



DEVELOPMENT AND PERFORMANCE OF TURBOFAN ENGINE: A REVIEW

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Abstract: The Mini turbine engine is an fuel combustion Engine which uses a Brayton cycle to run the cycles of the engine, in this specific scenario the Turbocharger of an IC engine has been used in a way so that it can optimally run The Brayton Cycle. The turbocharger is a very useful accessory of the IC engine which increases the efficiency of the engine by providing forced induction into the engine without actually depriving the engine performance of its own energy like in the case of a Supercharger. The Compressor (The cold side) and The Turbine (The hot side), of a Turbocharger are connected within which a combustion chamber is provided to sufficiently run The Brayton cycle. The Main aim and scope of this paper is to superimpose separated results to get integrated systems seek to reach the overall advanced design and benefits by integrating: (a) Physics, Aero, and Stealth Thermodynamics in simulations by flying unmanned or manned prototypes supported by artificial intelligence and Computer Simulations based on: (b) Component R&D of Turbo and Jet-Engines, Airframe, Helmet-Aiming-Systems and Ammunition based on: (c) Anticipated New Programs Missions based on (d) improved reliability, efficiency, economics, tactics, strategies and education in both the civil and military domains of Turbo and Jet Engines.

The International Journal of Turbo & Jet Engines is devoted to cutting edge research in theory and design of propagation of jet aircraft. It serves as an international publication fragment for new ideas, insights and results from industry and academic research on thermodynamics, combustion, behavior of related materials at high temperatures, turbine and engine design, thrust vectoring and flight control stabilizers as well as energy and environmental issues.

Keywords:- Mini turbine engine, Brayton Cycle, Turbocharger, IC engine, GAS Turbine, Efficiency.

I. INTRODUCTION

A turbine is any kind of spinning device that uses the action of a fluid to produce work. Typical fluids are: air, wind, water, steam and helium. Windmills and hydroelectric dams have used turbine action for decades to turn the core of an electrical generator to produce power for both industrial and residential consumption. Simpler turbines are much older, with the first known appearance dating to the time of ancient Greece. In the history of energy conversion, however, the gas turbine is relatively new. The first practical gas turbine used to generate electricity ran at Neuchatel, Switzerland in 1939, and was developed by the Brown Boveri Company. The first gas turbine powered airplane flight also took place in 1939 in Germany, using the gas turbine created by Hans P. von Ohain[1]. In England, the 1930s' invention and development of the aircraft gas turbine by Frank Whittle resulted in a similar British flight in 1941. The purpose of this paper is to examine the management of scientific research and technology development, using development in the United States as a case study. The first section of the paper addresses the period from about 1960 to 1985. This period was distinguished by many new aircraft platforms of great variety and, consequently, a large and varied number of opportunities to design new aircraft engines (Fig. 1). Technology development of jet engines was on a steep trajectory: Most of the key technologies to modern aircraft engine performance matured during this period. The second section focuses on 1985–2000 when the Integrated High Performance Turbine Engine Technology (IHPTET) Program was the primary U.S. government vehicle for coordinating turbine engine science and technology research. It addresses the impact culture on technology development during both periods and the changes brought about by the IHPTET program management process [2]-[5].

The third and final section analyzes historical data and the IHPTET process, especially with respect to the general issue of incremental innovation in research programs. The name "gas turbine" is somewhat deceiving, whereas to many it implies as the turbine engine that uses gas as its fuel. A gas turbine (as shown schematically in Fig. 1) has a compressor to draw in and compress gas and transfer it to a combustor (or burner) to add fuel to heat the compressed air; and a turbine to extract power from the hot air flow[6].

