminum 6061

Cost: Rs250 (Material Cost)

Time to complete: 1 days



1.4.6. Combustion chamber

The combustion chamber consisted of thin structure a sheet metal working was carried out for its manufacturing and due to high temperature during the operation of the engine a material with high temperature resistance was chosen for it. The sheet was taken from scrap and the made for the following use

Machines involved:

- 1) Angle grinder
- 2) Welding machine
- 3) Sheet bending machine
- 4) Radial drill

Following process are involved:

- 1) Cutting
- 2) Bending
- 3) Drilling
- 4) Welding

Material: SS-316 (1.5mm thick)

Cost: 1000(Material Cost)

Time to complete: 4 days

1.4.7. Outer casing

The outer casing is made from a piece of large scrap pipe the specification of the pipe are its internal diameter is 140mm and the outer diameter is 155mm. the piece is welded with 2 rings that which holds the compressor and turbine casings

Machines involved:

- 1) Angle grinder
- 2) Welding machine
- 3) Radial drill
- 4) Oxy-fuel welding and cutting
- 5) Lathe machine

Following process are involved:

- 1) Cutting
- 2) Welding
- 3) Drilling
- 4) turning

Material: MS EN-8 (140mm diameter and 170mm long)

Cost: 400 (Material Cost is included)

Time to complete: 3 days



1.4.8. Compressor and Turbine casings

The compressor and the turbine casing are the components which encloses the whole engine together and the flow to flow to channelize. the selection of the material should withstand high vibration and the forces acting on it.

Machines involved

- 1) Lathe machine
- 2) Drilling machine
- 3) Angle grinder

Following process are involved:

- 1) Turning
- 2) Cutting
- 3) Facing
- 4) Tapper turning
- 5) Drilling

Material: MS EN-8 (175mm diameter and 120mm long)

Cost: 3000 (Material Cost is included)

Time to complete: 5 days





1.5. Assembly of the Engine

1.5.1. Connecting shaft and the housing

The housing is first applied with lubricant and then the shaft is fitted inside the housing . two bearings are passed through the shaft and are fixed in the housing the outer diameter of the bearing is fitted inside the housing flanges then the shaft outer diameter is fixed in the bearing inner diameter.

Make sure to have a minimum clearance between the shaft and the inner race of the bearing and in outer race of the bearing to the housing.

The bearings here are used are 6900 deep groove ball bearings which have internal diameter of 10mm and a outer diameter of 22mm.



1.5.2. Connecting turbine and the compressor

The turbine and the compressor are fixed to the shaft by nut and washers. The model is quickly moved to check whether anything is loosely connected.



1.5.3. Connecting diffuser and the nozzle guide vanes

The diffuser is then bolted to the housing using nut and bolts of diameter 3.5 mm and the nozzle is also connected in the same way.



1.5.4. Connecting combustion chamber and the ignition pipe onto the housing

The combustion chamber is fixed to the housing just after the diffuser is placed and the ignition pipe is fitted into the combustion chamber through the holes

1.5.5. Inserting into the outer casing

The entire module is inserted inside the casing so that the nozzle guide vanes and the diffuser is perfectly fixed inside.



1.5.6. Fixing compressor and turbine casing

The turbine and the compressor casing are fixed on to the face of the outer casing that are fitted with bolts and nuts entire model is fixed firmly with any play.



1.5.7. Connecting model to the platform

The model is fixed to the wooden platform which consists of lubricating system and fuel tank etc... the model is thoroughly fixed with the nut and bolt so that it is firmly connected

1.6. Applications and Further study

APPLICATIONS

1) Unmanned aerial vehicle (UAV)

An unmanned aerial commonly known as a drone, is an air craft without human pilot onboard. UAVs are a component of an unmanned aircraft system, which include a UAV, a ground-based controller and a system of controller between the two. The flights of UAVs may operate with various degrees of autonomy, either under remote control by a human operator or autonomously by onboard computers.

Compared to manned aircrafts, UAVs were originally used for missions too “dull, dirty or dangerous” for human. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural and other applications, such as policing, peacekeeping, and surveillance, product deliveries aerial photography, smuggling and drone racing. Civilian UAVs now vastly outnumber military UAVs, with estimates of over a million sold by 2015.

2) Drag racing

Drag racing is a type of motor racing in which automobiles or motorcycles compete, usually two at a time, to be first to cross a set finish line. The race follows a short, straight course from a standing start over a measured distance, with a shorter becoming increasingly popular, as it has become the standard for top fuel dragsters and funny cars, where some bracket races and other sanctioning bodies have adopted it as the standard. Electronic timing and speed sensing systems have used to record race results since the 1960s.

3) Jet pack

A jet pack, rocket belt or rocket pack is a device worn on the back which uses jets of gas or liquid to propel the wearer through the air. The concept has been present in science fiction for almost a century and became widespread in the 1960s. real jet packs have been developed using a variety of mechanisms, but their uses are much more limited than their fictional counterparts because of the challenges of earth’s atmosphere, gravity, low energy density of available fuels, and the human body not being suited to fly, and they are principally suited for stunts. A practical use of jet pack has been in extra-vehicular activities for astronauts.

4) Hydro plane

A hydro plane is a fast motor boat, where the hull shape is such that at speed, the weight of the boat is supported by planing forces, rather than simple buoyancy.

A key aspect of hydro is that use the water they are on for lift rather than buoyancy, as well as for propulsion and steering,, when travelling at high speed water is forced downwards by the bottom of the boat’s hull. The water therefore exerts an equal and opposite force upward, lifting the vast majority of hull out of water. This process, happening at the surface of the water, is known as planing.

5) Radio-controlled aircraft

A radio controlled aircraft called as RC aircraft is small flying machine that is controlled remotely by an operator on the ground using a hand held radio transmitter. The transmitter communicates with a receiver within the craft that sends

signals to servomechanisms which move the control surfaces based on the position of joysticks on the transmitter. The control surface in turn, affects the orientation of the plane.

Scientific, government and military organization are also using RC aircraft for experiments, gathering weather readings, aerodynamic, modeling and testing.

FURTHER STUDY

This project can be extended by inserting a after burner and making it efficient that to making then possible to use in UAV for farther distance.

And further as possible as the combustion chamber can be also modified to get the better efficiency . If possible these are us in model drag racings

1.7. Conclusion:

Going through this project was a learning experience for both the supervisor and the team, everything was done according to the procedure and a good understanding was also developed both in the fields of designing and manufacturing.

The aim of this project was not just only designing but also to manufacture it with such detailed designing and a good idea about the manufacturing techniques we were able to manufacture all the components locally with in a budget of Rs. 25,000/- which is 4 times lesser than the proposed budget for this project. The assembly is going on as this report is getting submitted and a detailed testing for every component will also be performed in order to make sure the proper working of the engine.

This project not only has related the theoretical knowledge of the students to a practical implementation, but it has also provided them the knowledge and experience one should have if they wish to develop a product and while carrying out this project the students were able to learn and deal with challenges, they might face doing any project locally of this caliber.

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