Design and Fabrication of a Gas Turbine

A Major Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements
for the degree of Bachelor of Science

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Wednesday, April 24th, 2024

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Abstract

This MQP was to design and manufacture an internal combustion chamber for a gas turbine. Using SolidWorks and Creo Parametric, we created a working design of the combustion chamber assembly and machined an external combustion chamber for a small-scale turbocharger. The components of the combustion chamber were designed by the team and machined using CNC machining.

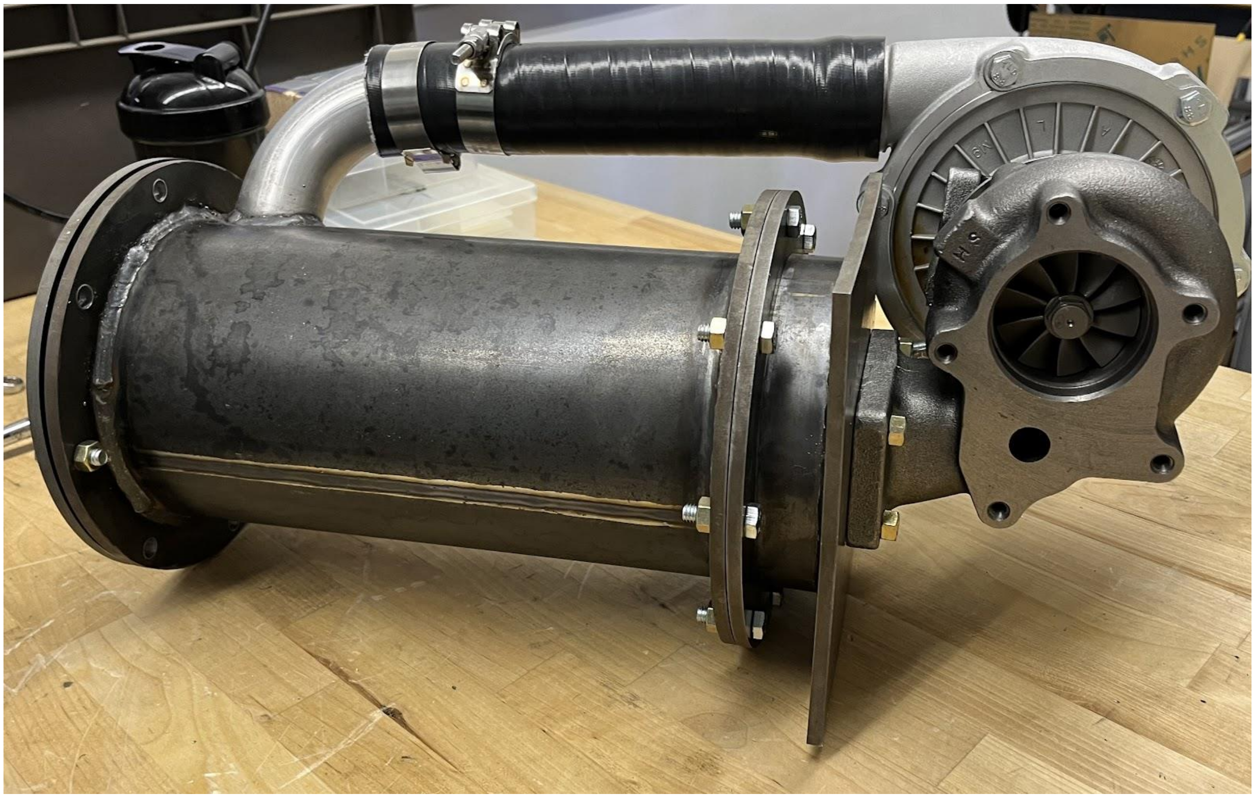

Table of Contents

List of Figures

1. Introduction

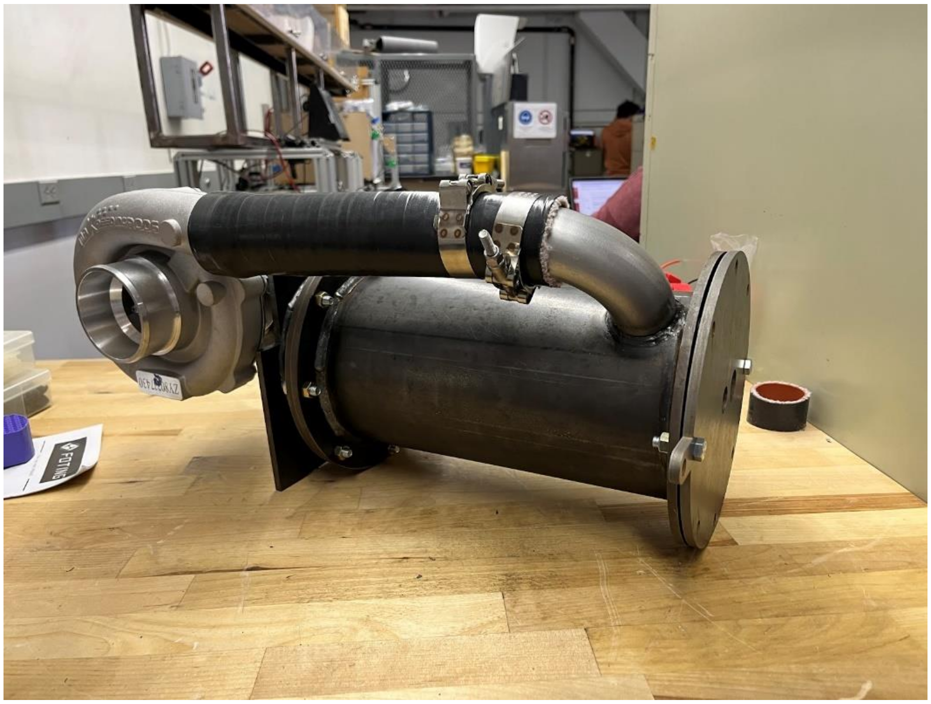

Figure 1: Completed Gas Turbine

Our journey towards achieving this milestone was characterized by a relentless pursuit of excellence, blending cutting-edge design methodologies with precision machining techniques. At the heart of this endeavor lies the integration of a turbocharger with our designed combustion chamber, a symbiotic relationship forged through the amalgamation of advanced software tools and state-of-the-art machining capabilities.

Our project began with recognizing the transformative potential of turbocharging technology in enhancing gas turbines' performance and efficiency. By harnessing the energy of exhaust gases to drive a compressor, turbochargers offer a pathway to augmented power output and improved fuel efficiency. Building upon this foundation, our endeavor sought to harness the benefits of turbocharging while complementing it with a meticulously engineered combustion chamber of our own design.

The design phase, facilitated by software's such as SolidWorks and Creo, served as the crucible in which our vision took shape. Through iterative design cycles and simulations, we meticulously crafted a combustion chamber optimized for performance, durability, and operational efficiency. Every aspect of the chamber, from the geometry of the combustion chamber walls to the placement of fuel injectors, was refined to maximize combustion efficiency, minimize emissions, and ensure compatibility with the turbocharged system.