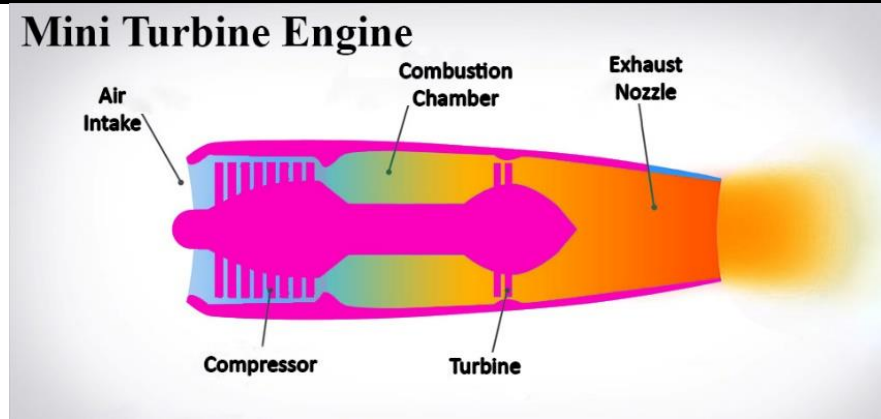


Fig. 1 Schematic for an Aircraft Jet Engine

The gas turbine is an internal combustion (IC) engine employing a continuous combustion process. This differs from the intermittent combustion occurring in Diesel and automotive IC engines. Because the 1939 origin of the gas turbine lies simultaneously in the electric power field and in aviation, there have been a profusion of "other names" for the gas turbine.[7]-[12]. For electrical power generation and marine applications, it is generally called a gas turbine, also a combustion turbine (CT), a turboshaft engine, and sometimes a gas turbine engine. For aviation applications it is usually called a jet engine, and various other names depending on the particular engine configuration or application, such as: jet turbine engine; turbojet; turbofan; fanjet; and turboprop or prop jet (if it is used to drive a propeller). The compressor combustor-turbine part of the gas turbine (Fig. 1) is commonly termed the gas generator.

II. Gas Turbine Usage

In an aircraft gas turbine, the output of the turbine is used to turn the compressor (which may also have an associated fan or propeller). The hot air flow leaving the turbine is then accelerated into the atmosphere through an exhaust nozzle to provide thrust or propulsion power.

A typical jet engine is shown in Fig. 2. Such engines can range from about 100 pounds of thrust to as high as 100,000 lbs. of thrust. with weights ranging from about 30 lbs. to 20,000 lbs. The smallest jets are used for devices such as the cruise missile, the largest for future generations of commercial aircraft. The jet engine of Fig. 2 is a turbofan engine, with a large diameter compressor-mounted fan. Thrust is generated both by air passing through the fan (Bypass air) and through the gas generator itself. With a large frontal area, the turbofan generates peak thrust at low (takeoff) speeds making it most suitable for commercial aircraft. A turbojet does not have a fan and generates all of its thrust from air that passes through the gas generator. Turbojets have smaller frontal areas and generate peak thrusts at high speeds, making them most suitable for fighter aircraft. In non-aviation gas turbines, part of the turbine power is used to drive the compressor. The remainder, the "useful power", is used as output shaft power to turn an energy conversion device such as an electrical generator or a ship's propeller[13]-[19].

The compressor power equals to gas generator turbine power. This determines the available force upstream of the power turbine. The available pressure ratio at the power turbine is sufficient to allow the airflow to be forced through the power turbine. Depending on the ambient temperature relative to the engine match temperature, the fuel flow into the engine will either be limited by reaching the maximum firing temperature or the maximum gas generator speed. The ambient temperature, where both control limits are reached at the same time,[20]-[25].

III. WORKING PRINCIPLE

An automotive turbocharger has a fine package system of a compressor and turbine operating on a single axle shaft. So, the proposition is to build a gas turbine engine by adding the third key component, the combustion chamber. The first step is to choose a turbocharger with the requirements, then along those specifications a combustor is to be designed and developed suitably for the chosen turbocharger. The combustor in combination with the turbocharger would then perform as a gas turbine engine. And the last component being the impulse turbine and gear box assembly (which includes A.C Generator, Starter Motor, Mechanical Fuel Pump) is connected to the exit of the nozzle or in between the compressor and turbine by elongating the bearing housing providing a wet sump lubrication to the gearbox as well as the bearings. A turbocharger, often called a turbo, is a small radial fan pump driven by the energy of the exhaust flow of an engine. A turbocharger consists of a turbine and a compressor on a shared shaft. The turbine inlet receives exhaust gases from the engine causing the turbine wheel to rotate[26]-[30].

