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College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Design of Turbojet Engine using Automobile Turbocharger.

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Mechanical Engineering

Group Members

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Abstract

Modern industry needs a simpler and faster optimum design methods to facilitate the development process of gas turbine engine combustion chamber. The combustion chamber design procedure requires the selection of optimum empirically derived formulas. This project work is about researching, designing, and building jet-engines. This work focusses mainly on design of an optimal combustion chamber geometry for turbojet engine. This design is characterized by small dimensions, with enhanced possibilities for air and fuel mixture circulation in the primary combustion zone to obtain good residence time in the flame tube, higher turbulence, and optimal radial temperature distribution.

In this research work, various types of combustion, mixing is studied. The focus of investigation is to explore the various types to enhance combustion mixing. Combustion mixing depends on the port fuel injection or direct fuel injection, number of the particle, nozzle angle and nozzle dimension.

After finishing research about combustion chamber optimum geometry, our main objective is to design, develop and manufacture a simple turbojet engine in this project using a large diesel car turbocharger on a small-scale level. Turbocharger consists of two chambers that are connected by center housing and the two chambers contain a turbine wheel and a compressor wheel connected by a shaft which passes through the center housing. The turbocharger serves as an integrated compressor & turbine assembly that is suitably manipulated and carefully converted into an open cycle constant pressure gas turbine. The project mainly involves modelling and designing of combustion chamber using software packages like AutoCAD, SolidWorks etc.; and then complete fabrication of the same by us.

The methods were then discussed and chosen in a way that would simplify the design work as well as the construction of the engine.

In this research, we will apply our mechanical engineering understanding to design, analyze and manufacture a jet engine. We will review literature regarding gas turbine engine components, designed each component, and manufactured them accordingly. We then assembled our engine and planned for testing.

Keywords– Jet engine, turbocharger, compressor, turbine, internal combustion engine, combustion chamber, efficiency. direct injector, port injector, mixing efficiency.

Acknowledgment

We also want to extend our gratitude to the officials and the staff of the PMU for their guidance and support. We would like to express our gratitude to our project advisor “Dr. Mohammad el Hassan for his guidance in this project. Project leader wants to thank and acknowledge the effort and team spirit shown by the team members during the project.

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1. Chapter: Introduction

The gas turbine engine is a machine, which work according to the thermodynamic Brayton Cycle by harnessing energy from a working fluid and converting the energy into a useable form. Various types of gas turbines are designed to perform a range of tasks, but all operate on similar principles. Air enters the engine, is compressed, mixed with fuel, combusted, and then expanded through a rotating turbine. Due to the extreme temperatures and high rotational speeds experienced by engine components, design and construction of a gas turbine demands accuracy, informed material selection, knowledge of thermodynamics, and the ability to model and machine metal components. From fine tolerance in space to resilience to high temperatures and stress, the jet engine has gone through a revolution over the years, with great improvements in performance, efficiency, and reliability. The most known jet engines are the turbojet engine, the turboprop engine, the turbofan engine, the turboshaft, and the ramjet engine. The major principle in all these engines are the same and they work according to similar concepts as the internal combustion engine:

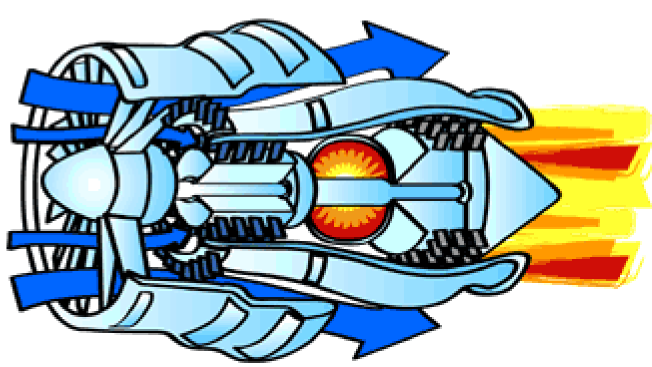


Figure 1.1: Turbojet Engine.

i. **Suck:** The engine sucks in a large volume of air through the fan and compressor stages. A typical commercial jet engine takes in 1.2 tons of air per second during takeoff. The mechanism by which a jet engine sucks in the air is largely a part of the compression stage. Some engines have an additional fan that is not part of the compressor to draw additional air into the system. This part is on left side in figure 1.

ii. **Squeeze:** Aside from drawing air into the engine, the compressor also pressurizes the air and delivers it to the combustion chamber. The compressor is shown in figure 1 just to the left of the fire in the combustion chamber and to the right of the fan. The compression fans are driven from the turbine by a shaft. Compressors can achieve compression ratios more than 40:1, which means that the pressure of the air at the end of the compressor is over 40 times that of the air that enters the compressor.

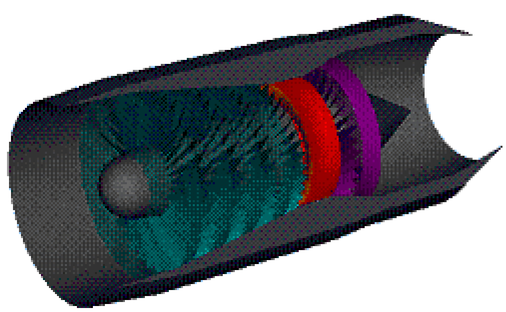


Figure 1.2: Compressor of Turbojet engine.

Figure 2 shows the green fans that compose the compressor gradually get smaller and smaller, as does the cavity through which the air must travel. The air must continue moving to the right, toward the combustion chambers of the engine, since the fans are spinning and pushing the air in that direction. The result is a given amount of air moving from a larger space to a smaller one, and thus increasing in pressure.

iii. **Bang:** In combustion chamber fuel is mixed with air to produce the bang, which is responsible for the expansion that forces the air into the turbine. Inside the typical commercial jet engine, the fuel burns in the combustion chamber at up to 2000 degrees Celsius. The temperature at which metals in this part of the engine start to melt is 1300 degrees Celsius, so advanced cooling techniques must be used.

The combustion chamber has the difficult task of burning large quantities of fuel, supplied through fuel spray nozzles, with extensive volumes of air, supplied by the compressor, and releasing the resulting heat in such a manner that the air is expanded and accelerated to give a smooth stream of uniformly heated gas. This task must be accomplished with the minimum loss in pressure and with the maximum heat release within the limited space available. The amount of fuel added to the air will depend upon the temperature rise required.

iv. **Blow:** The fourth part is focused on the outlet of the engine, the reaction of the expanded gas the mixture of fuel and air being forced through the turbine, drives the fan and compressor and blows out of the exhaust nozzle providing the thrust.

Thus, the turbine has the task of providing power to drive the compressor and accessories, by extracting energy from the hot gases released from the combustion system and expanding them to a lower pressure and temperature. To produce the driving torque, the turbine may consist of several stages, each employing one row of moving blades and one row of stationary guide vanes to direct the air as desired onto the blades. The number of stages depends on the relationship between the power required from the gas flow, the rotational speed at which it must be produced, and the diameter of turbine permitted.

1.1 Project Definition

This project consists of Design, fabrication, assembly and testing of a Jet Engine, using a large diesel car turbocharger, on a small-scale level. The turbocharger serves as an integrated compressor & turbine assembly which is suitably manipulated and carefully converted into an open cycle constant pressure gas turbine. The project mainly involves complex modeling, designing and analysis of combustion chamber using software packages like AutoCAD, SolidWorks etc.; and then complete fabrication of the same completely by us.

1.2 Project Objectives

Following are the objectives of our project:

- To optimize the design procedure of the combustion chamber.
- To determine the design parameters, the design constraints, and their effect on chamber performance.
- To construct a working scaled model of a turbojet engine using diesel car turbocharger which will be self-sufficient and requiring no separate power sources to operate thus allowing the unit to be mobile.

1.3 Project Specifications

Following are the initial design specification:

- The first constraint imposed by low cost involves the elimination of turbine blade cooling and limits the combustor exit temperature to 1100 K maximum to assure safe and long operation of turbine blades and nozzle guide vanes.
- The overall engine dimensions of 500 mm maximum length and 145 mm maximum diameter dictated a short length and small diameter combustor.

1.4 Project Applications

A modern jet engine is truly a miracle of engineering. Jet engines see wide use in many applications, aviation, and energy production among many others. Common applications of modern gas turbines include producing auxiliary power for ground or aircraft systems, propelling military aircraft at supersonic speeds, and driving the rotor system of helicopters.

2. Chapter: Literature Review

2.1 Project Background

In this section history of jet engines, applications, working principle and types of jet engines are discussed.

2.1.1 History of jet engine

The basic principle used in jet engines has been known for a long time. It dates to around 150 BC when the principle was used in the Aeolipile as shown in figure 2 [2], which is a simple construction using a radial steam turbine. The steam exits through a nozzle creating a spinning motion of a ball. All according to Newton's third law.

The key to a practical jet engine was the gas turbine, extracting power from the engine itself to drive the compressor. The gas turbine was not a new idea: the patent for a stationary turbine was granted to John Barber in England in 1791. The first gas turbine to successfully run self-sustaining was built in 1903 by Norwegian engineer Ægidius Elling. The interest continued during the 1800s. But it wasn't until Sir Frank Whittle of the Royal Air Force in the 1930s made the first patent for the jet engine and showed the possibilities through reliable energy conversion. He made the first static test in 1937. Two years later, in 1939, it was a German physicist named Hans von Ohain who made the first jet-powered-flight and demonstrated the possibilities of the jet engines. The ideas came about improving the propeller driven aircrafts of the time, where the main problem was the speed of the aircraft. The aircraft of the time were closing in on the speed of sound, and sometimes getting too close, which would result in shock waves being created, causing the propeller to shatter.

The jet engine allowed a continuous combustion and airflow. It was a big change from the piston engines dominating the industry. At the time, the greatest struggle the engineers had was to create a material that could withstand the temperatures generated in the combustion chamber, since it would often lead to the turbines melting. The development of the jet engine took off during World War II and performance was quickly raised because of the efforts made to try to get any advantage possible. Thus, paving the way for the modern jet engines.

Figure 2.1: Hero's Aeolipile (Source: Knight's American Mechanical Dictionary, 1876).

Following the end of the war the German jet aircraft and jet engines were extensively studied by the victorious allies and contributed to work on early Soviet and US jet fighters. The legacy of the axial-flow engine is seen in the fact that practically all jet engines on fixed-wing aircraft have had some inspiration from this design. By the 1950s the jet engine was almost universal in combat aircraft, except for cargo, liaison and other specialty types. The efficiency of turbojet engines was still rather worse than piston engines, but by the 1970s, with the advent of high-bypass turbofan jet engines fuel efficiency was about the same as the best piston and propeller engines.

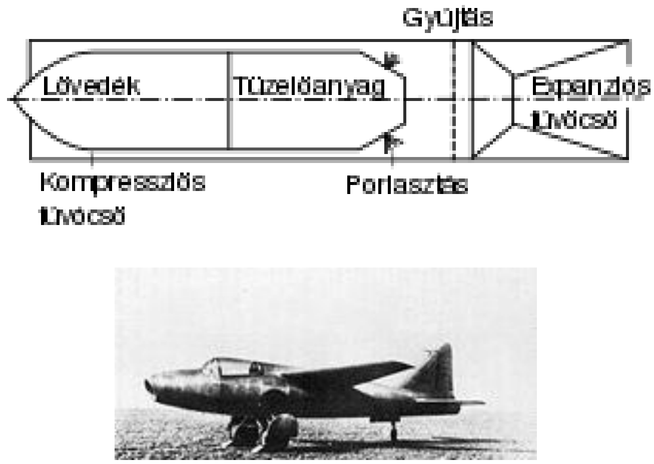


Figure 2.2: ***(a)*** *Albert Fonó's ramjet-cannonball from 1915.* ***(b)*** *Heinkel He 178, the world's first aircraft to fly purely on turbojet power.*

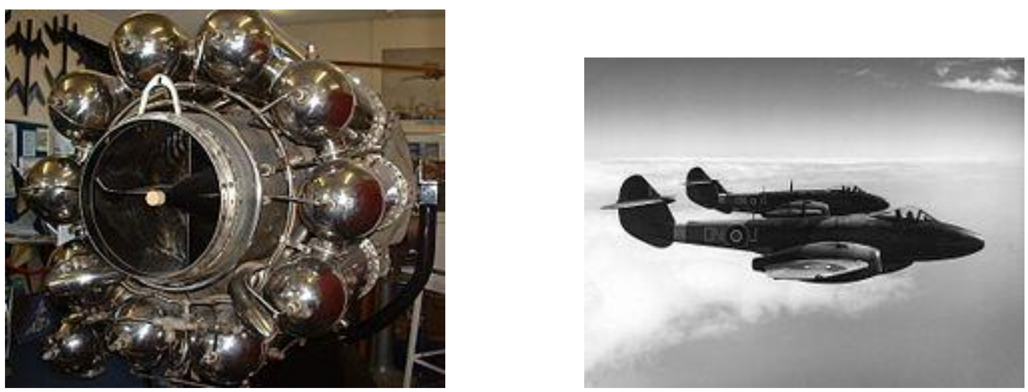


Figure 2.3: (a) The Whittle W.2/700 engine flew in the Gloster E.28/39. (b) Gloster Meteor F.3s.

2.1.2 Application of jet engine

Jet engines power jet aircraft, cruise missiles and unmanned aerial vehicles. In the form of rocket engine, jet engine power fireworks, model rocketry, spaceflight, and military missiles. Jet engine designs are frequently modified for non-aircraft applications, as industrial gas turbines or marine powerplants. These are used in electrical power generation, for powering water, natural gas, or oil pumps, and providing propulsion for ships and locomotives. Industrial gas turbines can create up to 50,000 shaft horsepower.

Jet engines are also sometimes developed into, or share certain components such as engine cores, with turboshaft and turboprop engines, which are forms of gas turbine engines that are typically used to power helicopters and some propeller-driven aircraft.

Figure 2.4: A JT9D turbofan jet engine installed on a Boeing 747 aircraft.

2.1.3 Working Principle of Jet Engine

All jet engines work on the same principle. The engine sucks air in at the front with a fan. A compressor made with many blades attached to a shaft spin at high speed and raises the pressure of the air by compress or squeeze the air. The compressed air is then sprayed with fuel and an electric spark lights the mixture. The burning gases expand and blast out through the nozzle, at the back of the engine. The engine and the aircraft get thrust forward as the jets of gas shoot backward. As the hot air is going to the nozzle, it passes through another group of blades called the turbine. The turbine is attached to the same shaft as the compressor. Spinning the turbine causes the compressor to spin. Figure 2.1 shows the air flow through the engine.