Central to our fabrication process was the acquisition of a turbocharger, a cornerstone component that serves as the driving force behind our gas turbine assembly. With the turbocharger as the nucleus, our focus shifted to the creation of a combustion chamber tailored to our specific requirements. Leveraging the advanced machining capabilities available at WPI, including water jet cutting and precision machining, we embarked on the realization of our design. The utilization of a water jet cutter and mini mill, renowned for its ability to precisely cut a wide range of materials with minimal distortion, proved instrumental in shaping the intricate components of our combustion chamber. From the combustion chamber housing to the intricate internal components, each element was meticulously crafted to exact tolerances, ensuring seamless integration and optimal performance within the gas turbine assembly.

As we stand on the threshold of unveiling our completed gas turbine assembly, we are propelled by a sense of anticipation and pride in our collective achievement. In the pages that follow, we delve deeper into the intricacies of our design and fabrication processes, unveiling the inner workings of our turbocharged gas turbine assembly and the transformative impact it promises to deliver in the realm of power generation and beyond.

2. Background

2.1 Turbochargers

Turbochargers have emerged as essential components in modern engines, contributing significantly to improved performance and efficiency across various industries. The concept of turbocharging traces its roots back to the pioneering work of Swiss engineer Alfred Büchi in the early 20th century (Schild, 2009). Büchi's innovative research laid the groundwork for harnessing exhaust energy to drive a compressor, thereby increasing engine power output. In the automotive sector, turbochargers gained widespread recognition during the 1960s and 1970s as a solution for achieving higher power densities while enhancing fuel efficiency (Schild, 2009). Initially embraced in motorsports, particularly in Formula 1 racing, turbochargers provided a competitive edge by delivering significant performance gains.

Furthermore, turbochargers revolutionized the commercial diesel engine industry, offering higher torque output and improved fuel efficiency in marine and locomotive applications (Saravanamuttoo & Cohen, 1992). Turbocharged engines became indispensable for marine propulsion systems, optimizing power output while reducing operational costs. Advancements in materials and manufacturing techniques have propelled the evolution of turbocharger technology. Variable geometry turbochargers (VGTs) and twin-scroll designs have become prevalent, enabling precise control of boost pressure and enhancing performance across a wide range of operating conditions.

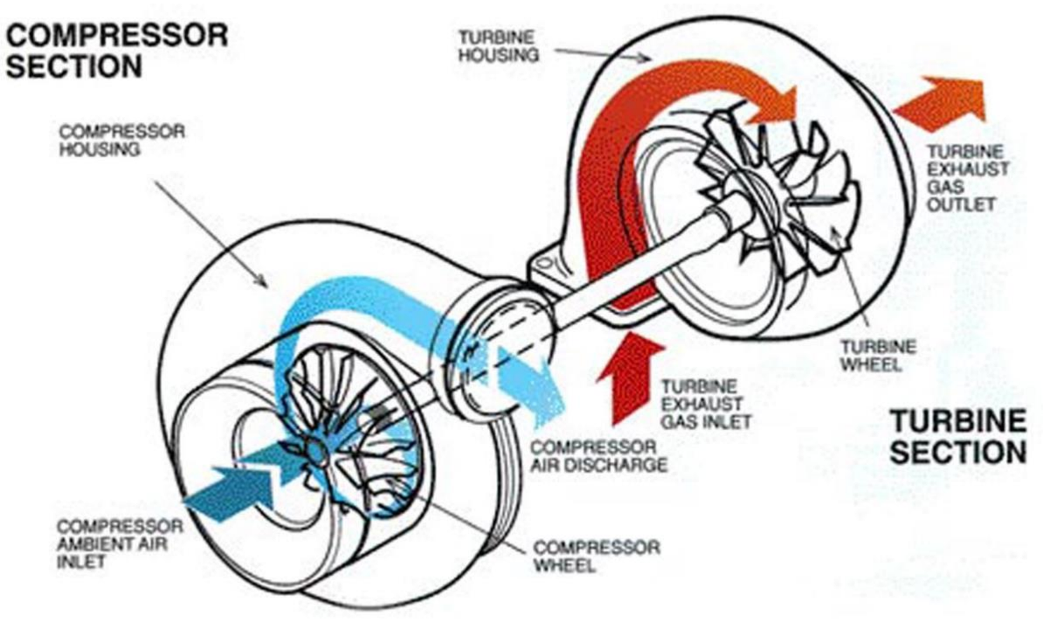

Figure 2: Diagram of Turbocharger

Turbochargers consist of two main components: a turbine and a compressor, connected by a shaft. Exhaust gases expelled from the engine spin the turbine, which in turn rotates the compressor. In automobiles, as the compressor spins, it draws in and compresses ambient air, increasing its density and delivering it to the engine intake manifold at higher pressure and temperature. This compressed air allows more fuel to be burned, resulting in increased power output from the engine. By harnessing otherwise wasted exhaust energy, turbochargers effectively provide a power boost without significantly increasing fuel consumption, making them a key technology for enhancing both performance and efficiency in modern engines.

Today, turbochargers are integral to both automotive and industrial applications. The automotive sector relies heavily on turbochargers to meet the demand for downsized engines that offer improved fuel economy without compromising performance (Grand View Research, Inc., 2022). Additionally, turbochargers play a vital role in industrial applications such as power generation and heavy-duty machinery, optimizing power output and efficiency.

2.2 Invention of the Gas Turbine

The gas turbine was first patented in 1791 by John Barber of England. Although the idea was there and the concept was given birth, the first successful self-sustaining gas turbine wasn't constructed until 1903 by Norwegian engineer Egidius Elling. Early issues with creating a gas turbine included safety, reliability, weight, and especially, sustained operation. For the next 30 years, gas turbine improvements started picking up to find more efficient methods of design, ultimately increasing thrust power and safety. In the early stages of World War II, Germany excelled in the turbine industry using an axial-flow compressor. This turbine design works by taking in air through the front and blowing it to the rear using a fan stage, where the air is crushed against a set of non-rotating blades called stators. This process isn't nearly as powerful as other concept turbines but is much smaller making it much more aerodynamic. After many years of tests and adjustments to the design, the axial-flow compressor turbine started mass production, supporting the first world-class fighter jets. From the end of World War II to the present day, turbines have evolved with many technological advances creating more efficient and safe designs for aircraft and other heavy machines.