This rotation drives the compressor, compressing ambient air and delivering it to the air intake manifold of the engine at higher pressure, resulting in a greater mass of air entering each cylinder. A naturally aspirated automobile engine uses only the downward stroke of a piston to create an area of low pressure in order to draw air into the cylinder through the intake valves. Because the pressure in the atmosphere is no more than 1 bar, there ultimately will be a limit to the pressure difference across the intake valves and thus the amount of airflow entering the combustion chamber. This ability to fill the cylinder with air is its volumetric efficiency.

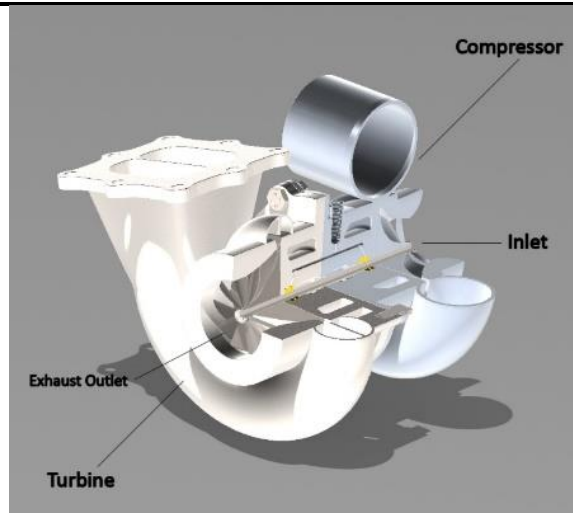


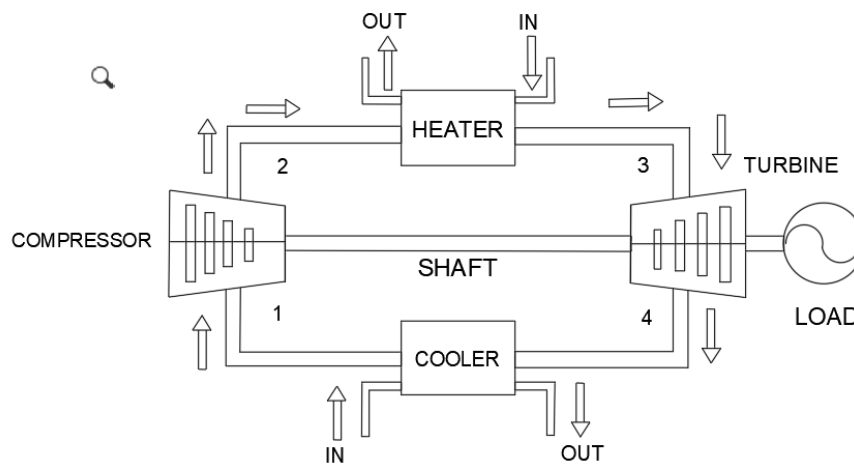
Fig. 2 Turbocharger Cut section

IV. BRAYTON CYCLE: THE IDEAL CYCLE FOR GAS-TURBINE ENGINES

The Brayton cycle was first introduced by George Brayton for trial on a reciprocating oil-burning engine that he developed around 1870's. Now, it has been in use for gas turbines only where both the compression and expansion processes take place in rotating machinery. Gas turbines usually operate on an open cycle, Fresh air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised. The high-pressure air proceeds into the combustion chamber, where the fuel is burned at constant pressure. The resulting high temperature gases then enter the turbine, where they expand to the atmospheric pressure while producing power. The exhaust gases leaving the turbine are thrown out (not recirculated), causing the cycle to be classified as an open cycle.