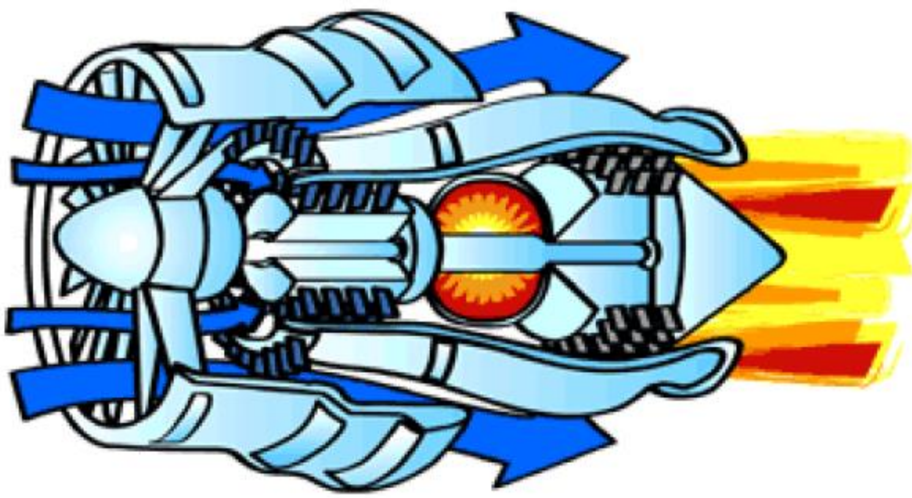


Figure 2.5: Air flow through the Jet engine.

2.1.4 Parts of jet engine

Following are the parts of jet engine:

- Fan - The fan is the first component in a turbofan. The large spinning fan sucks in large quantities of air. Most blades of the fan are made of titanium. It then speeds this air up and splits it into two parts. One part continues through the "core" or center of the engine, where it is acted upon by the other engine components.
- Compressor - The compressor is the first component in the engine core. The compressor is made up of fans with many blades and attached to a shaft. The compressor squeezes the air that enters it into progressively smaller areas, resulting in an increase in the air pressure. This results in an increase in the energy potential of the air. The squashed air is forced into the combustion chamber.
- Combustor - In the combustor the air is mixed with fuel and then ignited. There are as many as 20 nozzles to spray fuel into the airstream. The mixture of air and fuel catches fire. This provides a high temperature, high-energy airflow. The fuel burns with the oxygen in the compressed air, producing hot expanding gases. The inside of the combustor is often made of ceramic materials to provide a heat-resistant chamber. The heat can reach 2700°.
- Turbine - The high-energy airflow coming out of the combustor goes into the turbine, causing the turbine blades to rotate. The turbines are linked by a shaft to turn the blades in the compressor and to spin the intake fan at the front. This rotation takes some energy from the high energy flow that is used to drive the fan and the compressor. The gases produced in the combustion chamber move through the turbine and spin its blades. The turbines of the jet spin around thousands of times. They are fixed on shafts which have several sets of ball-bearing in between them.

- Nozzle - The nozzle is the exhaust duct of the engine. This is the engine part which produces the thrust for the plane. The energy depleted airflow that passed the turbine, in addition to the colder air that bypassed the engine core, produces a force when exiting the nozzle that acts to propel the engine, and therefore the airplane, forward. The combination of the hot air and cold air are expelled and produce an exhaust, which causes a forward thrust.

  The velocity of the air entering the nozzle is low, about Mach 0.4, a prerequisite for minimizing pressure losses in the duct leading to the nozzle [4]. The temperature entering the nozzle may be as low as sea level ambient for a fan nozzle in the cold air at cruise altitudes. It may be as high as the 1000 K exhaust gas temperature for a supersonic afterburning engine or 2200K with afterburner lit [5]. The pressure entering the nozzle may vary from 1.5 times the pressure outside the nozzle, for a single stage fan, to 30 times for the fastest manned aircraft at mach 3.[6]

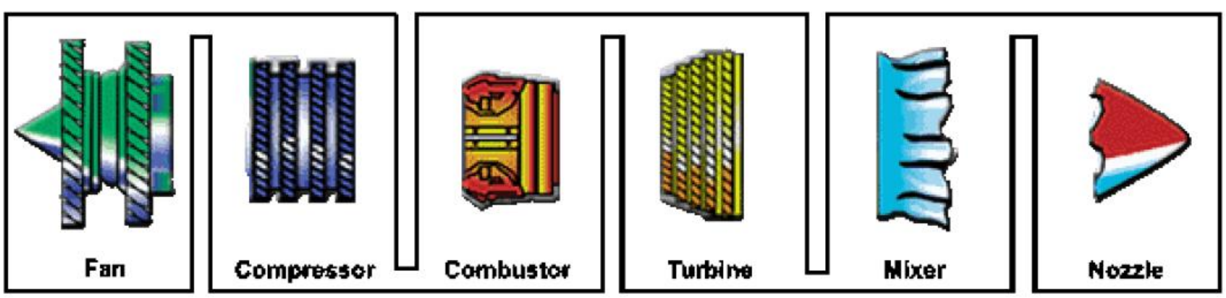


Figure 2.6: Parts of jet engine.

2.1.5 Types of Jet Engine

Following are the types of jet engine:

- **Turbojets:** The basic idea of the turbojet engine is simple. Air taken in from an opening in the front of the engine is compressed to 3 to 12 times its original pressure in compressor. Fuel is added to the air and burned in a combustion chamber to raise the temperature of the fluid mixture to about 1,100°F to 1,300° F. The resulting hot air is passed through a turbine, which drives the compressor.

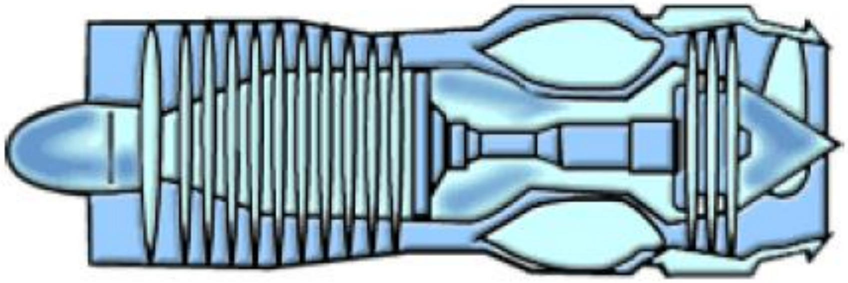


Figure 2.7: Turbojet engine.

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

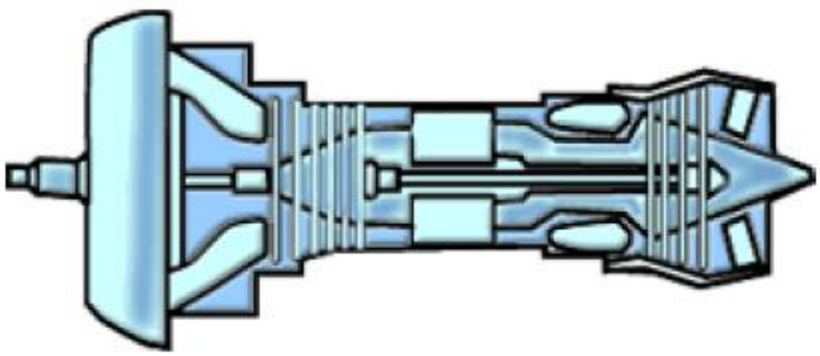


Figure 2.8: Turboprop engine.

- **Turbofans:** A turbofan engine has a large fan at the front, which sucks in air. Most of the air flows around the outside of the engine, making it quieter and giving more thrust at low speeds. 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.

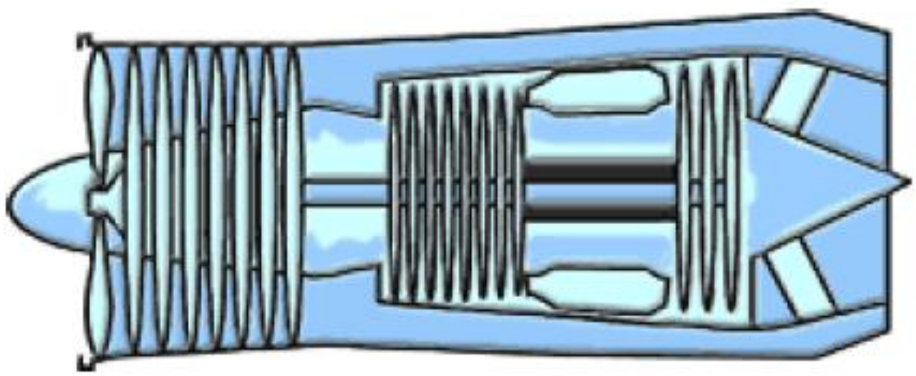


Figure 2.9: Turbofan engine.

- **Turboshafts:** 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.

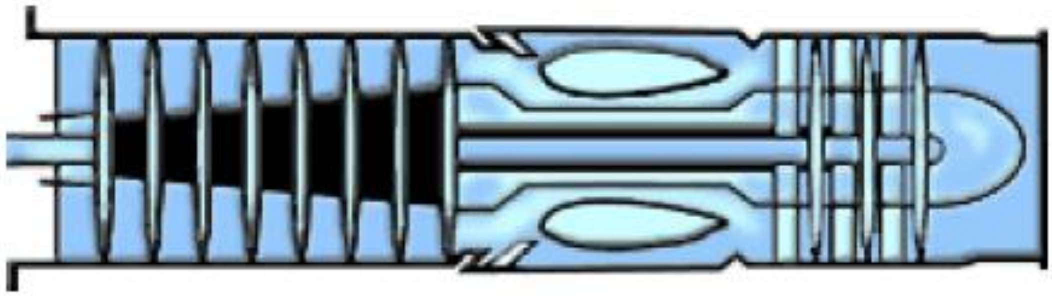


Figure 2.10: Turboshaft engine.

- **Ramjets:** The ramjet is the simplest jet engine and 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.

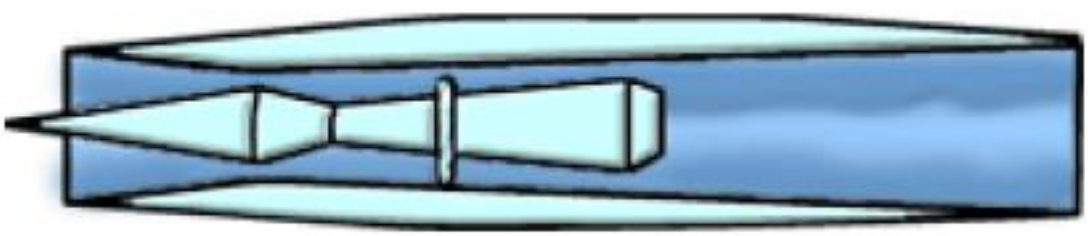


Figure 2.11: Ramjets engine.

3. Chapter: System Design

Design Constrains.

- The temperature of the working fluid should not exceed 1000^{o}C
- The model should be self-sufficient and would be able to operate without any outside assistance.

Design methodology

Designing of the model was done in SolidWorks. Different type of engines was analyzed to get design ideas and ultimately for the selection of the most suitable design for the project. Then those dimensions were used for modeling.

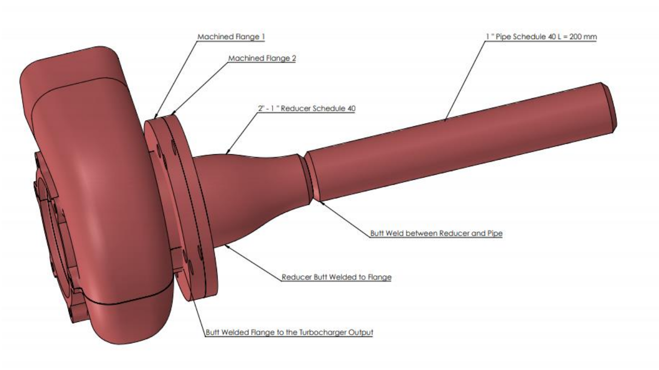


Figure 3.1: Model of turbocharger Diffuser

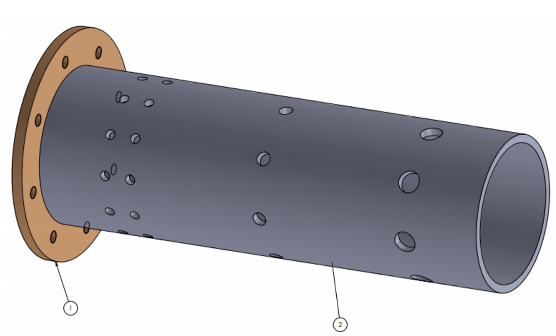


Figure 3.2: Inner Liner Assembly

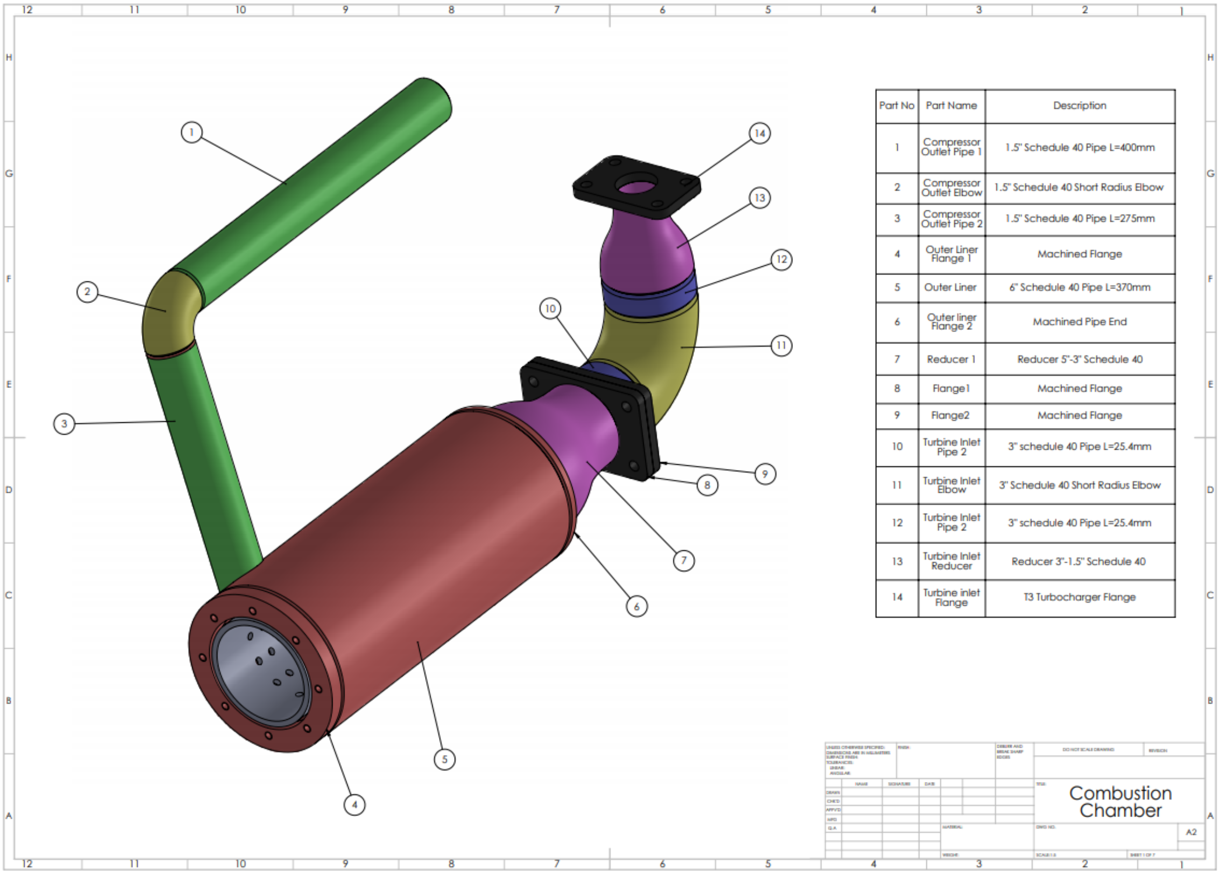


Figure 3.3: Combustion Chamber

Theoretical Calculations of the Model

The Net thrust which will be generated by the engine could be calculated by using the equation given below.