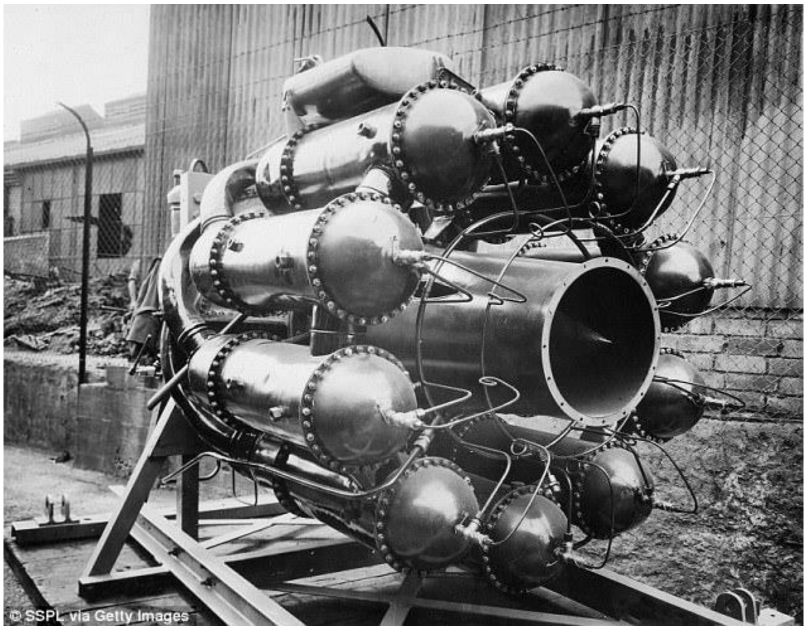
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Figure 3: First-ever tested jet engine (The Power Jets W.1)

2.3 Uses for Gas Turbines Today

Figure 4: General Electric Gas Turbine Generator

In the power generation sector, gas turbines play a pivotal role in producing electricity efficiently. Combined cycle power plants integrate gas turbines with steam turbines, maximizing energy utilization and enhancing overall efficiency (Rao, 2015). These plants are crucial for meeting peak electricity demands and providing grid stability. Gas turbines are also utilized in distributed generation systems, providing power to remote areas or as backup during grid failures (Choudhury et al., 2020). The oil and gas sectors also extensively employ gas turbines for various applications, including power generation, gas compression, and offshore platform operations (Sattler et al., 2019). Gas turbine-driven compressor stations enhance natural gas transmission, ensuring efficient flow through pipelines (Ahmed et al., 2018). Moreover, gas turbines are utilized in liquefied natural gas (LNG) production facilities for refrigeration and power generation, supporting the growing demand for cleaner energy sources. Gas turbines are used for cogeneration or combined heat and power (CHP) applications. CHP systems utilize waste heat from gas turbines for heating or industrial processes, significantly improving energy efficiency and reducing greenhouse gas emissions (Chmielniak et al., 2017). Industries such as manufacturing, petrochemicals, and food processing benefit from the cost savings and environmental advantages offered by CHP systems.

Figure 5: Military Gas Turbine Propulsion in Vessel (GE Aviation)

In the aviation industry, gas turbines power aircraft engines, enabling safe and swift air travel. Modern turbofan engines incorporate advanced gas turbine technology for propulsion, offering high thrust-to-weight ratios and fuel efficiency (Mattingly, 2002). Gas turbines drive both commercial airliners and military aircraft, contributing to global connectivity and national defense capabilities. Gas turbines also find applications in marine propulsion systems, powering ships and vessels with efficient and reliable propulsion (Bansal et al., 2013). Modern marine gas turbines are designed to operate in harsh maritime environments, offering high power density and low emissions (Galea et al., 2020). They play a crucial role in commercial shipping, naval fleets, and offshore operations, ensuring safe and efficient maritime transportation.

3. Design Phase

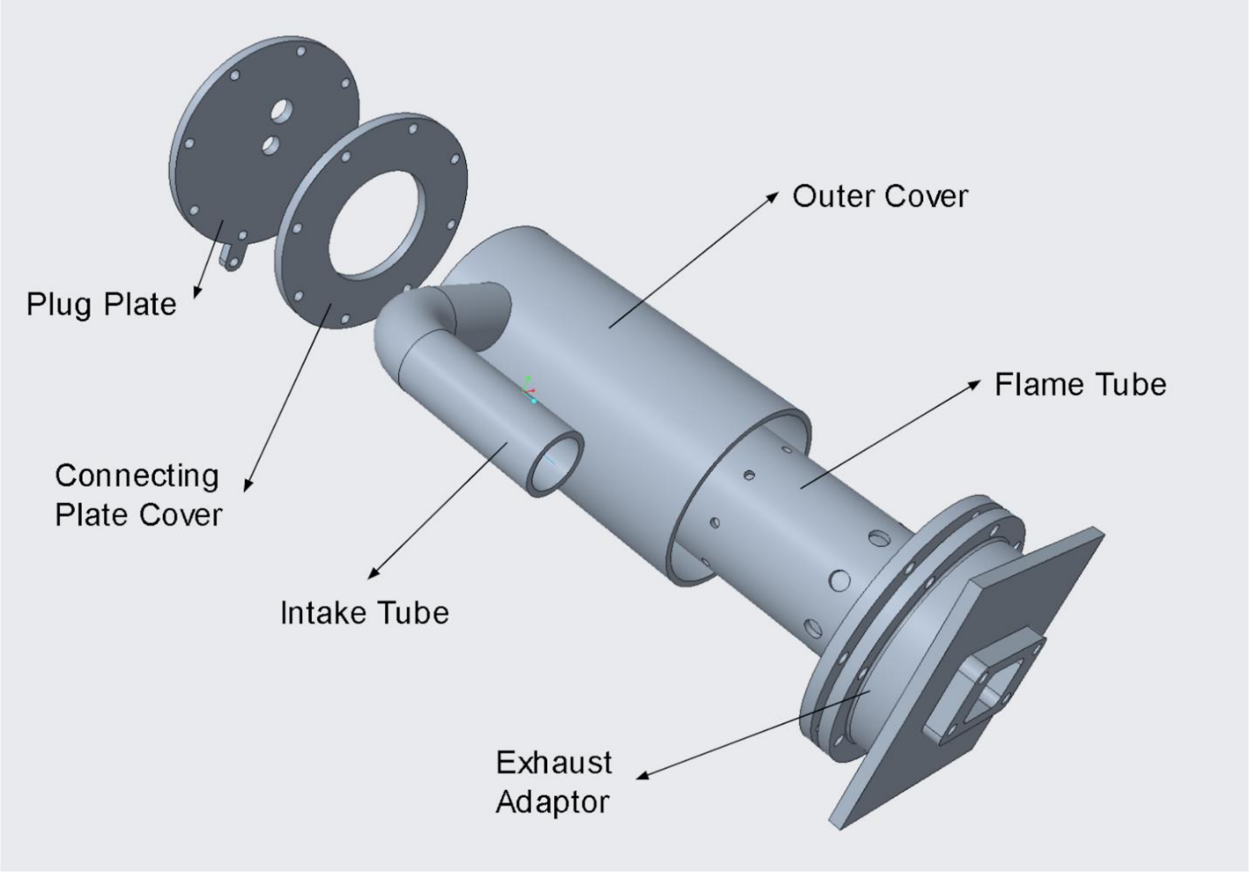

Figure 6: Exploded Photo of Combustion Chamber Design

3.1 Design Process

The design of the gas turbine was completed during B and C terms. This process included doing background research into how similar gas turbines work, designing a combustion chamber, and then designing all the accessories to let the turbine run. The major accessories we built include the oiling and fueling systems. After the basic design was completed, parts for each system were ordered. As parts came in certain design changes were made to fit the constraints of the parts we had.