The open gas-turbine cycle described above can be modeled as a closed cycle, by utilizing the air-standard assumptions. Here the compression and expansion processes remain the same, but the combustion process is replaced by a constant-pressure heat-addition process from an external source, and the exhaust process is replaced by a constant pressure heat-rejection process to the ambient air. The ideal cycle that the working fluid undergoes in this closed loop is the Brayton cycle, which is made up of four internally reversible processes:

- 1-2 Isentropic compression (in a compressor)
- 2-3 Constant-pressure heat addition
- 3-4 Isentropic expansion (in a turbine)
- 4-1 Constant-pressure heat rejection



CLOSED CYCLE GAS TURBINE

Fig. 3: A Closed Cycle Gas Turbine

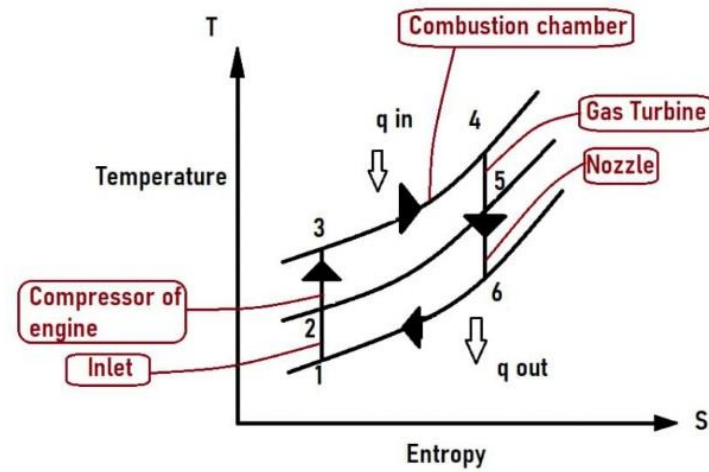


Fig. 4 T-s diagram of the Ideal Brayton Cycle

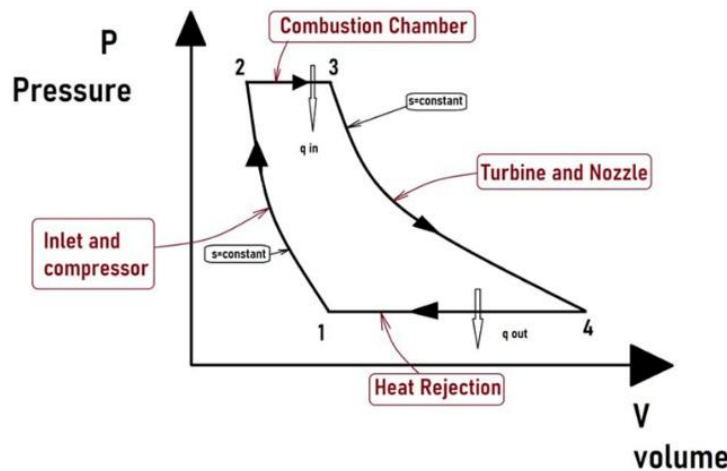


Fig. 5 P-V diagram of the Ideal Brayton Cycle

The maximum temperature in the cycle occurs at the end of the combustion process (state 3), and it is restricted by the maximum temperature that the turbine blades can withstand. This also limits the pressure ratios that can be used in the cycle. There should be a compromise between the pressure ratio (thus the thermal efficiency) and the net-work output. With less work output per cycle, a larger mass flow rate (thus a larger system) is needed to maintain the same power output, which may not be economical. In most common designs, the pressure ratio of gas turbines ranges from about 10 to 15. The air in gas turbines performs two important functions: It supplies the necessary oxidant for the combustion of the fuel, and it serves as a coolant to keep the temperature of various components within safe limits. The second function is accomplished by drawing in more air than is needed for the complete combustion of the fuel. In gas turbines, an air-fuel mass ratio of 50 or above is not uncommon. Therefore, in a cycle analysis, treating the combustion gases as air does not cause any appreciable error. Also, the mass flow rate through the turbine is greater than that through the compressor, the difference being equal to the mass flow rate of the fuel. Thus, assuming a constant mass flow rate throughout the cycle yields conservative results for open-loop gas-turbine engines. The two major application areas of gas-turbine engines are aircraft propulsion and electric power generation. When it is used for aircraft propulsion, the gas turbine produces just enough power to drive the compressor and a small generator to power the auxiliary equipment. The high-velocity exhaust gases are responsible for producing the necessary thrust to propel the aircraft.