$$F_N = (\dot{m}_f + \dot{m}_{air})V_j - V\dot{m}_{air}$$

Where,

$V = Velocity\ of\ the\ aircraft$

$V_j = exit\ \ jet\ speed$

$\dot{m}_f = fuel\ consumption\ rate\ of\ the\ engine$

$\dot{m}_{air} = Air\ mass\ flow\ rate$

The amount of thrust produced by the engine can be increased by increasing the exhaust velocity. It will result in an increase in thrust with our increasing the mass flow rate of the air or mass flow rate of the fuel could be increased to increase the thrust with our increasing exhaust speed. This is the same process which is used in the engines of the modern commercial engines known as bypass ratio.

For the purpose of thermodynamic calculations of the system, we have to make some assumptions first to make calculations simple.

Assumptions

1. The system will be considered as steady-state control volume system
2. The air and the gasses in the system will be considered as ideal gases at each point of the analysis.
3. Within the system effects of kinetic energy will be neglected.
4. Potential energy will be considered negligible for the system.
5. The work produced by the turbine of the engine will be considered equal to the energy consumed by the compressor of the engine.
6. Pressure drop in the system will be considered zero for flow.
7. All of the processes will be considered as isentropic processes.

Calculations for different components of the engine are given below.

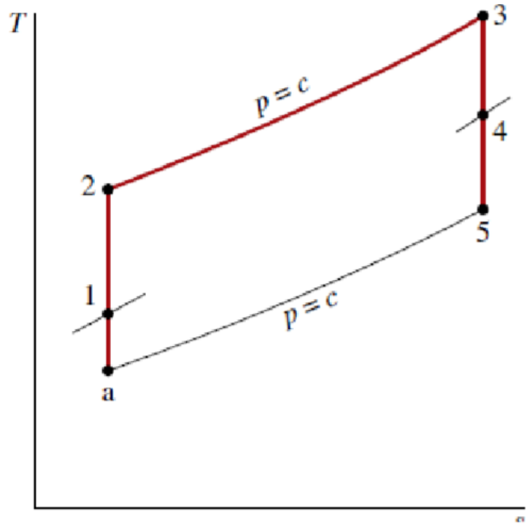


Figure 3.4: T-s Diagram of Ideal turbojet engine cycle.

Diffuser.

By considering mass and energy balance across the diffuser the enthalpy of the air after the diffuser could be calculated as.

$$h_1 + \frac{V_1^2}{2} = h_a + \frac{V_a^2}{2}$$

$$V_1 \approx 0$$

$$h_1 = h_a + \frac{V_a^2}{2}$$

Compressor

Pressure after the compressor could be calculated by using the compression ratio of the compressor.

$$\frac{p_2}{p_1} = \pi_c$$

Turbine

The power produced by the turbine could be given by the following equation as we know the power produced by the turbine will be equal to the power consumed by the compressor.

$$\frac{\dot{W}_t}{\dot{m}} = \frac{\dot{W}_c}{\dot{m}}$$

Enthalpy of the air exiting the turbine could be given as below.

$$h_3 - h_4 = h_2 - h_1$$

$$h_4 = h_3 + h - 1 - h_2$$

Nozzle:

By apply the Bernoulli's equation across the nozzle

$$h_4 + \frac{V_4^2}{2} = h_3 + \frac{V_5^2}{2}$$

By neglection the velocity of the gasses at the inlet of the nozzle.

$$V_5 = \sqrt{2(h_4 - h_3)}$$

Some of the other formulas used for the calculations of different parameters during calculations are given below.

Brake Power of the Engine

Brake power of the engine is calculated by using the formula given below:

$$P_b = 2\pi\tau N$$

Where

P_b=Power produced by the engine

T= Torque produced by the engine

N= Rotational Speed of the engine

BMEP

Brake mean effective pressure in the engine are calculated using equations given below.

$$bmep = \frac{4\pi\tau}{V_d}$$

Air Density

Density of the air is calculated by using the equation given below

$$\rho_i = \frac{p_i}{RT_i}$$

Where

p_i=pressure of the gas

R=Gas Constant

T_i=Temperature of the gas

Components and the Subsystems

The turbojet engine could be divided into three major systems which are given below.

1. Combustion System of the Engine
2. Turbocharger System
3. Lubrication System of the Engine

The three major systems of the engine are made of several smaller subsystems. The three major system and their subsystems could be seen in the figure below.

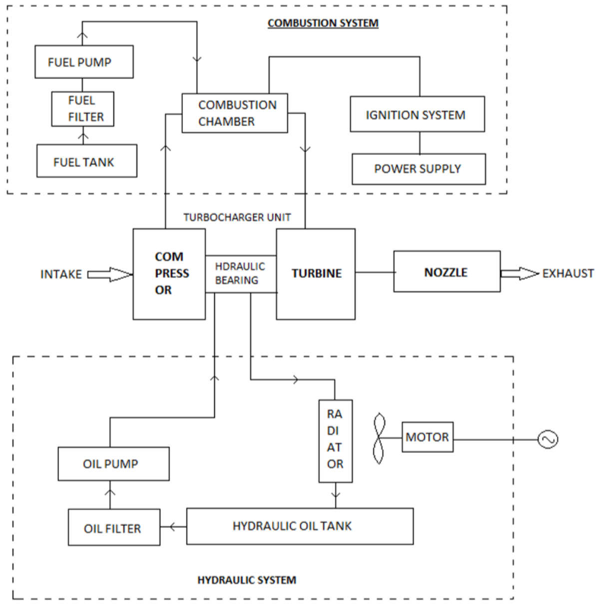


Figure 3.5: Turbojet Engine Block Diagram

Turbocharger Unit

The Turbocharger of an engine consist of Turbocharger along with Inlet diffuser and outlet nozzle.

Turbocharger

The turbocharger is a device which is used to increase the pressure of the inlet air for an engine it is usually a centrifugal compressor which is either rotated by a turbine powered by the exhaust of the vehicle or by connecting the main power drive of the vehicle. The turbocharger increases the power produced by the engine by increasing the amount of the air supplied to the cylinder in each stroke.

Turbocharger Compressor

Turbocharger compressor is a centrifugal device which takes the air from the atmosphere at low pressure and compresses it to a higher pressure with the help of mechanical power. In the compressor air is drawn axially then it is accelerated to higher velocity and then expelled radially out into the diffuser.

Turbocharger Turbine

Turbocharger turbine is made up of a turbine wheel and housing it is powered by the exhaust of the engine. The exhaust of the engine is at a higher pressure than the pressure of the atmosphere this pressure difference is used to drive the turbine which is connected to the compressor and drives it as a result.

Propelling nozzle

Nozzle or exhaust nozzle is one of the most important components of a turbojet engine the turbojet engines are used to produce jets. The power is in the form of the energy of the exhaust gases the mechanical power produced by the engine is minimum. It is only used to drive the compressor and some other important components. Most of the power produced by the engine is in the form of gasses exiting at very high speed. The nozzle of an engines takes the exhaust from the turbine which is at very high pressure and low velocity as these gasses passes through the nozzle their potential energy is converted into kinetic energy.

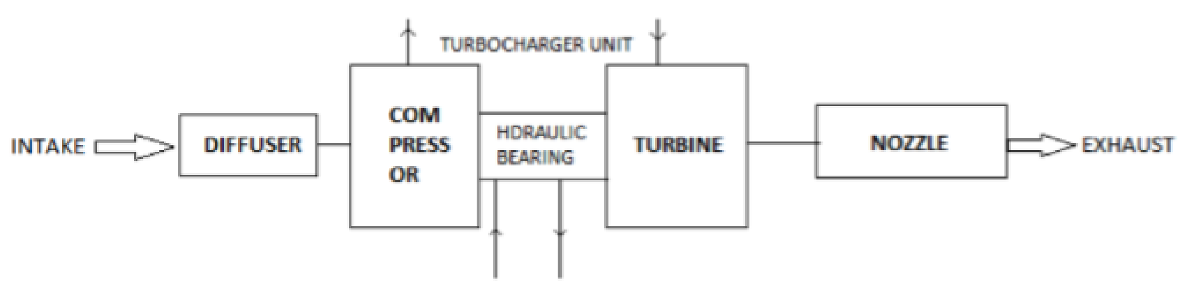


Figure 3.6: Schematic diagram of turbocharger

Hydrostatic Unit

The hydrostatic system is used to lubricate the rotating parts of the engine. This system consists of a hydraulic pump, oil filters and an oil storage tank.

Hydraulic Oil Pump

An oil pump is used to provide oil at constant pressure to the hydrostatic bearings of the engine. For the oil and flow requirements of the engine, the external gear pump is the most suitable choice.

Oil Filter

Oil filters are very important in any engine the purpose of these filters is to remove any outside particles from the oil which can cause damage to the system. Especially in internal combustion engines or in the case of hydrostatic bearings where particles or small metallic pieces broken from the machinery can block small holes which can hinder the flow of the oil and cause damage to the engine. Loke in the piston of an internal combustion engine.

Oil Storage Tank

The oil storage tank is used to store the oil for the hydrostatic system as some of the oil is usually lost during operation of the machinery to compensate for that and to provide flexibility in the system usually an oil tank is used in lubrication systems.

Radiator

Radiators are used to exhaust the heat from the engine to the atmosphere. As engines like jet engines and internal combustion engines use thermal energy to produce mechanical energy. this combustion raises the temperature of the engine which can cause damage to the engine. To prevent that usually a cooling system is integrated into the combustion engine. The cooling system uses some type of fluid to transfer energy from the engine to the radiator where that energy is exhausted to the atmosphere. Radiators usually have a large number of fins along with pipes caring the coolant to increase the surface area of the radiator for better heat removal.

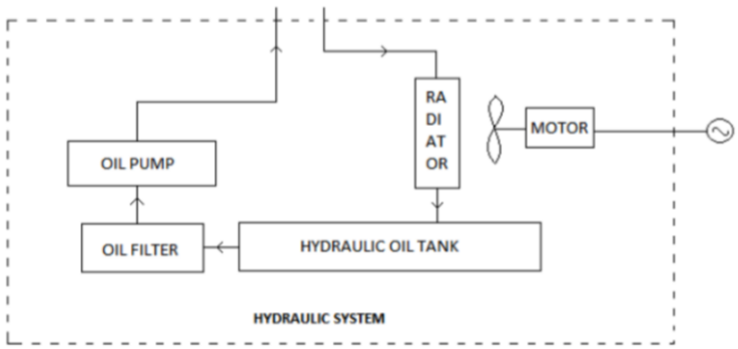


Figure 3.7: Hydraulic System.

Combustion system

The combustion system of any system is the system which produces thermal energy from the combustion of fuel. This consists of a fuel pump a combustion chamber and an ignition system.

Combustion Chamber

The combustion chamber of an engine is the chamber where the combustion of the fuel takes place it could continue like in the case of jet engines or it could be periodic like in the case of the internal combustion engine. In the jet engine where there is a continues supply of the fresh air it is difficult to sustain a continuously burning flame. For this purpose, the combustion chamber of the engine has a smaller internal cylinder with holes in it. The fuel injector nozzle is placed at the center of the internal cylinder which sprays the fuel in the form of very fine droplets into the cylinder. The internal cylinder could be divided into three different sections depending on the state of combustion in them. These three sections are primary, secondary, and tertiary.

Ignition system

The purpose of an ignition system in any engine is to produce flame to start combustion. The combustion system consists of a 230 V power supply which provides AC power for its operation, an ignition coil, an ignition coil driver circuit, and a spark plug. The purpose of the ignition coil is to provide high volt pulses of the current at regular intervals. The ignition coil is provided with 230V power and it delivers 15000V to the spark plug for ignition.

Fuel Pumping System

The purpose of the fuel pumping system is to provide fuel at high pressure into the combustion chamber for combustion. Parts of the fuel combustion system are given below.

Fuel Tank

The purpose of the fuel tank is to store fuel its the part of the engine which holds the fuel for the usage of the system. As fuels are flame able so special precautions should be taken to ensure the safety of the fuel tank.

Fuel Filter

Fuel filters are an integral part of the fuel injection system used to remove any foreign particles or paint chips which may be present in the unfiltered fuel. The removal of these foreign objects is very important because these particles are very important because they can reduce the life of the fuel pump and the fuel injector due to the abrasive action of them on these parts.

Fuel Pump

The fuel pump of any internal combustion engine is used to provide small quantities of the fuel to the fuel injectors to produce good atomization of fuel. An internal gear pump is usually the most suitable candidate for this type of applications.