3.2 Background Research

The major point of the background research was to decide on the overall design we would use. After some discussions with our advisor, he told us that the best style of turbine engine would be a banana style. This is a very simple design that would be well integrated with the type of compressor in a car turbocharger. This would allow us to use a store-bought turbocharger in its entirety and let us manufacture the rest of the parts necessary with the tools available at WPI.

To find out how to design this type of gas turbine, we took most of our inspiration from a video by the YouTube channel Tech Ingredients called “The Turbojet!”. This video detailed exactly how he designed a similar type of gas turbine from a car turbocharger.

3.3 Designing the Combustion Chamber

To operate the engine, you would start by turning on the oiling system and then revving up the turbocharger. The turbocharger is attached with its exhaust intake connected to the exhaust adapter and the compressor outlet connected to the intake tube. When the turbo is revved up it forces air down the intake tube. This compressed air then meets up with fuel and spark that is put in through the two holes in the plug plate. The small holes in the start of the flame tube limit the amount of air that it can get in so the fuel mixture here is very dense. This allows for a good flame to start here and travel up the flame tube towards the exhaust adapter. As this happens more air is allowed in the increasingly larger holes of the flame tube which makes the fuel mixture leaner, so the burn becomes more efficient. The flame speeds up the air and forces it out of the exhaust adapter and into the impeller portion of the turbocharger. As air flows past it forces the turbine to spin so the compressor also spins faster, and more fresh air is forced in back in the beginning. To stop this, fuel must be cut.

3.3.2 Materials

The combustion chamber was the largest piece and the most complicated design challenge. For the overall material, we decided on using mild steel. This was mostly decided based on what was available to us. It would have been better to use stainless steel as that is much stronger and more heat resistant, but it was prohibitively expensive. Aluminum was cheap enough, but too weak to stand up to the temperatures and pressures we needed. Mild steel was a good compromise between the two. The intake tube we decided to create was out of aluminum because this part was exposed to far less heat, and aluminum pipes with pre-made bends are more available.

3.3.3 Flame Tube Design

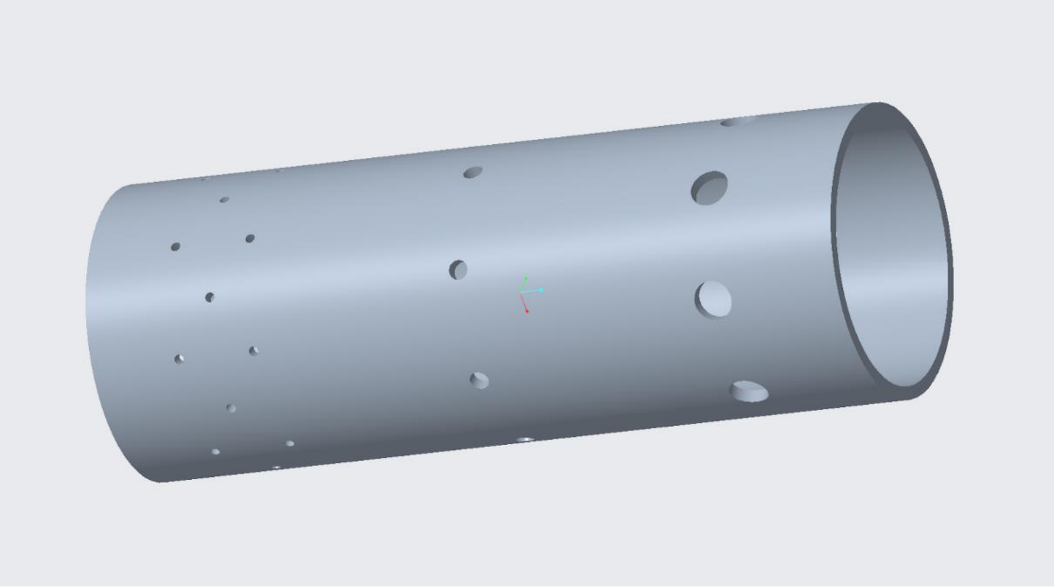

Figure 7: Design of Flame Tube

The flame tube was the most complicated piece within the combustion chamber. Its purpose is to limit the amount of air that can be mixed with the fuel until a good flame has started. This increases the efficiency of the engine and lets more power be made with a limited amount of fuel. The flame tube's diameter is about two times the diameter of the inducer of our turbocharger and about six times its length. The total surface area of all the holes is about the total surface area of the inducer. The largest holes have a diameter twice as big as the middle which is twice as big as the smallest. There are three times as many of the smallest holes as any other. All these sizes are based on the inducer size because all of it is dependent on how much air can be pushed into the engine and that is directly correlated with the inducer size. The size and spacing of the holes in the burn tube are based on our background research but the specifics may not be perfect. Because of this, the flame tube can come out easily and is inspected to see how good it was. Then depending on the inspection, a new flame tube can be made with fewer holes to improve efficiency.