Gas turbines are also used as stationary power plants to generate electricity as stand-alone units or in conjunction with steam power plants on the high-temperature side. In these plants, the exhaust gases of the gas turbine serve as the heat source for the steam. The gas-turbine cycle can also be executed as a closed cycle for use in nuclear power plants. This time the working fluid is not limited to air, and a gas with more desirable characteristics (such as helium) can be used. The majority of the Western world's naval fleets already use gas-turbine engines for propulsion and electric power generation. The General Electric LM2500 gas turbines used to power ships have a simple-cycle thermal efficiency of 38 percent. The General Electric WR-21 gas turbines equipped with intercooling and regeneration have a thermal efficiency of 42.9 percent and produce 21.61 MW (29040 hp). The regeneration also reduces the exhaust temperature from 599.9°C to 350°C. Air is compressed to 3 atm before it enters the intercooler. Compared to steam-turbine and diesel propulsion systems, the gas turbine offers greater power for a given size and weight, high reliability, long life, and more convenient operation. The engine start-up time has been reduced from 4 h required for a typical steam propulsion system to less than 120 seconds for a gas turbine. Many modern marine propulsion systems use gas turbines together with diesel engines because of the high fuel consumption of simple-cycle gas-turbine engines. In combined diesel and gas-turbine systems, diesel is used to provide for efficient low-power and cruise operation, and gas turbine is used when high speeds are needed.

In gas-turbine power plants, the ratio of the compressor work to the turbine work, called the back work ratio, is very high. Usually more than one-half of the turbine work output is used to drive the compressor. The situation is even worse when the isentropic efficiencies of the compressor and the turbine are low. This is quite in contrast to steam power plants, where the back work ratio is only a few percent. This is not surprising, however, since a liquid is compressed in steam power plants instead of a gas, and the steady-flow work is proportional to the specific volume of the working fluid. A power plant with a high back work ratio requires a

larger turbine to provide the additional power requirements of the compressor. Therefore, the turbines used in gas-turbine power plants are larger than those used in steam power plants of the same net power output.

V. Application

This engine has a variety number of applications from the automotive industry to a common household appliance, The mini turbine engine can be placed in a drone shell to provide thrust to the aircraft and have a sufficiently longer range than the other electrical companions and a prospect of refueling it in mid-air to increase the range and not only the range will increase with a thrust engine we can increase the output by placing a afterburner which will then increase the speed tremendously compared to the counterpart.

In Household the Mini Turbine Engine Can be used as a Gas-Powered Heat generator which will provide instant heat at higher temperatures which is also suitable for Small Scale Gas-powered furnaces

VI. Literature & Review

Development of Gas Turbines has experienced phenomenal progress and growth since its first successful development in the 1930s. The early gas turbines built in the 1940s and even 1950s had simple cycle efficiencies of about 17 percent because of the low compressor and turbine efficiencies and low turbine inlet temperatures due to metallurgical limitations of those times. Therefore, gas turbines found only limited use despite their versatility and their ability to burn a variety of fuels. The efforts to improve the cycle efficiency concentrated in three areas [1].