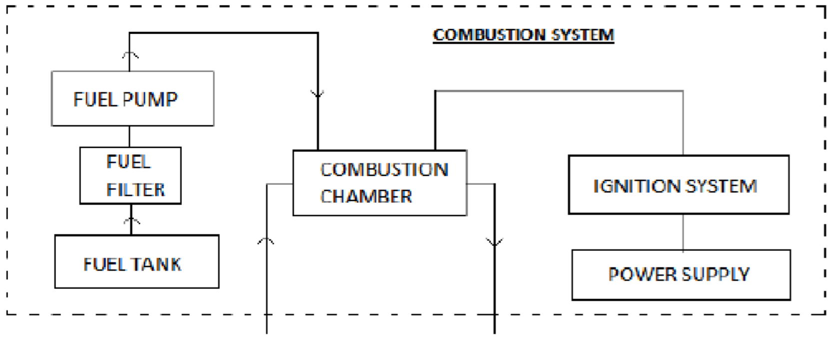


Figure 3.8: Combustion System

Theoretical Working of the model

To understand the working of a jet engine we have to understand the concept of the gas turbines. All these work on the same principles the change in only in the final output of the engine in the case of jet engines the output is in the form of mechanical power and in the form of exhaust gases. A gas turbine consists of three main components turbine, combustion chamber and compressor. Air from the atmosphere is sucked and compressed by the compressor. As the turbine used the pressure of the gases to produce work so it is important to compress the gas before combustion. After passing from compressor air goes into the combustion chamber where fuel is mixed into it and combustion takes place the which increases the energy of the gases. Then these hot gases enter the turbine which uses their thermal energy to produce work. The compressors are connected with the turbine and are powered by it. The external loads are also connected with the turbine to power them.

The jet engines also work on these exact principles so by understanding gas turbine we can understand the working of the jet engine.

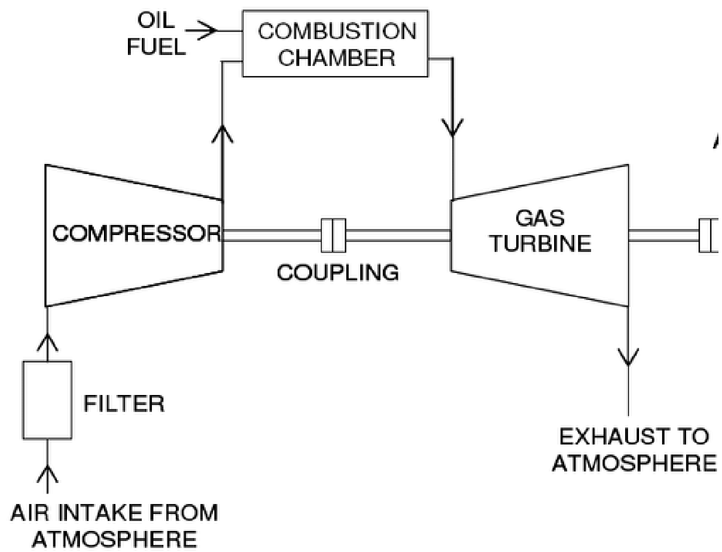
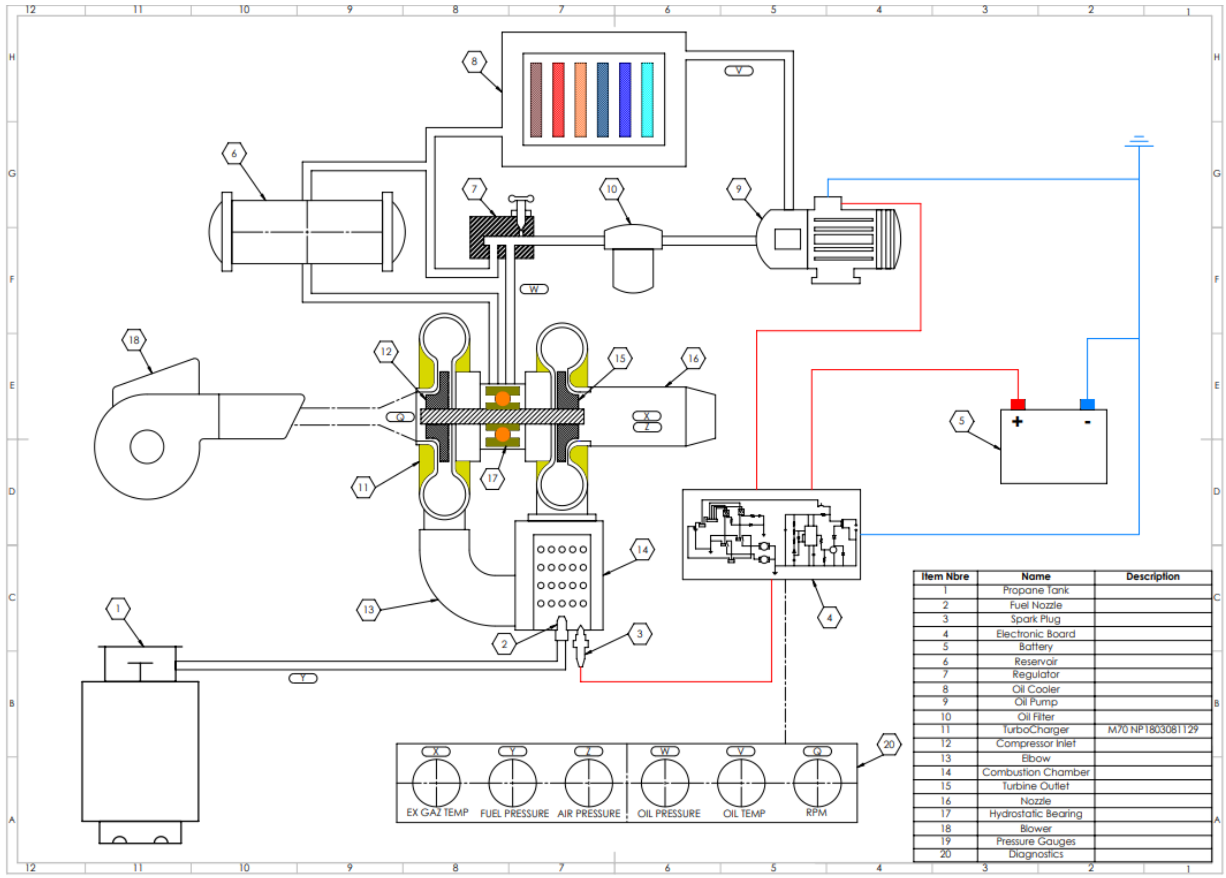


Figure 3.9: Simple Gas Turbine System

Manufacturing and Assembly

For the manufacturing and assembly we started with the selection of the turbocharger of the car engine as this is the most important part of the design and the whole design of the engine is built around it. The selection f the turbocharger the 3D model of the engine was constructed and then the drawings anf the bil of material was generated. After the finalization about the material required for the construction materials were acquired. We hired a workshop for the purpose of the cutting and welding sifferent parts of the engine which were used in the manufacturing of the engine. During the process of machining and welding the wekers were superwised by the members of the team to endure that the product is according to the design. The final assambly of the model was done by the team members. The engine was asswmbwled on a mobile platform which allows to move the engine from one place to the other and also provides the space for the essential componets whichare required for the workingof the engien like the fuel cylinder. It also provides space for the instalation if the sencors and their monitors so that the data from the engine could be monitered and the inout variables of the engine could be changed accordingly.



Item Nbre	Name	Description
1	Propane Tank	
2	Fuel Nozzle	
3	Spark Plug	
4	Electronic Board	
5	Battery	
6	Reservoir	
7	Regulator	
8	Oil Cooler	
9	Oil Pump	
10	Oil Filter	
11	TurboCharger	M70 NP1803081129
12	Compressor Inlet	
13	Elbow	
14	Combustion Chamber	
15	Turbine Outlet	
16	Nozzle	
17	Hydrostatic Bearing	
18	Blower	
19	Pressure Gauges	
20	Diagnostics	

Figure 3.10: Schematic Diagram of the Experiment Setup

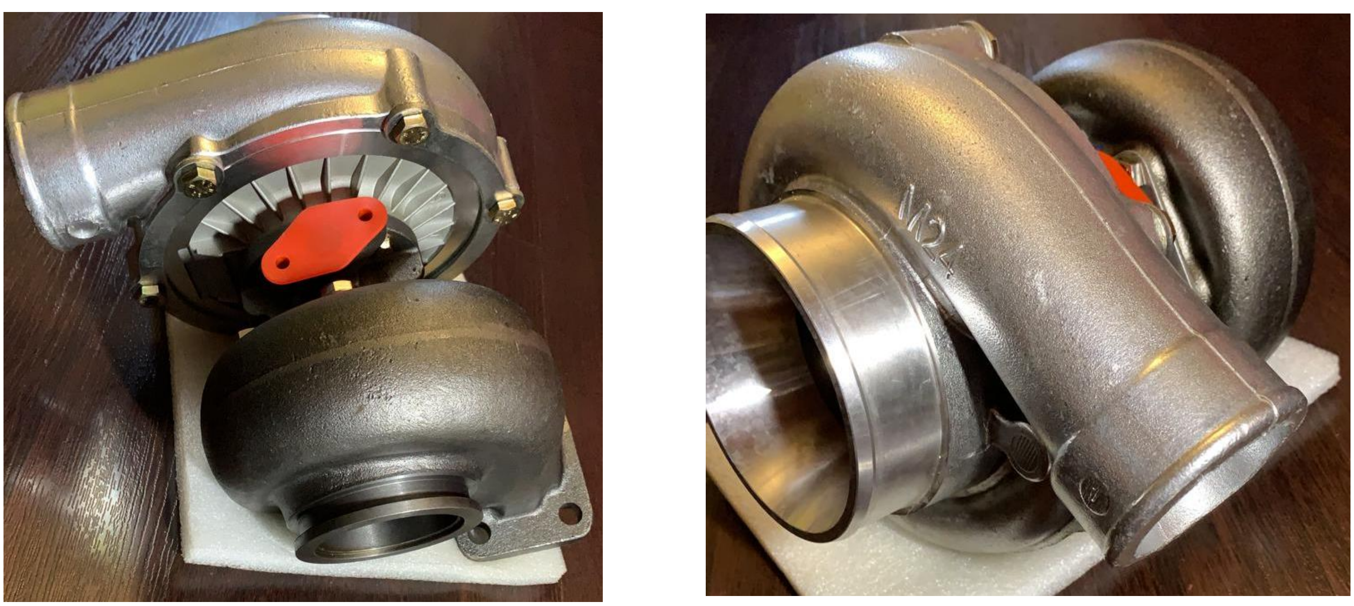


Figure 3.11: Turbo Charger

Figure 3.12: Final model of the turbojet engine.

Figure above shows the final assembly of the engine which is installed on a trolly which carry the engine and every other essential accessory as a single unit.

4. Chapter : System Testing and Analysis

Testing and Analysis

Experimental Setup, Sensors, and data acquisition system

For the monitoring of the vital parameters of the model which in this case were the temperature and the pressure at the different stages of the process. Different types of temperature and pressure measuring sensors were used but no data acquisition system was used as the sensors used were equipped with their own standalone meters which were used for taking the measurements of the model.

Results Analysis and Discussion

The constants and the efficiency values used for calculation of the system are:

$\eta_c = 75\%$

$\eta_{noz} = 86\%$

$\eta_T = 78\%$

$\eta_c = 75\%$

$\eta_{Tran} = 93\%$

$\eta_{comb} = 86\%$

$\gamma_a = 1.4$

$\gamma_g = 1.33$

$C_{pa} = 1005 \frac{J}{kg.K}$

$C_{pg} = 1147 \frac{J}{kg.K}$

$T_{amb} = T_0 = 293\ K$

$P_{amb} = P_0 = 0.98\ bar$

$Q_f = 43\ MJ$

$Pressure\ Ratio = \frac{P_{02}}{P_{01}} = 2.5$

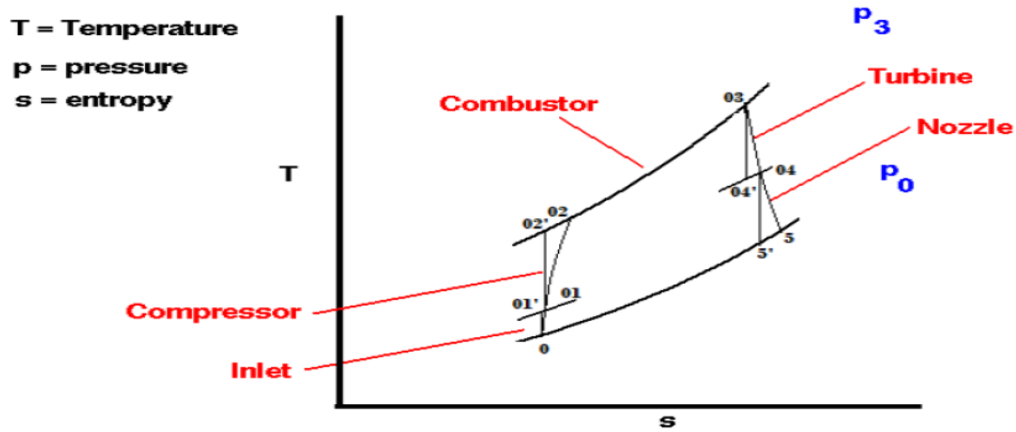


Figure 0.1: Ts-Diagram of the turbojet engine.

Table 4.1: Calculated and the Experimental Results of the model.

Sr. No.	Output Variable	Calculated Values	Expected Values	Comment on Calculated Values	Status of acceptance
1	Compressor outlet temperature T_{02}	408.35K	430K	OK	Acceptable
2	Turbine inlet temperature T_{03}	1030.9K	1100K	OK	Acceptable
3	Turbine Pressure Ratio	1.95	2.1	OK	Acceptable
4	Nozzle outlet temperature T_{05}	860.75K	900K	OK	Acceptable
5	Jet speed C_5	388.59 m/s	420m/s	OK	Acceptable

6	Intake air mass flow rate m_a	0.4 kg/s	0.8kg/s	LESS	Acceptable
7	Air fuel ratio AF_R	60:1	85:1	LESS	Acceptable
8	Fuel Flow Rate m_f	0.4 kg/min	0.55 kg/m	OK	Acceptable
9	Exhaust gas mass flow rate m_e	0.4kg/s	0.81kg/s	LESS	Acceptable
10	Thrust produced	155.436 kgm/s	340.2 kgm/s	LESS	Acceptable

Before starting the project values for the efficiencies and the coefficients were defined for the system, it is very important to define appropriate values for these parameters as these values could make a vast difference in the results of the engine. After assigning proper efficiencies and other coefficients the calculations were performed for the system. The values for efficiencies were selected based on the literature available for similar systems.