3.3.4 Outer Cover Design

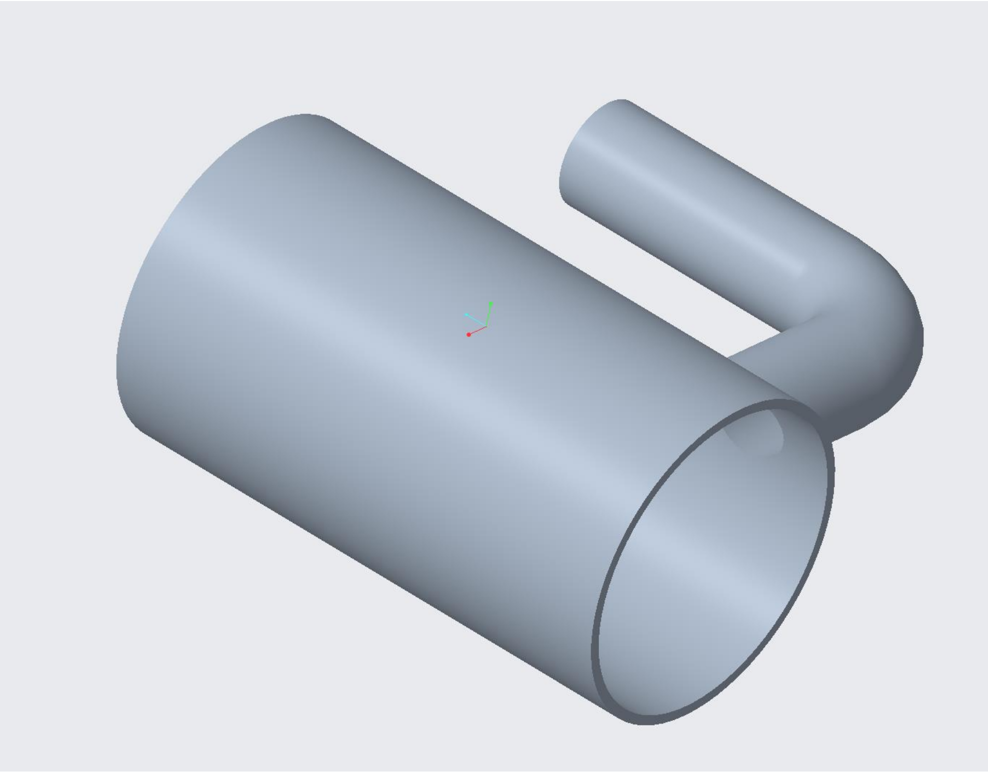

Figure 8: Design of Outer Cover

The outer cover is there to collect the compressed air from the turbocharger and contain it and the flame inside while allowing it to move toward the exhaust. It is also the largest peace that all the others are attached to. The diameter of the large tube is the diameter of the flame tube plus the diameter of the inducer. This allows enough space inside for air travel outside of the flame tube but isn’t so much that all pressure is lost. The intake tube collects the fresh air from the turbocharger. Its diameter is about the same as that of the compressor outlet of the turbo. It is welded to the outer cover off-center from the tube to allow the compressed air to circulate the burn tube. It is not to the edge because that would make welding very difficult.

3.3.5 Connecting Plates Design

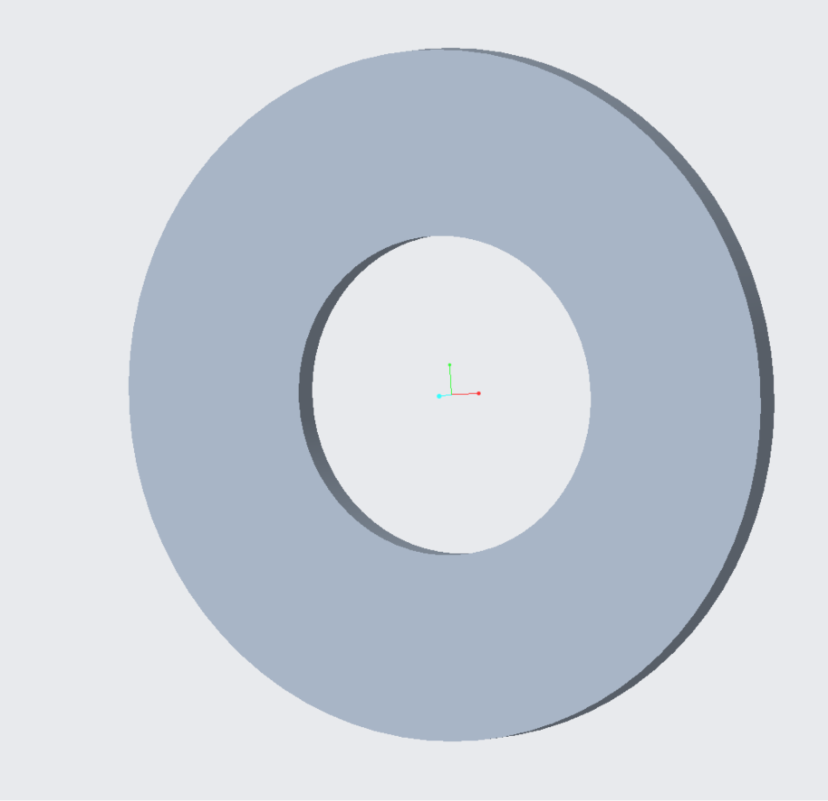

Figure 9: Design of Connecting Plates

The connecting plates are pieces that are welded on the ends of the outer cover that allow it to be bolted to the exhaust adapter and the plug plate. Their size is based on how large they need to be to fit around the outer cover and how much extra space they need to fit half-inch bolts. The inner hole on the side of the plug plate is slightly larger than the outer diameter of the burn tube so that it can slide into the outer cover. The plate connecting to the exhaust adapter has a hole slightly smaller than the outer diameter of the burn tube with a groove cut around the hole. This allows the burn tube to sit in the groove, so it does not move around and still allows air to pass through. These bolts were chosen because they are widely available but strong enough to hold up to the pressures we are using.

3.3.6 Exhaust Adapter Design

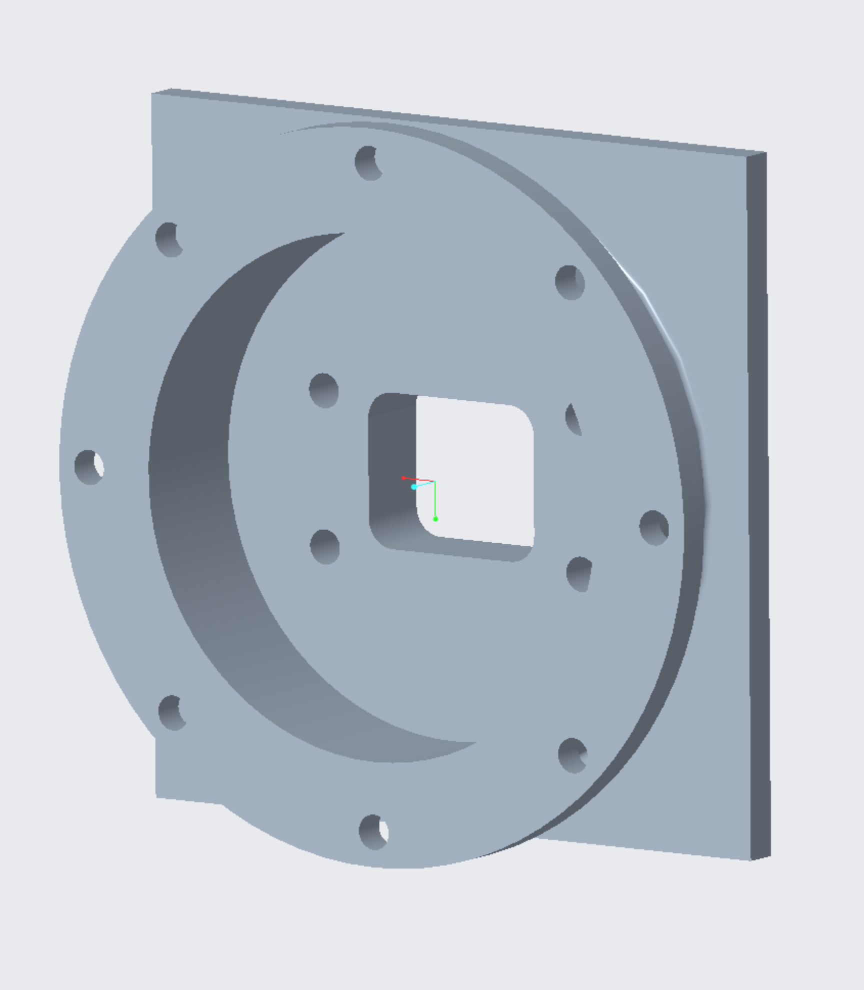

Figure 10: Design of Exhaust Adapter

The exhaust adapter bolts to the connecting plate and allows the rest of the combustion chamber to attach to the exhaust side of the turbocharger. The adapter is necessary because if the connecting plate were attached directly to the turbocharger, the bolt pattern of the turbo would impact the burn tube. This separates the two so there are no issues. The pieces we are designed from extra metal we already had to order so it would not increase the cost.