Increasing the turbine inlet (or firing) temperatures this has been the primary approach taken to improve gas-turbine efficiency. The turbine inlet temperatures have increased steadily from about 540°C in the 1940s to 1425°C and even higher today. These increases were made possible by the development of new materials and the innovative cooling techniques for the critical components such as coating the turbine blades with ceramic layers and cooling the blades with the discharge air from the compressor. Maintaining high turbine inlet temperatures with an air-cooling technique requires the combustion temperature to be higher to compensate for the cooling effect of the cooling air. However, higher combustion temperatures increase the amount of nitrogen oxides (NO_x), which are responsible for the formation of ozone at ground level and smog. Using steam as the coolant allowed an increase in the turbine inlet temperatures by 200°F without an increase in the combustion temperature. Steam is also a much more effective heat transfer medium than air.[2]-[4]

Increasing the efficiencies of turbomachinery components the performance of early turbines suffered greatly from the inefficiencies of turbines and compressors. However, the advent of computers and advanced techniques for computer-aided design made it possible to design these components aerodynamically with minimal losses. The increased efficiencies of the turbines and compressors resulted in a significant increase in the cycle efficiency [5].

Adding modifications to the basic cycle the simple-cycle efficiencies of early gas turbines were practically doubled by incorporating intercooling, regeneration (or recuperation), and reheating, discussed in the next two sections. These improvements, of course, come at the expense of increased initial and operation costs, and they cannot be justified unless the decrease in fuel costs offsets the increase in other costs. The relatively low fuel prices, the general desire in the industry to minimize installation costs, and the tremendous increase in the simple-cycle efficiency to about 40 percent left little desire for opting for these modifications. The first gas turbine for an electric utility was installed in 1949 in Oklahoma as part of a combined-cycle power plant. It was built by General Electric and produced 3.5 MW of power. Gas turbines installed until the mid-1970s suffered from low efficiency and poor reliability. In the past, the base-load electric power generation was dominated by large coal and nuclear power plants. However, there has been an historic shift toward natural gas-fired gas turbines because of their higher efficiencies, lower capital costs, shorter installation times, and better emission characteristics, and the abundance of natural gas supplies, and more and more electric utilities are using gas turbines for base-load power production as well as for peaking.[6]-[7]

The construction costs for gas-turbine power plants are roughly half that of comparable conventional fossil-fuel steam power plants, which were the primary base-load power plants until the early 1980s. More than half of all power plants to be installed in the foreseeable future are forecast to be gas-turbine or combined gas-steam turbine types. A gas turbine manufactured by General Electric in the early 1990s had a pressure ratio of 13.5 and generated 135.7 MW of net power at a thermal efficiency of 33 percent in simple-cycle operation. A more recent gas turbine manufactured by General Electric uses a turbine inlet temperature of 1425°C and produces up to 282 MW while achieving a thermal efficiency of 39.5 percent in the simple-cycle mode. A 1.3-ton small-scale gas turbine labeled OP-16, built by the Dutch firm Oprah Optimal Radial Turbine, can run on gas or liquid fuel and can replace a 16-ton diesel engine. It has a pressure ratio of 6.5 and produces up to 2 MW of power. Its efficiency is 26 percent in the simple-cycle operation, which rises to 37 percent when equipped with a regenerator. Early Stage and Brayton Cycle[8]

The modern-day jet engine wasn't developed until the early 20th century and didn't see proper use until the latter end of WWII. However, the concept of jet propulsion and its precursors had been around for centuries. The first known use of jet propulsion is the aerophile which was built around 150 BCE. The aerophile was a device that generated steam and funneled it through two nozzles. This pressurized steam was then used to spin a sphere on its axis. The aerophile was not used for any practical operations and was just seen as a novelty. Jet propulsion didn't see any practical applications until the Chinese invention of the rocket in the 7th century during the Tang Dynasty.