For the experimental data of the experiment the data was recorded with the usage of the proper sensors. For making the results as accurate as possible multiple readings were take for each value and then the averages were taken to minimize the chances of the error.

From the comparison of the theoretical and the experimental data it could be seen that experimental efficiencies are lower as compared to the calculated ones this could be due to defects in the manufacturing, we tried to keep the dimensions of the model as close to the 3D model so that accurate results could be obtained but as this is a very complex machine there were some minor issues with surface finish and aligning. Some of this was also due to the lake of specialized machines for this task. As facilities usually have general instruments not specialized ones for specific applications and sizes.

5. Chapter: Project management

Project plan

Before starting the project, the project was divided into small tasks and each of the task was assigned time limit to keep the project on track so that we can finish the project in time. Gant chart below represents the different components of the project and time assigned.

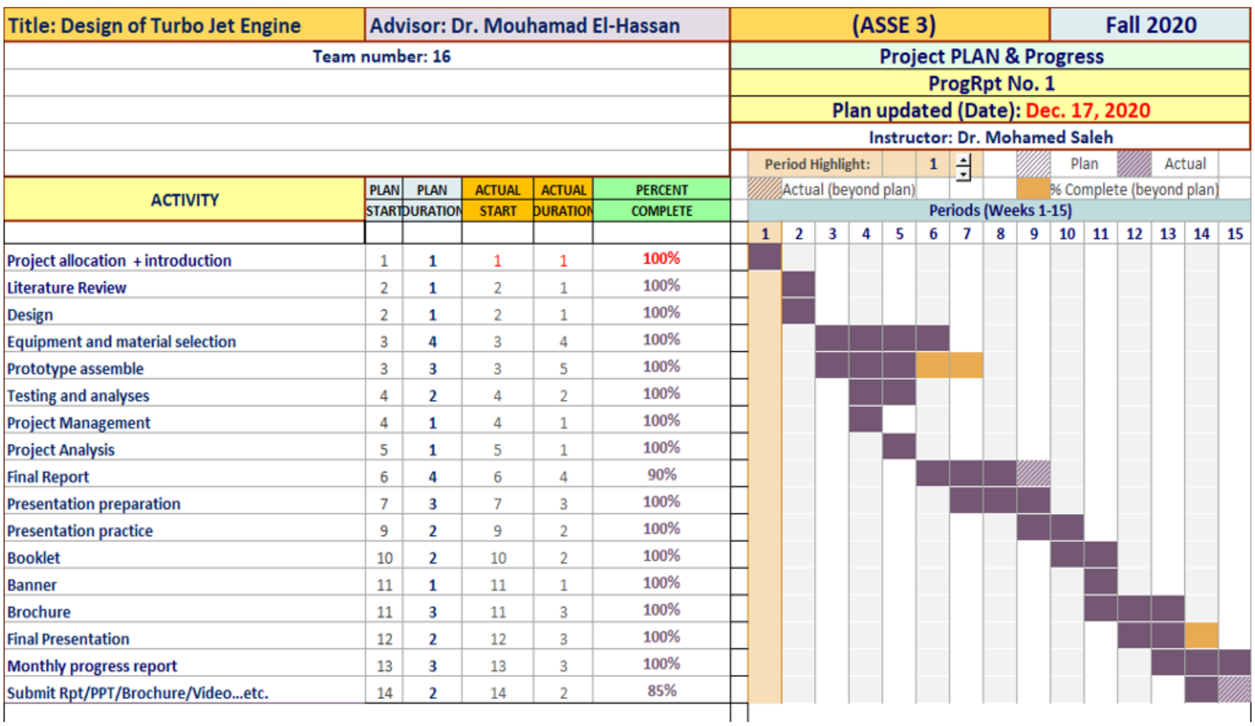


Figure 5.1: Gantt Chart

Contribution of the team members

To equally distribute the workload on the team members team members were assigned task for each week on the start of the week so that work could be finished in an organized way. The major contributions by the team members are shown in the table below.

#	Task description	Team member assigned
1	Calculations of the model	Murtada Almozayen
2	3D model of the prototype	Abdullah Alshaer

3	**Material Purchase**	Mohammed Aljishi
4	**Manufacturing arrangements and Presentation**	Ahmed Alsadiq

Project Execution Monitoring

For the monitoring of the project regular meeting were conducted with the supervisor and with team members only to discuss design issues and taking appropriate decisions. Usually one meeting of all the members with the supervisor was scheduled, while 2 to 3 meanings were also scheduled as members only per week.

Challenges and Decision Making

The biggest challenge which we face during this project was related to the availability of the material and component were able to find sensors from the foreign sellers and bought them using various online stores. But the issue was with the materials which could not brought in from some other country easily like fuel and the pipes. Most of the suppliers refused to sell us the materials we needed as they usually supply to companies were able to eventually find and buy all the required materials.

Project Bill of Materials and Budget.

Table 4.2 the bill of material for the project.

Item		Price
Pipes		1000
Oil Pump		500
Machine workshop		1000
Reguleter		237
Turbo		850
Gauges		830
Calf+Clips		187.25
Fittings		384
Propane		900
Blower		40
Poster & Brochure		350
Total		6278.25

6. Chapter: Project Analysis

Life-long Learning

During this project we learned about turbojet engines in detail how they work, how they produce power, what are the main parts of a turbojet engine. After going through all that information, we decided to build our engine as we realized that the best way to really understand and appreciate the science behind a machine as complex as a turbojet engine is to build one. During our research about the engine, we learned a lot about different type of components, different sensors they advantage, disadvantages, how they work, how to select the best sensors for the given application, we learned about system design how to design a system, how to integrate different components to get a working machine. We learned about performing the theoretical calculation of a system, which does not exist, which is true for every new product. For our design, we decided to go with easily available and over the shelf components because it was the only possible solution within our budget, time and resources constrains. During our university study, we learned a lot about different aspects of a project including the designing, supply chain management, Project management, manufacturing, and testing. We learned many things about practical work of an engineer and that knowledge will guide us for our entire life.

Impact of Engineering Solutions

Air travel is coming more and more important with each passing day and the jet engines are on of the most important and the complex component of a plane. Turbo jet engine is the most complex part of the plane and most difficult part to manufacture. The purpose of this purpose is to develop very simple form of that engine which will allow in future to establish further development on the results of this project. Which may one day allow us to develop to design a turbojet engine domestically.

Contemporary Issues Addressed

Turbojets are very important machines in this modern era. The development of a modern turbojet engine is crucial for every modern nation as they not only bring jobs and revenue, but they are also a sign of technological development of any nation. In this project, the main issue which was addressed is the designing of the combustion chamber. In the chamber of the turbojet engine the flow of the fuel and air is continuous so it is very important to design combustion chamber properly so that it will allow proper mixing and combustion of the fuel in the continuous stream of the air. This study will provide some important data for the development of a modern jet engine.

Conclusion and Recommendations

Conclusion

In this project, we have designed a model of turbojet engine by using a turbo charger of the car engine. The main purpose of the project was to develop an efficient combustion chamber design for the engine and then utilize that design for the construction of the working model of the turbo jet engine. One other requirement for the model was that it should be self-sufficient. It would be constructed as a single unit, which could be move from one place to the other place. The design process was started with the selection of the turbo charger and then designing the combustion chamber according to it. So that maximum efficiency could be achieved. So we design the combustion chamber and after the manufacturing tested the engine to prove that the concept and the design is valid and that the designed engine model could operate without any assistance on its own and can produce thrust.

Recommendations

There is room for further studies on the topic of combustion efficiency in the combustion chamber. Another field, which is very crucial for the development of a modern turbo jet engine, is the material sciences as the material selection is very important for engine turbine as the internal parts of the chamber are exposed to very high temperature and pressure. This field requires a lot of research in the feature before a proper engine model could be developed.

Reference

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2. Hero's Aeolipile (Source: Knight's American Mechanical Dictionary, 1876).
3. Types of jet engine and how engines work, https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/engines.html
4. Design and construction of a simple turbojet engine Simon FahlströmRikard Pihl-Roos Teknisk- naturvetenskaplig fakultet UTH-enheten Besöksadress: Ångströmlaboratoriet Lägerhyddsvägen 1 Hus 4, Plan 0 Postadress: Box 536 751 21 Uppsala Telefon: 018 – 471 30 03 Telefax: 018 – 471 30 00 Hemsida: http://www.teknat.uu.se/stude

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:		**ACADEMIC YEAR:**	
PROJECT TITLE	Design of Turbojet Engine using Automobile Turbocharger.		
SUPERVISORS	Dr. Mouhamad El Hassan		

Month 1: September

ID Number	Member Name
201700994	Mohammed Aljishi
201502694	Abdullah Alshaer
201501591	Murtada Almozayen
201600718	Ahmed Alsadiq

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Calculations of the model**	Murtada Almozayen	100%	
2	**3D model of the prototype**	Abdullah Alshaer	100%	
3	**Material Purchase**	Mohammed Aljishi	100%	
4	**Manufacturing arrangements and Presentation**	Ahmed Alsadiq	100%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Receive the delivery of the Equipment and order if any remaining**	Mohammed Aljishi
2	**Contact with the dealer for fuel delivery**	Ahmed Alsadiq
3	**Manufacturing of the components**	Abdullah Alshaer
4	**Assembly of the model**	Murtada Almozayen

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts

Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks
MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives

MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Abdullah Alshaer	4	4	4	4
2	Murtada Almozayen	4	4	4	4
3	Mohammed Aljishi	4	4	4	4
4	Ahmed Alsadiq	4	4	4	4

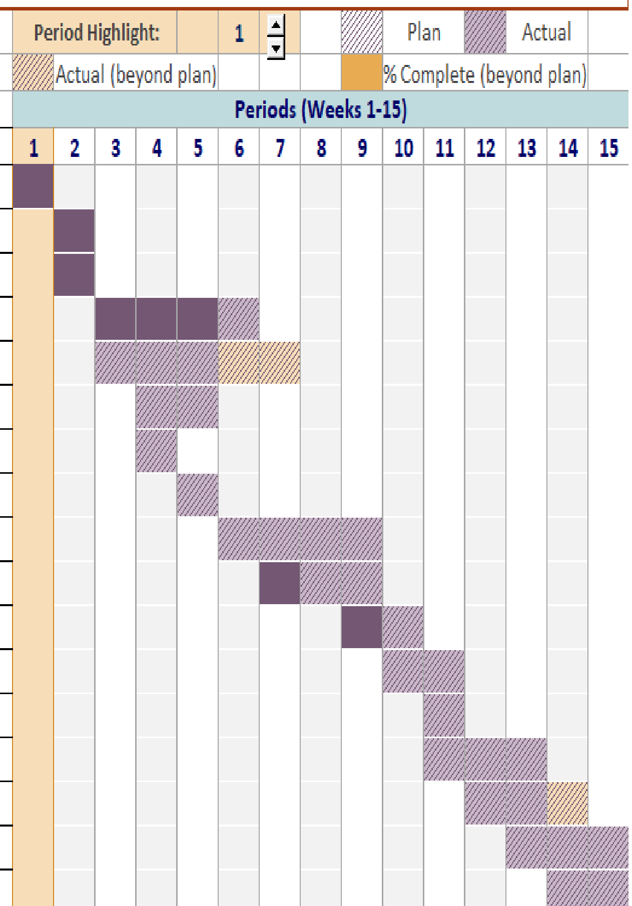
Comments on individual members

Name	Comments
Abdullah Alshaer	Modelling of the prototype is excellent.
Murtada Almozayen	Excellent work, through calculations of the model.
Mohammed Aljishi	Excellent work, id everything possible for tracing down all required materials.
Ahmed Alsadiq	Presentation is excellent.

Gantt Chart:

Title: Design of Turbo Jet Engine	Advisor: Dr. Mouhamad El-Hassan
(ASSE 3)	Fall 2020
Team number: 16	Project PLAN & Progress
	ProgRpt No. 1
	Plan updated (Date): Sep. 17, 2020
	Instructor: Dr. Mohamed Saleh

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Project allocation + introduction	1	1	1	1	100%
Literature Review	2	1	2	1	100%
Design	2	1	2	1	100%
Equipment and material selection	3	4	3	4	90%
Prototype assemble	3	3	3	5	0%
Testing and analyses	4	2	4	2	0%
Project Management	4	1	4	1	0%
Project Analysis	5	1	5	1	0%
Final Report	6	4	6	4	0%
Presentation preparation	7	3	7	3	60%
Presentation practice	9	2	9	2	60%
Booklet	10	2	10	2	0%
Banner	11	1	11	1	0%
Brochure	11	3	11	3	0%
Final Presentation	12	2	12	3	0%
Monthly progress report	13	3	13	3	0%
Submit Rpt/PPT/Brochure/Video...etc.	14	2	14	2	0%



Progress Report

Pipes Purchase

We were trying to procure schedule 40 pipes for our project for some time. Last month after a long search to find a vendor who can provide us with the required pipe we struck a deal with a supplier named “Al Riyadh Al- Oula”. They promised to supply us pipes in few days but due to the procrastination of the supplier, we contacted a new supplier for the procurement of pipes for our project.

We went to the shop and we receive them at the same day.

Fuel Purchase

It is decided to use propane gas as fuel for our engine, to get the fuel for the engine we contacted many suppliers and struck a deal with Abdullah Hashim Industrial Gas and Equipment company for the purchase of the propane gas for our model. We went to the company to take the supply of gas for our project.

Manufacturing

We took the pipes from the supplier and took those to the workshop. First, the pipes were cut into pieces according to our requirement, and holes were drilled in them for the combustion chamber. After that pipes were welded together for the construction of the combustion chamber.

Assembly

After manufacturing the combustion chamber, the next step was the assembly of the prototype. The combustion chamber along with the fuel pump and gauges were installed on the turbocharger for the construction of the prototype.

Testing

After the construction of the prototype, we did the final checks before connecting the fuel tank with the model, and the testing was done to see the working of it.

Video Submission

To demonstrate the working of our prototype a video of it was recorded while it was running. That video was submitted for evaluation.