3.3.7 Plug Plate Design

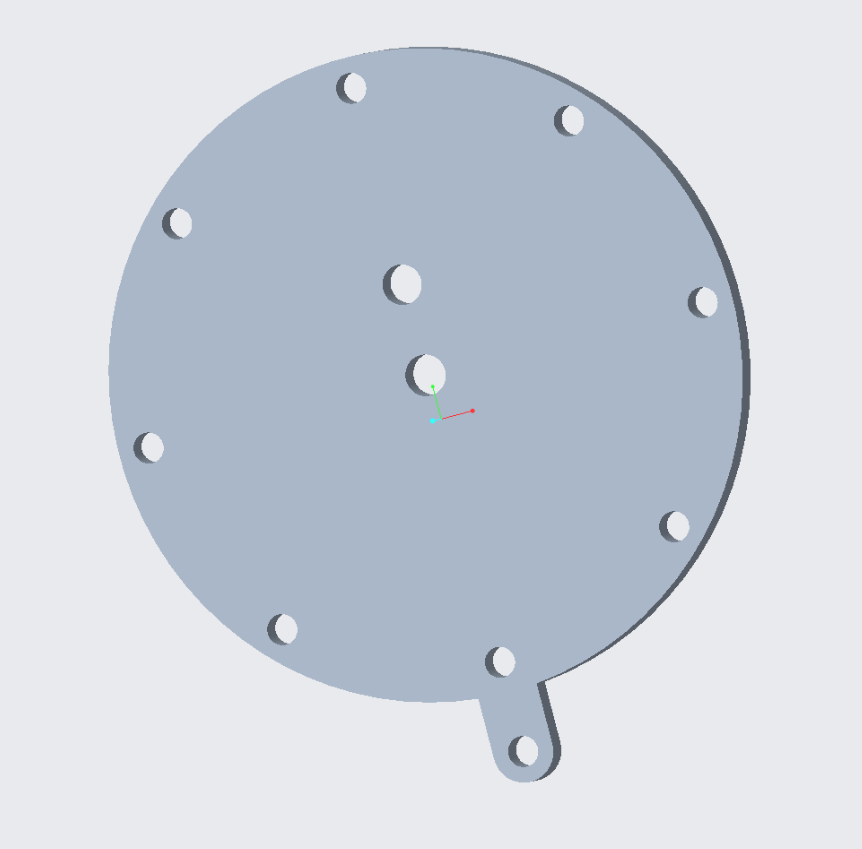

Figure 11: Design of Plug Plate

The plug plate holds the injector and spark plug while keeping the air and flame inside the engine and holding in the burn tube. The small part coming off the plate allows a mounting system to be attached to this end of the engine. The central hole is for fuel so there can be an even mix around all the burn tubes. The other hole is for the spark plug to start the flame.

3.4 Oil System Design

The oil system is designed to lubricate and cool the turbocharger. The two open ends will be attached to the inlet and outlet of the turbocharger with one-way valves so that oil cannot go the wrong way through the turbo. The oil system is designed on a two-loop system. One loop goes through the pump, radiator, and oil tank. The other loop goes through the turbocharger and the oil tank. The pressure going through the loop with the turbocharger is regulated with a valve that connects the loop. This design allows us to keep the pump running at full capacity, which simplifies the system and allows the maximum amount of oil to continuously go through the radiator to cool the turbo. This also allows us to adjust the exact amount of pressure that goes to the turbo, so we do not under or over-lubricate it.

3.5 Fuel System Design

The fuel system is a very simple design. We planned on using propane for fuel so there is no need for a fuel pump because propane is already under pressure. The fuel system starts with the propane tank that would attach to the end of the tube. The tube allows the fuel to travel a distance away so we can adjust the amount of fuel from a distance. Then there is a fine adjustment valve for more specific adjustment once it is already running. Then there is a one-way valve so burning fuel cannot get sent down the wrong end of the line. Then there is an on-off valve to turn off the engine and finally a fuel nozzle. This whole system would be attached by the nozzle to the plug plate.

4. Manufacturing Phase

After completing the design phase, the goal of manufacturing the combustion chamber was to make a structurally sound unit that can withstand high temperatures and mild pressures. With those characteristics in mind, we decided to use mild steel at ¼ inch thick for plates and ⅛ inch thick for pipes. Not only can these metals withstand the environment of a combustion chamber but also help financially since they aren't as expensive as heavy and stainless steel. We ordered three 12'' x 24'' steel plates, a four foot 4'' diameter pipe, and a four foot 6'' diameter pipe.

4.1 Water Jet Cutter

When the metals arrived the first step was to measure out the cuts for the steel plates and confirm the 2D design sheets that we had previously made in the design phase. The water jet uses 2D tracing software using dxf files. The water is mixed with an abrasive to provide a clean-cut edge on the steel. The abrasive for this machine was garnet, which is a 7 on Mohr's rock hardness scale. The process of cutting the shape out of the plates took about 30 minutes for each piece. The biggest benefit of using the water jet is the precision of the cuts, all the steel plates had the exact same dimensions, and all the circle cutouts were on point. The figure below is the end plate which was one of five plates cut with the water jet.

Figure 12: Plate Cover Cut by the Water Jet

4.2 Horizontal Band Saw

The horizontal band saw was used to cut the pipes to the perfect lengths. The flame tube was cut to a length of 11.8125 inches and the cover tube was cut to a length of 11.5625. The tubes were cut a different size to avoid welding the flame tube, giving us the ability to interchange tubes if adjustments need to be made. With this design, the flame tube is secured into a position using the inner cut-out holes of the plates and secured using the end plate in the figure above. To ensure precise measurements, we utilized the band saw's automated measuring tools to avoid hand measuring and cutting. One extra flame and cover tube were cut to account for any mistakes made while drilling holes. The figure below shows all the tubes after being cut.

Figure 13: Flame Tube and Cover Tube Cut to Size Using the Horizontal Band Saw

4.3 CNC Mill

The CNC mill played a vital role despite being used for only one cut. As mentioned in the previous section, the flame tube needed a secure fitting and the best way to do that was to cut a lip in one of the plates to hold the tube in place. The lip was cut to a depth of 0.16 inches on the inside edge of the inner hole of the plate with a width matching the diameter of the flame tube. Simple calculations and once again precision cutting allowed the assembly to fit together perfectly.