The Chinese used jet propulsion in the form of fireworks for a multitude of festivals and celebrations. These fireworks are a mainstay in Chinese culture to this day. Later in the 13th century, during the Song Dynasty, the Chinese also invented gun powder which spurred the invention of modern-day firearms and rocketry. Soon after the Mongol invasions of China, the rocket technology spread throughout the globe. The real use of jet engines in airplanes would come in the form of hybrid engines. Forgoing to World War airplanes were propelled by propellers that were attached to a simple gas turbine engine or a rotary engine. These engines weren't varied than the engines that you would see in an automobile. They would translate the linear motion of the pistons into a rotational movement of the propellers. These propellers would drive air towards the rear and over the wings, which would then generate the lift. However, at the turn of the 20th century, engineers realized that the efficiency of the propellers takes a severe dip

when as they approach higher velocities. When the airplanes started to approach the speed of sound, the engine efficiency would drop. This inevitably led to the start of research into the jet engine[5],[9]-18]

VII. Result and Discussion

From the Above material and studies we can conclude that a gas turbine engine is a very useful and efficient engine for a variety of applications and we can see the following advantages of the system over other systems

1. Lower operational cost - Lower operational cost is one of the primary reasons why gas turbines have gained so much popularity. When compared with other low-carbon emission alternatives like nuclear and renewable energy, the cost involved in the initial operation of gas turbines is quite low. Therefore, along with being cost-effective, gas turbines are also one of the best options for cleaner power generation.
2. Efficient and durable - With stringent carbon emission regulations, volatility in fuel costs, as well as emphasis on high performance at low costs, gas turbines have emerged as the most viable option. Not only are they cheap, gas turbines are also durable and efficient with less operational failure and downtime. In fact, gas turbines manufacturers have created highly durable turbines that require less frequency of service.
3. Facilitates distributed power generation - Power generation systems in most parts of the world are moving towards distributed power generation. Distributed power technology is quite flexible and can operate both in standalone and as part of an integrated system. It is also a better option when compared with solar panels, hydro-power, fuel cells, and small wind turbines.
4. High operational speed and low lubrication cost - Unlike other engines, gas turbines do not require high levels of lubricating oil. This automatically brings down the cost of operation. Also, as they have a higher operational speed, gas turbines assist in quicker power/energy generation. Gas turbines help lower operational costs and provide better service in less time. Some of the key vendors in the global gas turbine market include Ansaldo Energia, RR, G.E, and Siemens
5. In general, the jet engine is an interesting piece of machinery, and though its basic principles are very simple. There are many variables to control for, and many are not yet fully understood. What are the material properties required? The science of jet engines is still to a large degree a factual one, where experimental data and a good amount of trial and error is needed to push the field forward. Each part that comes in to making a jet engine could in its own be the basis for many projects of this kind and trying to do it all at the same time in a project of this size was perhaps a bit too ambitious as we have come to learn during our work. When attempting to design this kind of engine one needs first to have a good grasp of each of these different bits of knowledge, how each component works and how it interacts with the others. The literature on this subject is often dense and not always easy to navigate. Still, we have learned a lot about both the theory, the design process and about working with metal to create something of your own.

VIII. Conclusion

The Mini Turbine Engine shows the same properties as the Normal Gas turbine engines but on a quiet smaller scale and the variability of the applications makes the project to be deemed worthy for suitable uses, miniaturized gas turbine generator to be made using automotive turbocharger, where the combustion chamber was optimized to yield better efficiency than the engines available in the current market. As said the efficiency is found to be very high compared to other types of engines one thing as to be taken into account as this is an air breathing engine, it has no moving parts inside the combustion chamber. In this particular engine we can use any fuel for combustion. The only thing that as to be looked into is the fuel injector and the A/F (Air to Fuel) Ratio which is varying for different fuels , the fuel injector has to adapt depending on the fuel characteristics being used for combustion (fuel injector size depends on the fuel characteristics).

We built a real life version of turbo jet engine using a turbocharger from a truck.⁷ The system consists of an air handling system, ignition system, fuel system, and oil cooling system. The whole air pathways are made from stainless steel with parts either fabricated in a machine shop or purchased. An engineering analysis shows the thrust generated is 6.61 N/kg s, specific fuel consumption is 6038.9 mg/ Ns. The adiabatic flame temperature is 1923 K. The thermal efficiency is calculated to be 23 %.⁶

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