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering Prince Mohammad bin Fahd University

SEMESTER:		ACADEMIC YEAR:	
PROJECT TITLE	Design of Turbojet Engine using Automobile Turbocharger.		
SUPERVISORS	Dr. Mouhamad El Hassan		

Month 1: September

ID Number	Member Name
201700994	Mohammed Aljishi
201502694	Abdullah Alshaer
201501591	Murtada Almozayen
201600718	Ahmed Alsadiq

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Purchase of Pipes and Fuel**	Murtada Almozayen	100%	
2	**Manufacturing of Combustion Chamber**	Abdullah Alshaer	100%	
3	**Assembly of the prototype**	Mohammed Aljishi	100%	
4	**Testing and Video Recording**	Ahmed Alsadiq	100%	

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4:
an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts
Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks
MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Abdullah Alshaer	4	4	4	4

2	Murtada Almozayen	4	4	4	4
3	Mohammed Aljishi	4	4	4	4
4	Ahmed Alsadiq	4	4	4	4

Comments on individual members

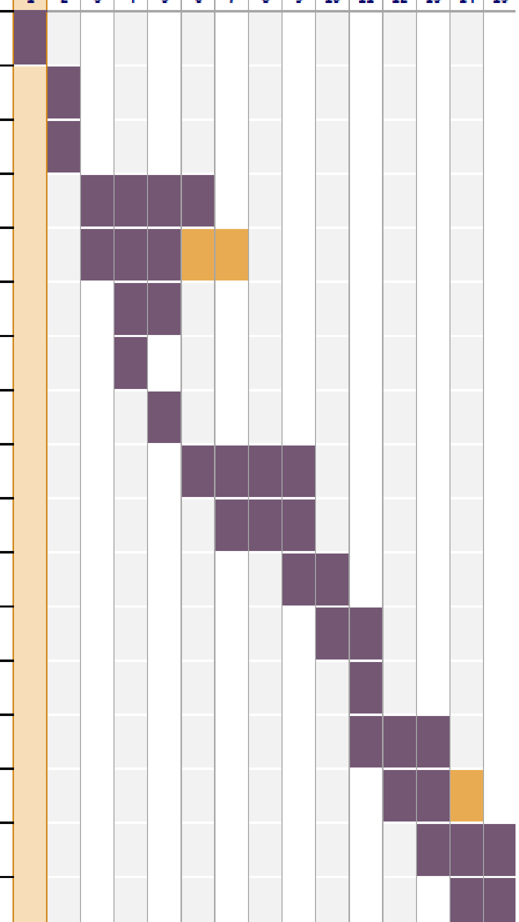
Name	Comments
Abdullah Alshaer	Excellent work Purchased pipes and fuel for the project.
Murtada Almozayen	Excellent work, manufacturing of the combustion chamber was in time and according to specifications.
Mohammed Aljishi	Excellent work, Assembled the project perfectly and according to standards.
Ahmed Alsadiq	Tested the model and the video was excellent.

Gantt Chart:

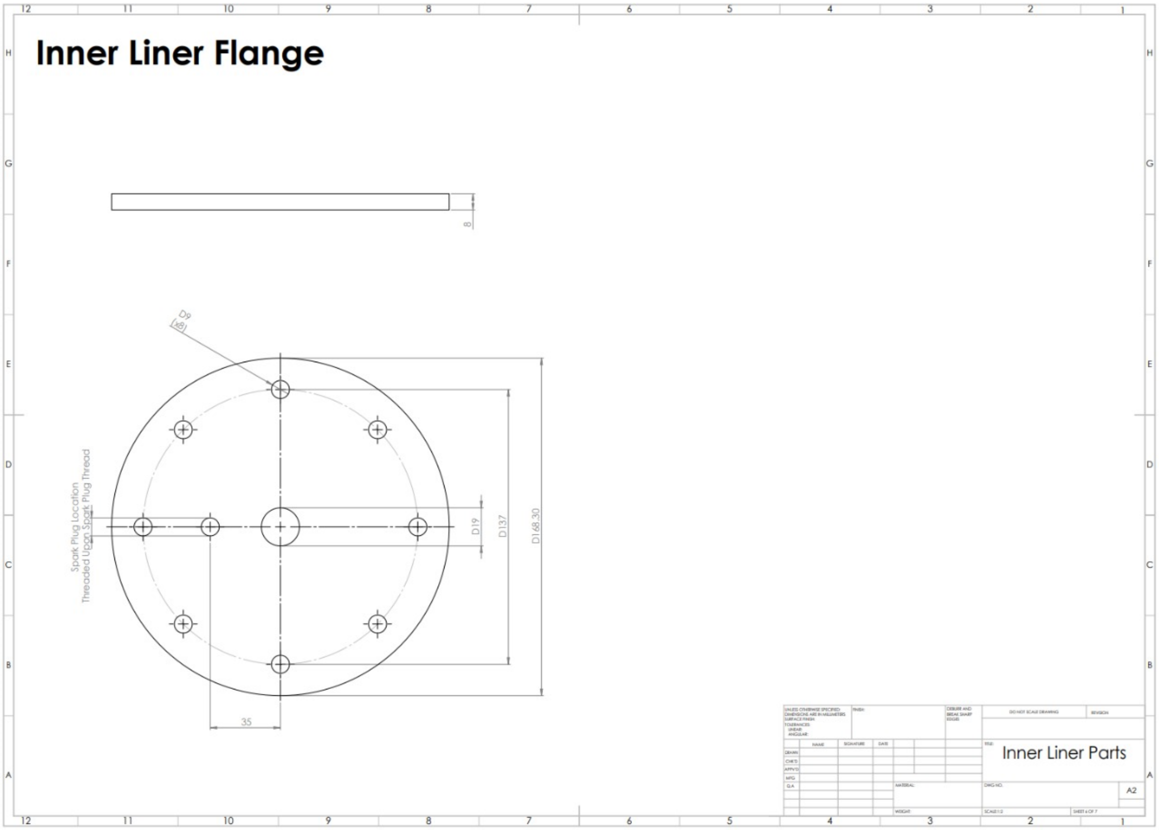
Title: Design of Turbo Jet Engine	Advisor: Dr. Mouhamad El-Hassan	(ASSE 3)	Fall 2020
Team number: 16		Project PLAN & Progress	
		ProgRpt No. 1	
		Plan updated (Date): Dec. 19, 2020	
		Instructor: Dr. Mohamed Saleh	
		Period Highlight: 1	Plan / Actual
		Actual (beyond plan)	% Complete (beyond plan)

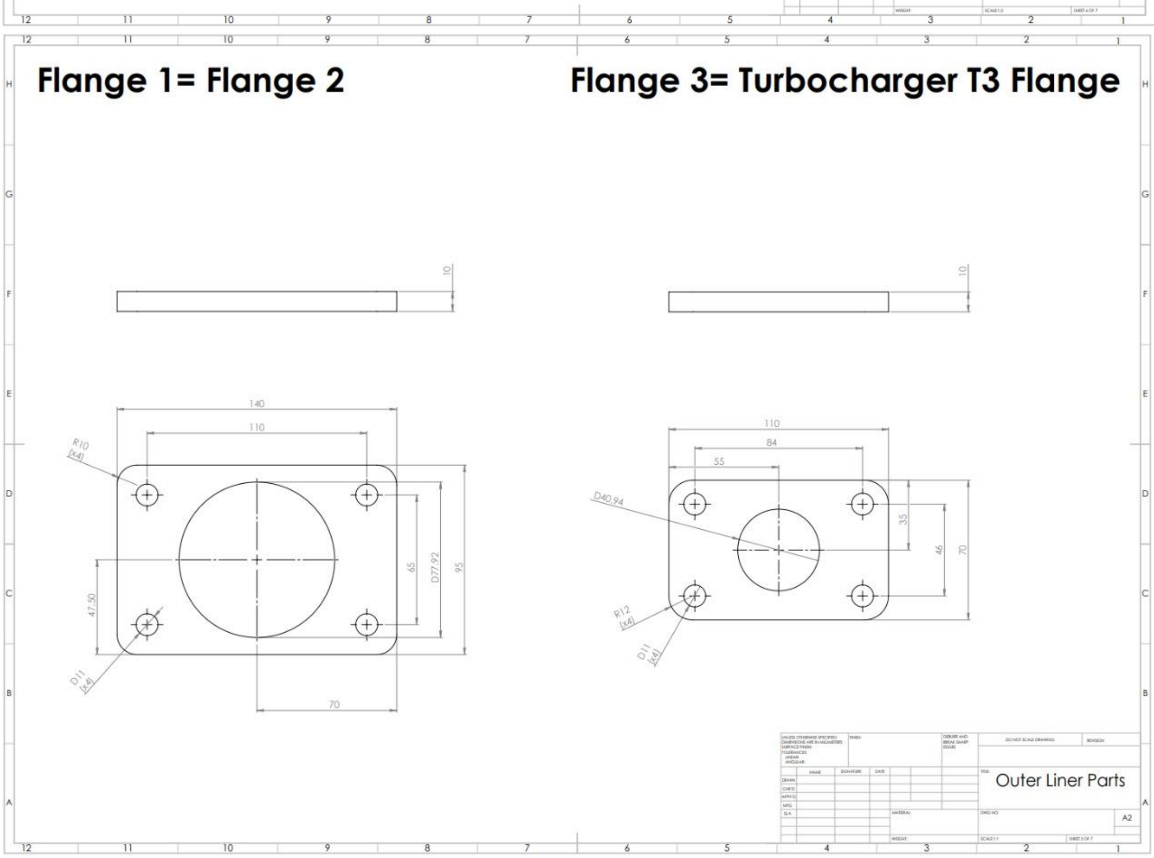
Periods (Weeks 1-15): 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

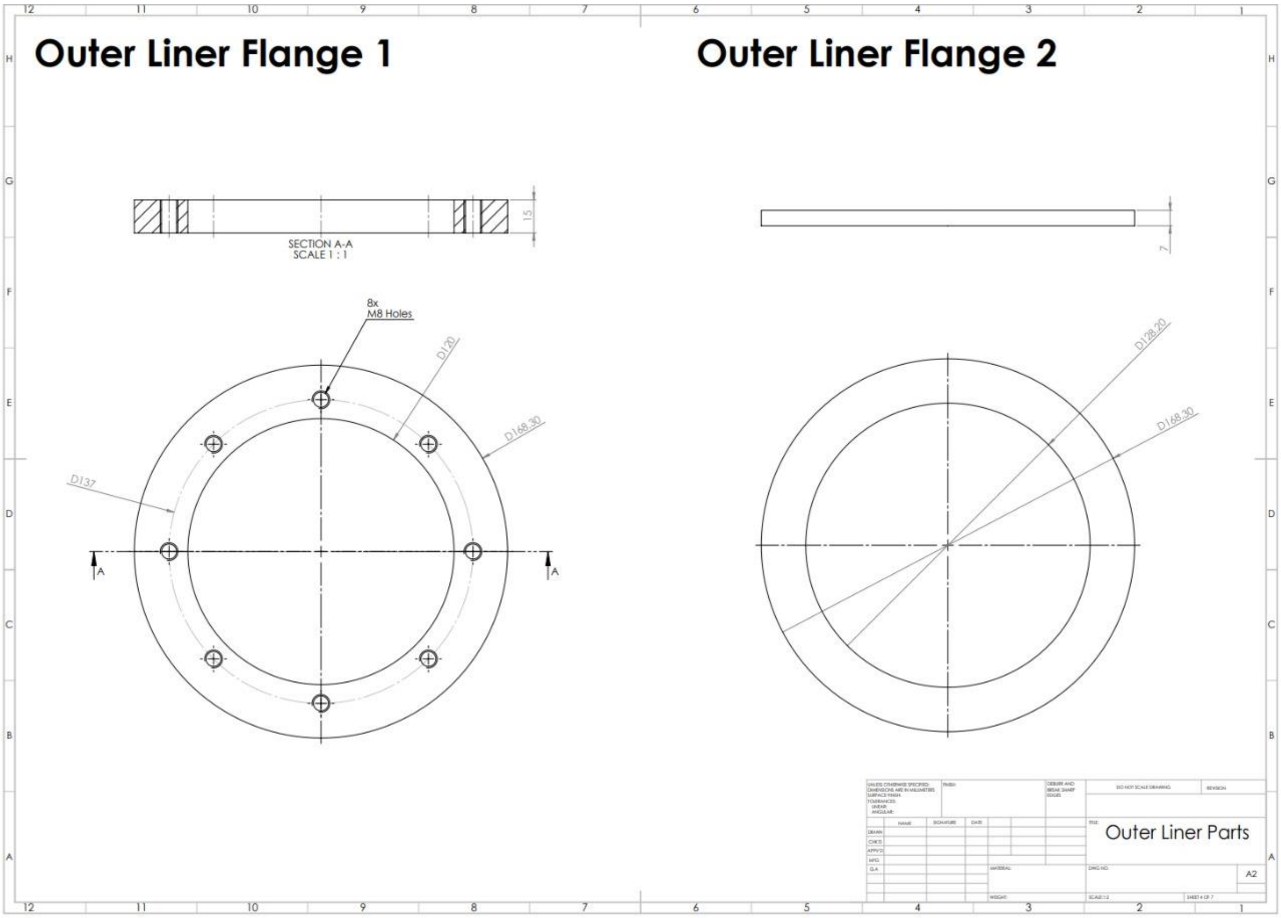
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Project allocation + introduction	1	1	1	1	100%
Literature Review	2	1	2	1	100%
Design	2	1	2	1	100%
Equipment and material selection	3	4	3	4	100%
Prototype assemble	3	3	3	5	100%
Testing and analyses	4	2	4	2	100%
Project Management	4	1	4	1	100%
Project Analysis	5	1	5	1	100%
Final Report	6	4	6	4	100%
Presentation preparation	7	3	7	3	100%
Presentation practice	9	2	9	2	100%
Booklet	10	2	10	2	100%
Banner	11	1	11	1	100%
Brochure	11	3	11	3	100%
Final Presentation	12	2	12	3	100%
Monthly progress report	13	3	13	3	100%
Submit Rpt/PPT/Brochure/Video...etc.	14	2	14	2	100%