4.4 Drill Press

The drill press was the most important machine in this project as it was used to drill out all the holes in the flame tube, cover tube, and bolt holes in the plates. The holes in the flame tube were the most difficult as the holes needed to be very precise in size and location. The holes from smallest to largest measure 5/32, 5/16, and ⅝. Each hole started with a tap at the center of the hole allowing the drill bit to fit nicely into its position. To avoid a messy cut or breaking the drill bit, the bigger holes needed a step bit. This is simply drilling a smaller hole first, so the bigger bits don’t take on all the force of cutting the hole. After completing the holes in the flame tube, the sharp edges on the inside were filed down to avoid any safety hazards when pulling the tube in and out. The figure below represents the flame tube post-drilling.

The cover tube also needed a very precise hole for the air intake to the combustion chamber. The hole is off centered to create a circular flow of air around the flame tube which provides the cleanest burn. The diameter of the hole that was cut into the c-over tube was 1.75 inches, matching that of the intake pipe which would then be welded on.

Lastly, the bolt holes in the plates were drilled out. These holes were about 10mm (about 0.39 in) in diameter. Eight holes 45° apart for each plate is the metric we used when approaching this part of the machine. The holes on each plate needed to line up with the holes of the other plates, providing easy connections.

Figure 14: Flame tube with Holes Pressed

4.5 Welding

The welding was the only part of the manufacturing phase not done by our team, as we did not have access to any welding equipment during our project's timeframe. Because of this, we reached out to professional welder Chad Vincent who was very helpful in getting the welding done in a timely manner. The welding consisted of three main components: the cover tube welded to a plate on each side, the intake pipe onto the cover tube, and the adapter piece to two pipes. The figures below show the welded components.

Figure 15: Cover Tube Welded to Two Plates and Intake Pipe

Figure 16: Adaptor Piece Welded to Two Plates

4.6 Fasteners

The final part of the manufacturing phase was to get bolts and nuts for connecting the components of the combustion chamber. With temperature and pressure in mind, we used grade 8 bolts and nuts as they can withstand far more intense environments than we plan to see with our design. The bolts are 1.25 inch long and 5/16 thread size.

5. Assembly and Results

5.1 Assembly Process

The assembly of the turbocharged gas turbine assembly was a meticulous process that involved integrating various components with precision and care. The manufactured combustion chamber components, including the flame tube, cover tube, outer cover, connecting plates, exhaust adapter, and plug plate, were assembled according to the design specifications.

The flame tube was inserted into the outer cover with a manufactured lip inside, ensuring a secure fit and alignment with the connecting plates. The connecting plates were then bolted to the outer cover and the exhaust adapter, creating a robust framework for the combustion chamber assembly. The plug plate, equipped with the injector and spark plug, was securely attached to the combustion chamber, completing the assembly of the core components.

Finally, the starter motor, acquired specifically for the project, was mounted onto the intake of the turbocharger using a triangular bolt pattern, allowing for efficient and safe engine startup. With all subsystems integrated and connections verified, the turbocharged gas turbine assembly was ready for testing and evaluation. The following image is the final assembly of the gas turbine assembled by the team.

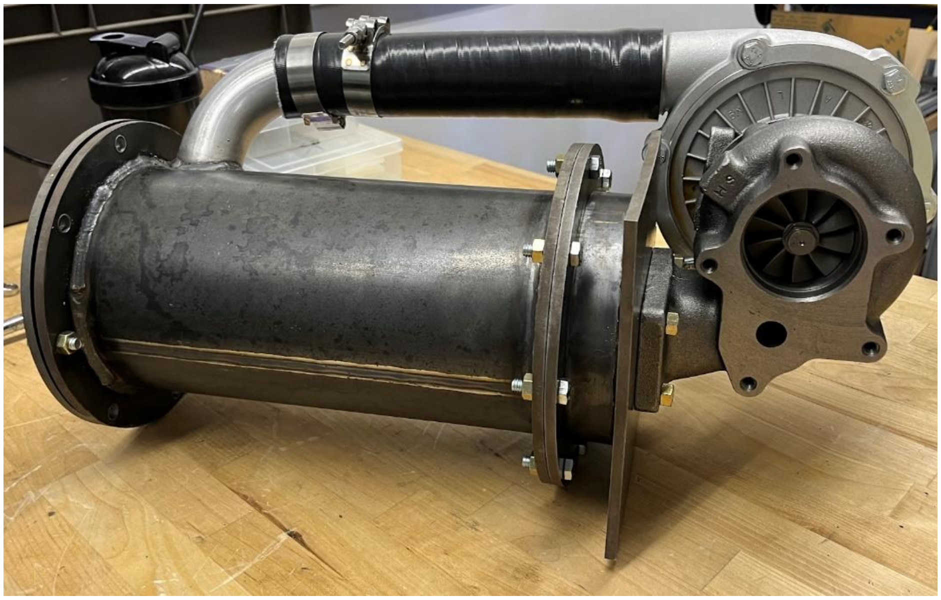

Figure 17: Final Gas Turbine Assembly

5.2 Challenges

When it came to manufacturing and assembling our gas turbine, we faced many challenges that we ultimately had to overcome. The first challenge our team faced was ordering the materials and parts needed to complete our project. Due to the poor supply chain that our country is facing currently, we did not receive crucial material for our combustion chamber until 9 weeks (about 2 months) after initially ordering. From that point, we were at a standstill and could not move on to the next phase of the project which was manufacturing.

Another challenge that arose was the limitations of the Washburn Laboratory. Our team would not have been able to complete our project without the expertise of the Washburn staff; however, due to time and machine restrictions put in place, some things could not be accomplished immediately. For instance, Washburn Laboratory staff were not granted access to welding supplies. Therefore, our team had to prevail and find another resource to weld parts of our combustion chamber. Along with the welding issue, scheduling time in Washburn to use the machines was also challenging due to the limited space and time available for other MQP teams to also complete their projects.

If it were not for the challenges mentioned, we would have confidently been able to complete more and gone above and beyond the goals set for our project initially. Regardless, we were able to design and manufacture a gas turbine with the potential of producing continuous internal combustion and thrust. Future work on the gas turbine could be completed to reach this goal.

6. Future Work

Before the operation of the gas turbine, several subsystems need to be implemented into the engine. In this section, we delineate the operations and future work needed, outlining key areas of focus and potential avenues for refinement and innovation. Through implementing a starter motor, to all the electrical components for the fuel and oiling system and the sensors, these integrations will allow the engine to run, and collect data for future tests to enhance the efficiency of the engine. The following are future work needed for the gas turbine to run and collect data on the engine's efficiency.

6.1 Starter Motor

When starting the engine, an initial 80,000 rpm for the turbine blades is required for the engine to collect enough compressed ambient air for combustion. The acquired starter motor was the brushless starter motor used for the Rhino 200 (Rhino 2024). Bolting the motor using three anchor points in a triangle shape on the intake of the compressor can help secure the motor without limiting the air intake. This allows for a reduced restriction on the airflow allowed into the compressor, and when connected to the compressor, energy can be collected from the turbocharger after the engine starts. The turbine’s compressor rotor has low torque and high rpm, allowing for a smaller starter motor that does not require high torque. Using the starter motor bought by the team, the operators can start the engine efficiently and safely, and generate electricity when the motor is running after the engine starts.