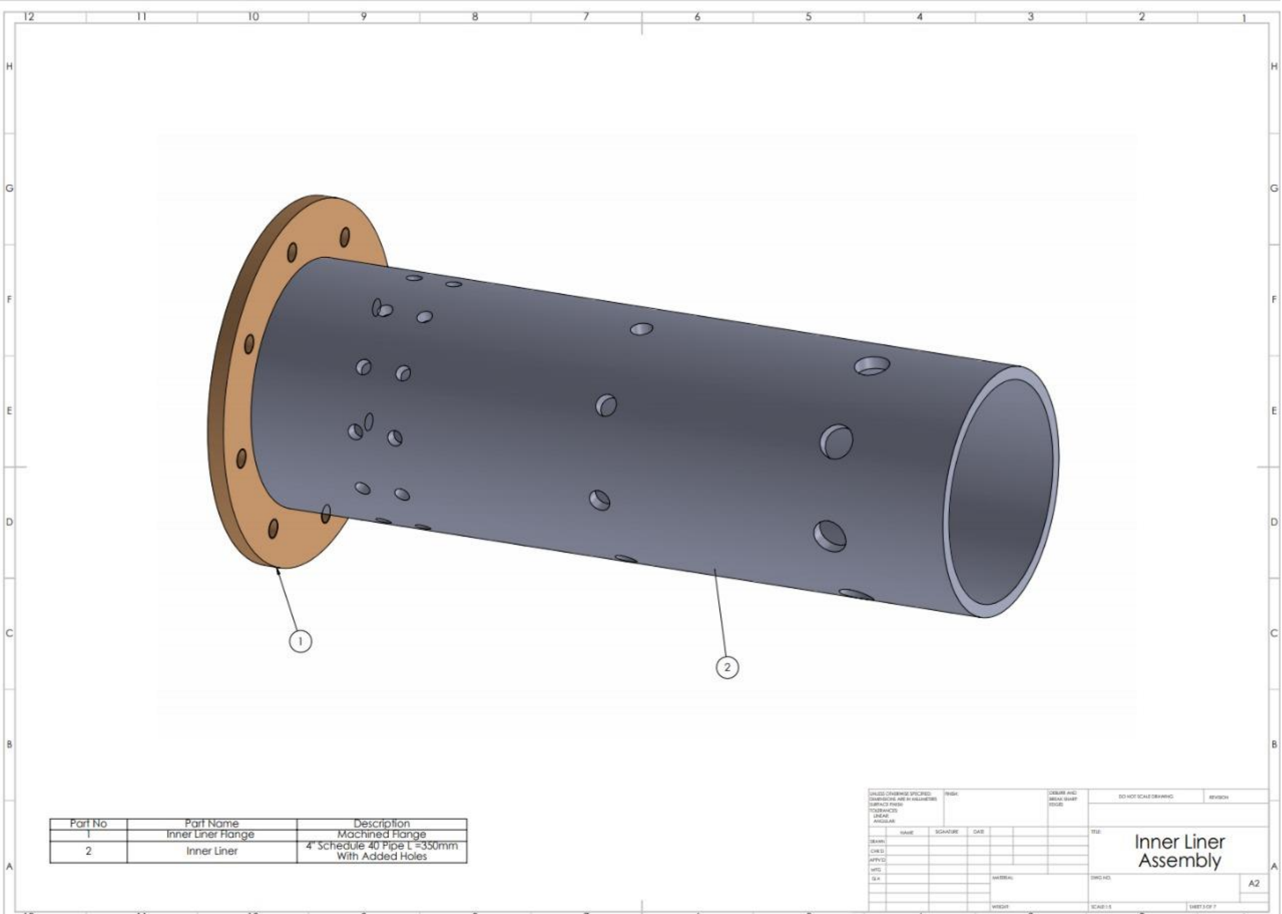


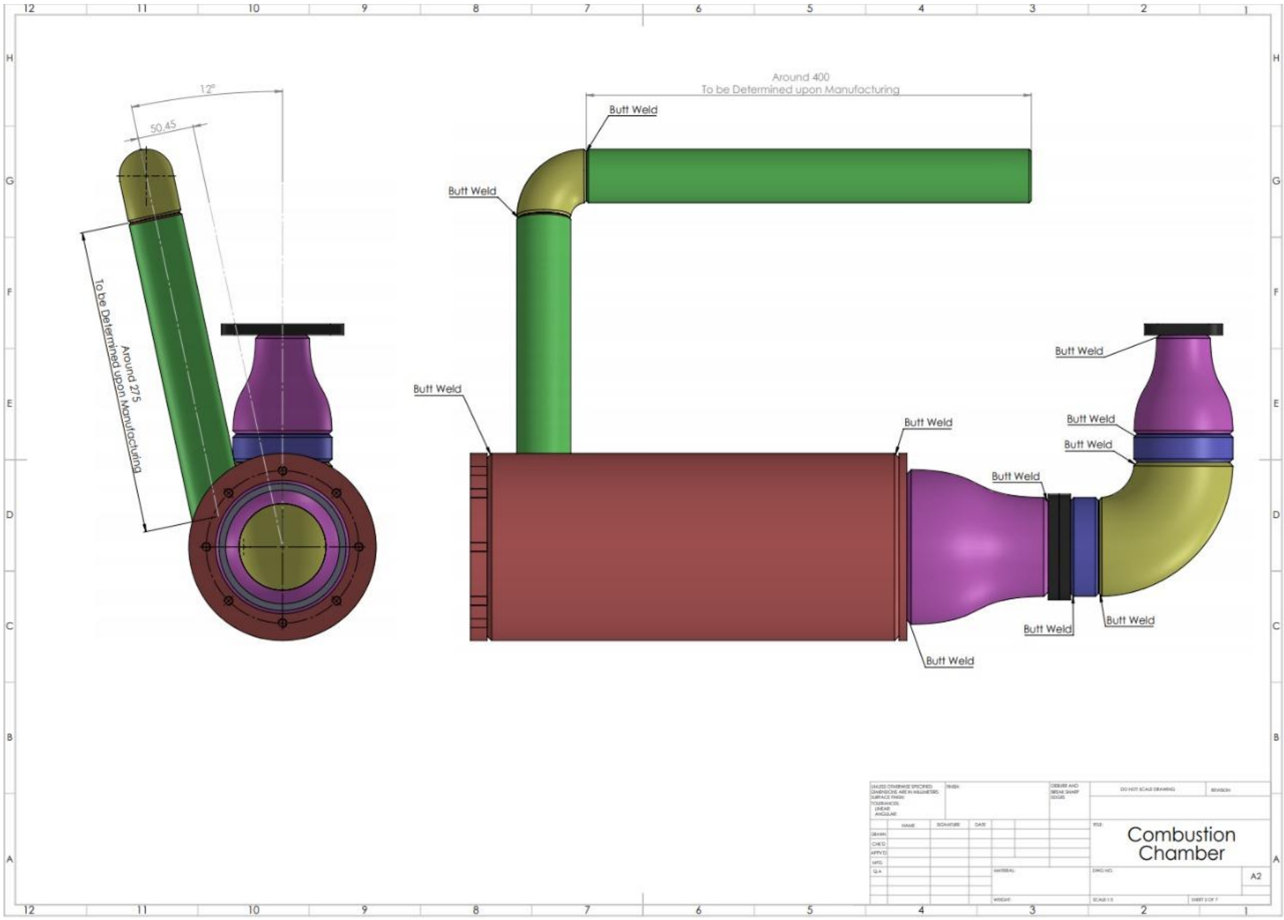
Appendix B: 3D model and drawings

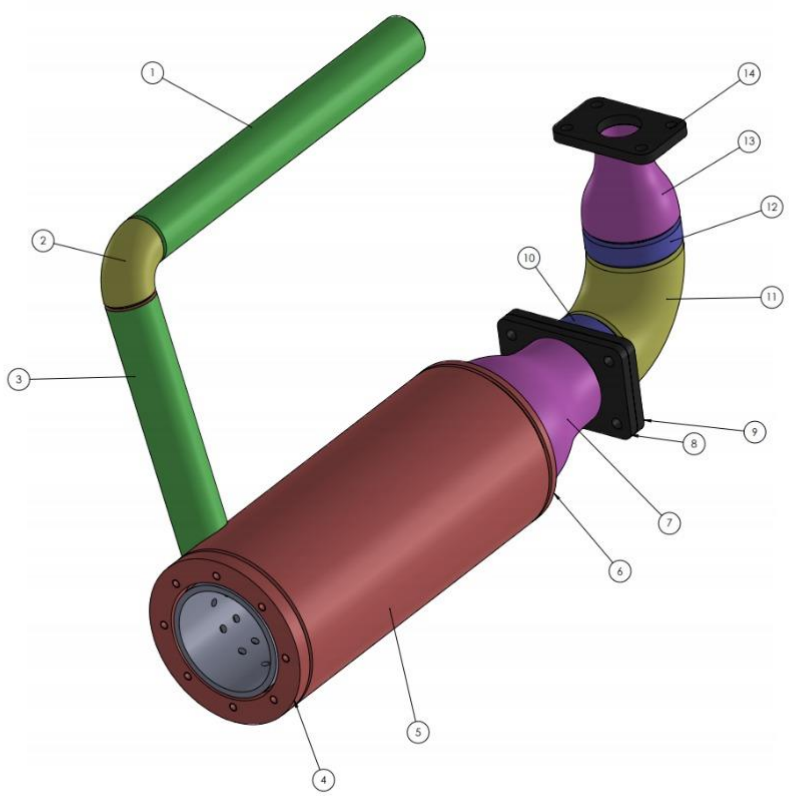





Outer Liner Flange 1
Outer Liner Flange 2
SECTION A-A
SCALE 1 : 1
15
7
8x
M8 Holes
D120
D168.30
D137
D128.20
D168.30
A
A
Outer Liner Parts
A2


1
2
Part No
Part Name
Description
1
Inner Liner Flange
Machined Flange
2
Inner Liner
4" Schedule 40 Pipe L =350mm
With Added Holes
Inner Liner
Assembly
A2



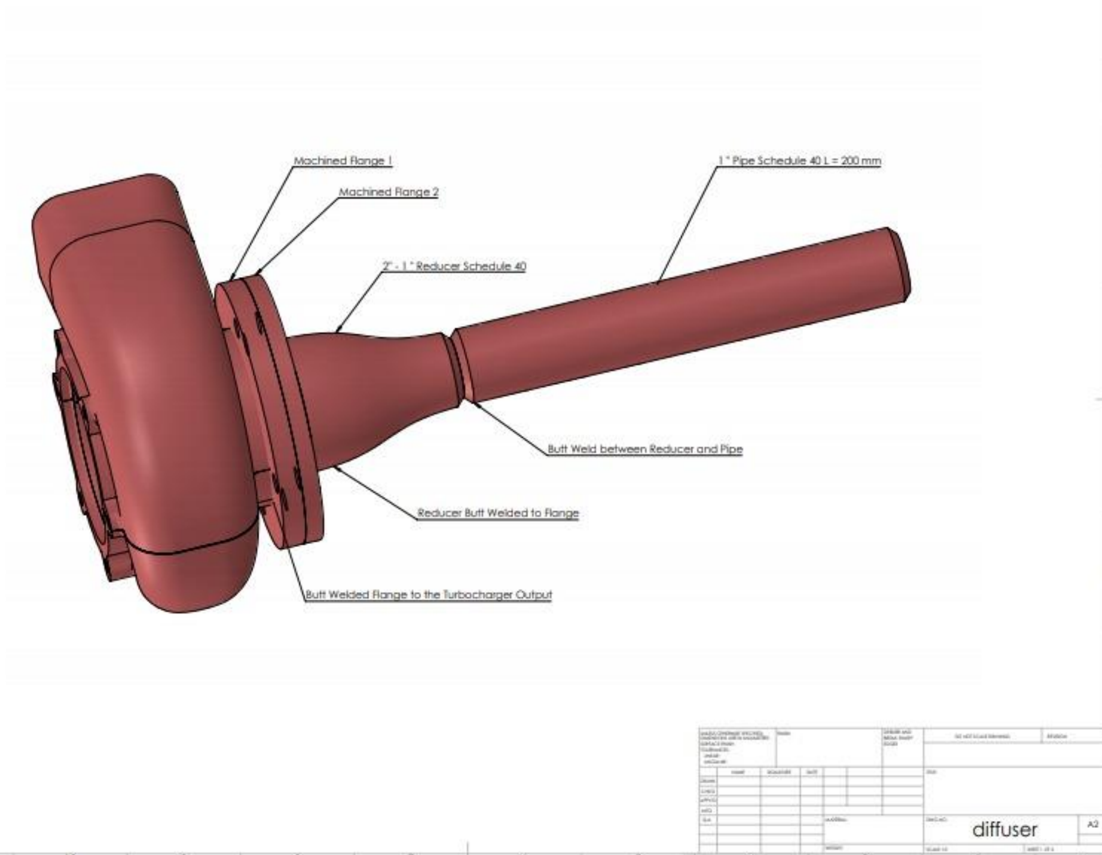


Part No	Part Name	Description
1	Compressor Outlet Pipe 1	1.5" Schedule 40 Pipe L=400mm
2	Compressor Outlet Elbow	1.5" Schedule 40 Short Radius Elbow
3	Compressor Outlet Pipe 2	1.5" Schedule 40 Pipe L=275mm
4	Outer Liner Flange 1	Machined Flange
5	Outer Liner	6" Schedule 40 Pipe L=370mm
6	Outer liner Flange 2	Machined Pipe End
7	Reducer 1	Reducer 5"-3" Schedule 40
8	Flange1	Machined Flange
9	Flange2	Machined Flange
10	Turbine Inlet Pipe 2	3" schedule 40 Pipe L=25.4mm
11	Turbine Inlet Elbow	3" Schedule 40 Short Radius Elbow
12	Turbine Inlet Pipe 2	3" schedule 40 Pipe L=25.4mm
13	Turbine Inlet Reducer	Reducer 3"-1.5" Schedule 40
14	Turbine inlet Flange	T3 Turbocharger Flange

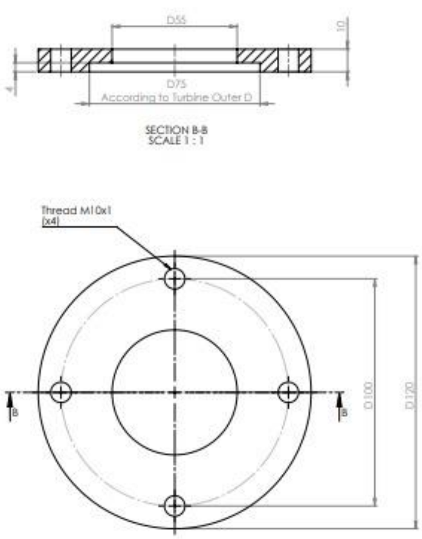
Combustion Chamber

A2

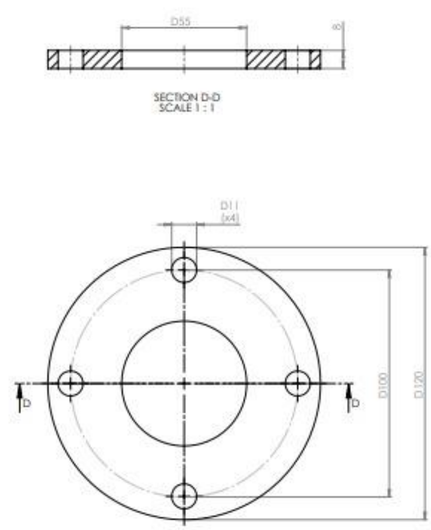
Turbocharger Diffuser



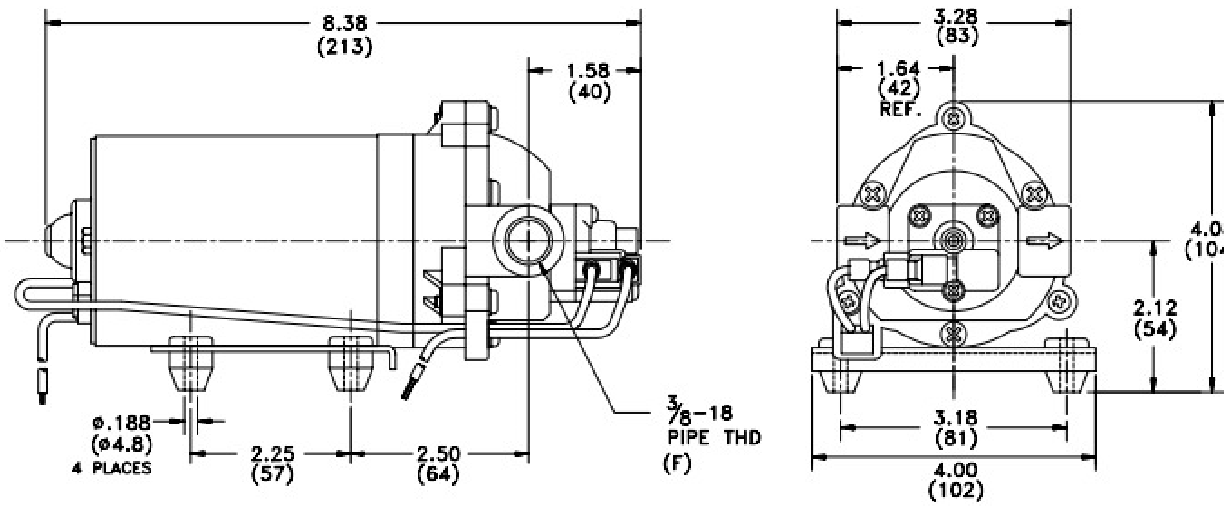
Turbocharger Flange 1

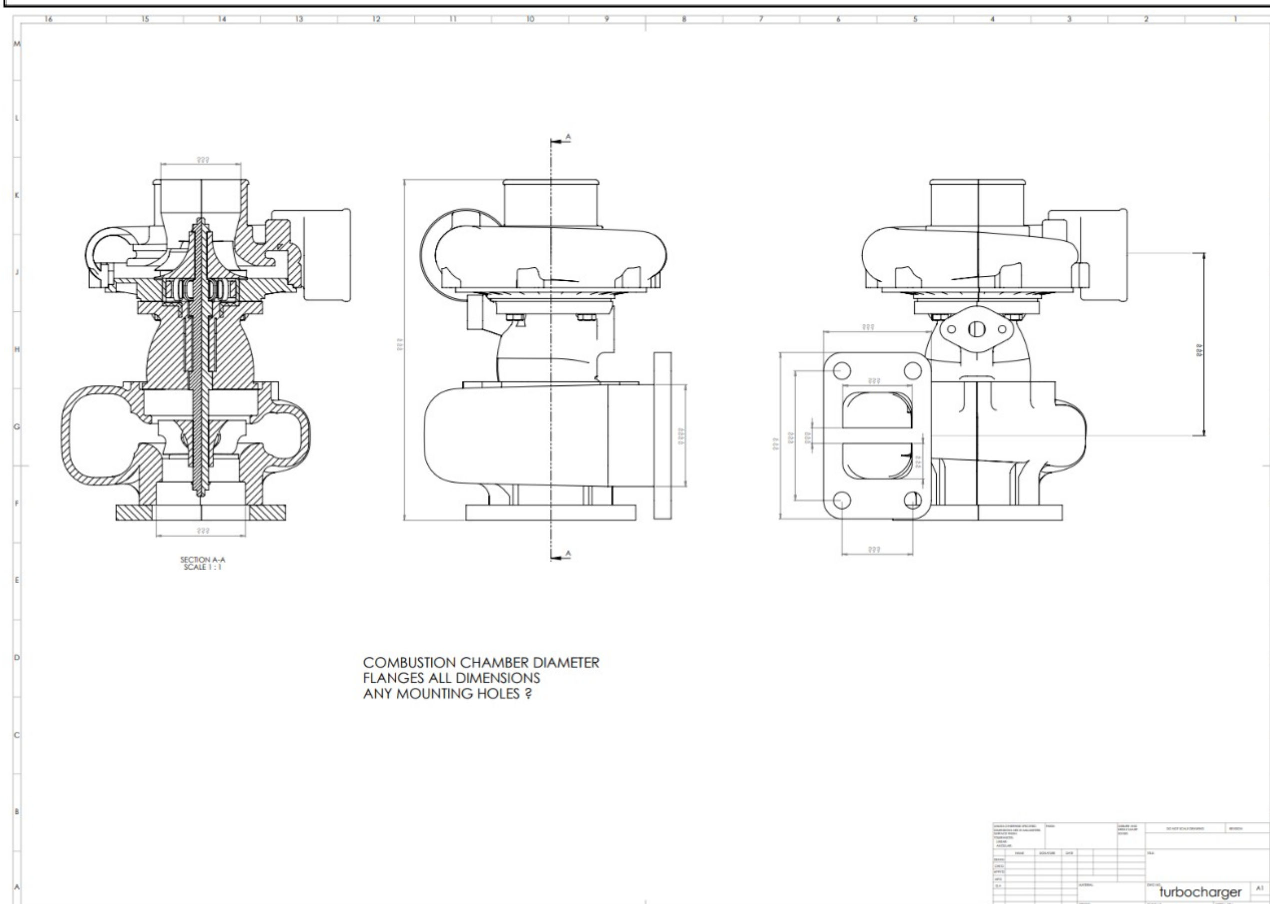


Turbocharger Flange 2

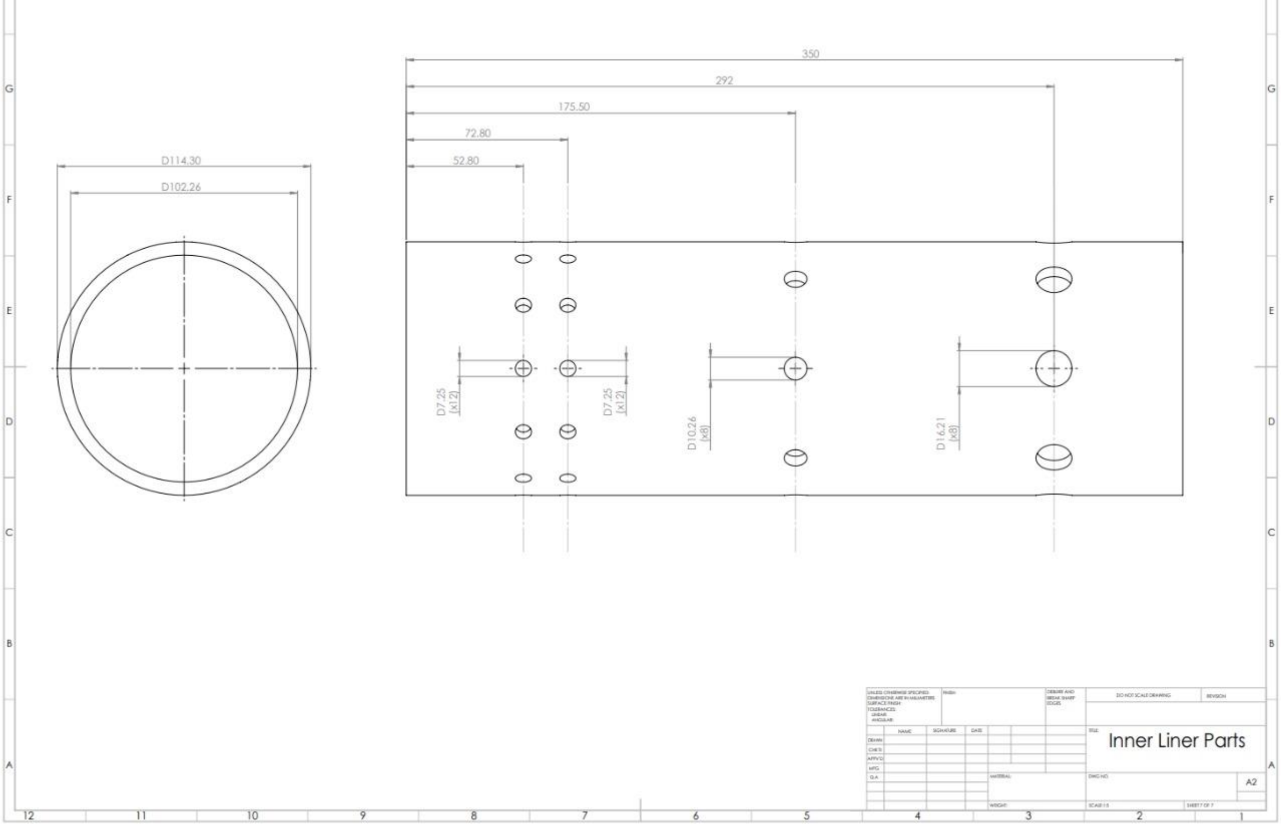


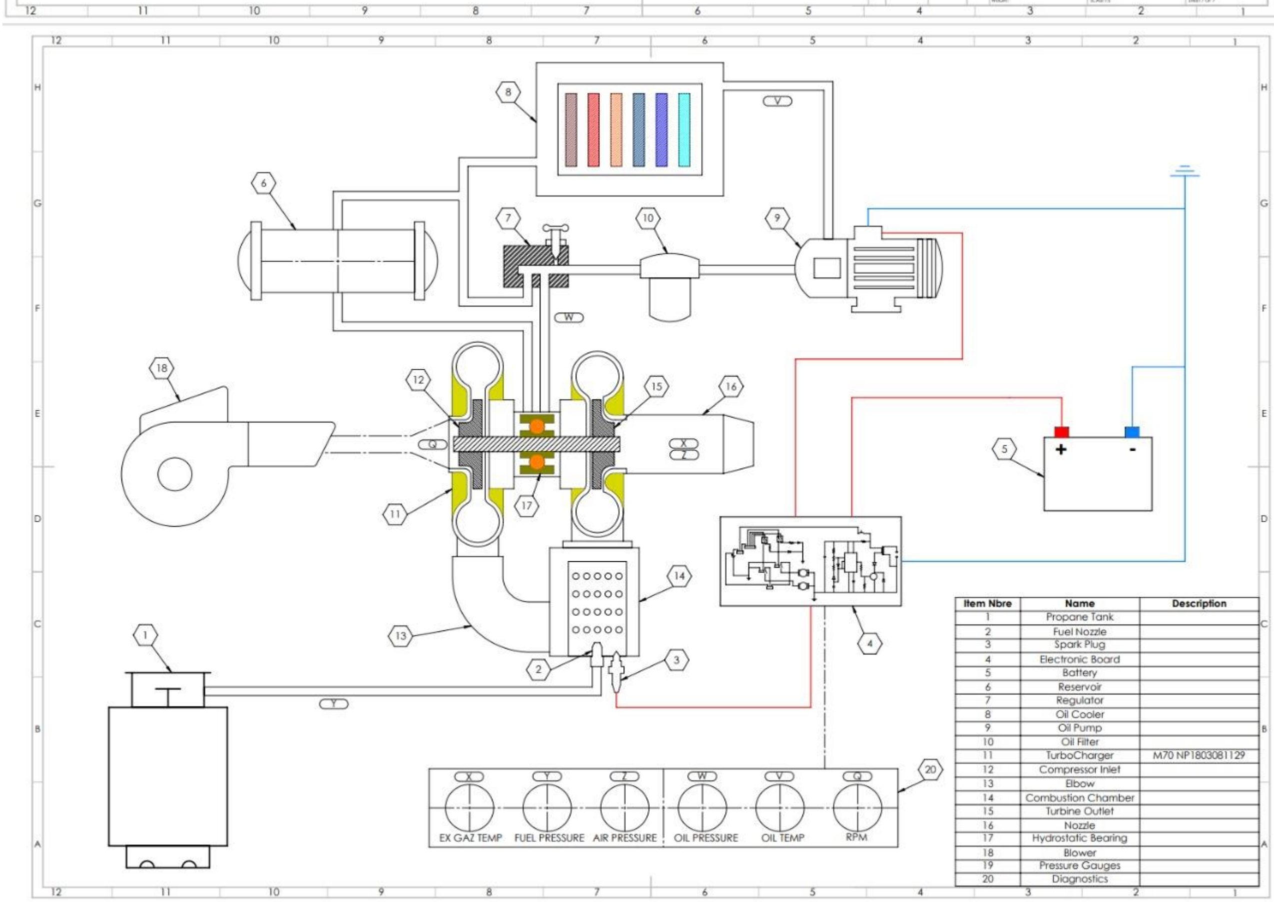
DIMENSIONS:


8.38
(213)
1.58
(40)
ø.188
(ø4.8)
4 PLACES
2.25
(57)
2.50
(64)
3/8-18
PIPE THD
(F)
3.28
(83)
1.64
(42)
REF.
4.08
(104)
2.12
(54)
3.18
(81)
4.00
(102)


SECTION A-A
SCALE 1 : 1
COMBUSTION CHAMBER DIAMETER
FLANGES ALL DIMENSIONS
ANY MOUNTING HOLES ?
turbocharger
A1

Inner Liner : Made From 4" Pipe Schedule 40





Item Nbre	Name	Description
1	Propane Tank	
2	Fuel Nozzle	
3	Spark Plug	
4	Electronic Board	
5	Battery	
6	Reservoir	
7	Regulator	
8	Oil Cooler	
9	Oil Pump	
10	Oil Filter	
11	TurboCharger	M70 NP1803081129
12	Compressor Inlet	
13	Elbow	
14	Combustion Chamber	
15	Turbine Outlet	
16	Nozzle	
17	Hydrostatic Bearing	
18	Blower	
19	Pressure Gauges	
20	Diagnostics	