6.2 Electrical Components

For the engine to run and collect testing results, several electrical components must be implemented into the turbocharger and the combustion chamber. This section focuses on refining the design of the electrical components such as sensors and control units to enhance the turbine system's efficiency and reliability.

6.2.1 Thermocouples

Various sensors can be used to monitor the engine's efficiency, for both the exhaust temperature, thrust power and the psi within the combustion chamber. The most important sensor needed for data collection for the gas turbine is thermocouples in the combustion chamber. These sensors measure the temperature within the combustion chamber and turbocharger exhaust and are critical for regulating the amount of air and fuel entering the combustion phase. Because our gas turbine is expected to reach a minimum of 900 degrees Fahrenheit in the combustion chamber and turbocharger exhaust, thermocouples will be able to provide accurate and reliable temperature measurements, allowing operators to monitor and control temperatures within safe operating limits. These readings will help prevent overheating, and damaging components (specifically electrical components), and maximize the turbine’s efficiency.

Figure 18: Thermocouple Temperature Probe for Gas Turbines (1200 degrees C)

Thermocouples also allow for turbine design optimization and specifically the flame tube. By monitoring the different temperature variations within the turbine system, the fuel-air ratios can be adjusted to optimize the combustion process, ensuring uniform temperature distribution across turbine components. This will maximize energy conversion efficiency and power output while minimizing fuel consumption and emissions. Both the combustion chamber and the exhaust of the turbocharger will require thermocouples for tracking both the internal combustion temperature and the temperature coming out of the engine. These two areas are key for collecting data and improving the efficiency of the engine.

6.2.2 Pressure Sensors

When monitoring the engine, pressure monitoring allows for optimization and, most importantly, the safety and reliability of the engine and its operators. When working with high temperatures and pressures, abnormal fluctuations in pressure can ensure the safe and reliable operation of the turbine. Uniform pressure flow should be observed throughout the turbine and abnormal overpressure and under pressure in these conditions may indicate leaks or system failures that pose safety risks or could lead to equipment damage.

To monitor pressure throughout the turbine, implementing piezoelectric pressure transducers in both the compressor and combustion chamber can allow for continuous pressure monitoring, and can detect even the smallest changes in pressure levels within the gas turbine system. With this fast response time for data and rapid feedback to control systems, safety measures, and troubleshooting can be implemented in the engine. By correlating pressure data and other operational parameters and diagnostic information, potential problems such as turbine blade erosion, combustion instability, or airflow restrictions can be pinpointed, and active measures can be taken to resolve the issues. The following is an image of the pressure transducer that can be used to regulate and monitor the internal pressure of the combustion chamber and turbocharger.

Figure 19: Ultra-Fast High-Temperature Pressure Transmitter

This pressure transmitter is optimized for dynamic (pressure pulsations in proximity) and dynamic (fast pressure pulsations at proximity) and static pressure measurements. It also withstands extremely high temperatures of 1000 °C with appropriate cooling. The pressure range for this specific pressure transmitter is 3 bar, 10 bar, and 30 bar (absolute) but with pressures within the combustion chamber designed to be approximately 40 psi, this pressure transmitter withstands the extreme environment of our turbine system. Using pressure transmitters, the turbine system can be optimized through data collection and implement safety features for the gas turbine operators.

6.2.3 Flow Sensors

Gas turbines require precise control of airflow to ensure optimal combustion efficiency and turbine performance. Mass flow sensors measure the rate of airflow entering the turbine compressor, allowing operators to adjust fuel flow rates for the desired air-to-fuel ratio for efficient combustion.

The key areas for implementing flow sensors are the compressor intake and the exhaust's outtake. Airflow rate, velocity, and mass flow rate data of the intake ambient air can be measured for both the compressor and the exhaust of the turbocharger.

6.3 Mounting System

This gas turbine's successful operation relies on the mounting system's efficiency and reliability. Our design of the gas turbine is heavily unbalanced, designing our manufactured combustion chamber in series with our turbine caused extreme weight distribution of our engine. An adequate mounting system allows for stability and support for the operation of the engine. Designing a mounting system to allow for the engine to move back and forth enables the ability for thrust calculations out of the turbine’s exhaust. Using the mounting fixtures on the manufactured plug plate and the turbine’s mounting component, the engine can be mounted to 20mm (about 0.79 in) aluminum extrusions, allowing for the force of the engine to act along the t-shaped aluminum extrusions. Strain gauges can be implemented into the mounting system to test both the stability of the mounting system and the stress of the gas turbine on the extrusions when operating. These implications for the gas turbine are necessary for the operation and data collection of the engine's efficiency.

7. Conclusions

The development of the turbocharged gas turbine assembly presented in this report represents a culmination of ingenuity, perseverance, and interdisciplinary collaboration. We were able to use our engineering skills to understand the workings of a gas turbine, design an external combustion chamber for a small-scale turbocharger, and use our manufacturing skills to fabricate the chamber and implement it with the turbocharger. From the initial conceptualization to the design and precision manufacturing, each phase of the project has been driven by a commitment to excellence and innovation.

The integration of turbocharging technology with a combustion chamber design reflects a forward-thinking approach to enhancing the performance and efficiency of gas turbines. By harnessing exhaust energy to drive a compressor, turbochargers offer a pathway to augmented power output and improved fuel efficiency, laying the foundation for transformative advancements in power generation and beyond. The design phase, facilitated by advanced computer aided design software and informed by comprehensive background research, ensured that every aspect of the combustion chamber was optimized for performance, durability, and operational efficiency.

The manufacturing phase, characterized by precision machining and meticulous assembly, transformed design concepts into machined components to withstand high temperatures and pressures. Despite facing challenges such as supply chain disruptions and resource limitations, the team demonstrated resilience and adaptability, finding creative solutions to overcome obstacles and move the project forward.

Looking ahead, future work aims to further enhance the turbocharged gas turbine assembly by implementing additional subsystems, including a starter motor, electrical components for monitoring and control, and a robust mounting system. These integrations will not only enable the engine to operate efficiently and reliably but also provide valuable data for ongoing optimization and refinement.

In conclusion, the development of the turbocharged gas turbine assembly represents a significant milestone in the pursuit of advanced propulsion technologies. With its potential applications spanning power generation and transportation, this project underscores the transformative impact of interdisciplinary collaboration and innovative engineering solutions in addressing the challenges of the future. With the completed assembly of the engine, we look forward to the continued advancement and utilization of turbocharged gas turbine technology in shaping a more sustainable and efficient world.

This project was extremely educational for learning and understanding how engines operate, especially turbochargers. By overcoming challenges throughout the manufacturing phase, we were able to lay the groundwork for testing and data collection of the gas turbine and allow for the next group to develop ways to make the engine more efficient and even use the engine for applications like generating power. This was a fun yet demanding project that allowed for our group’s creativity to govern the design of the combustion chamber. The knowledge gained from this project will help our members in their future endeavors when we go out into the workforce.

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