Design and calculations of a combustion chamber for a turbojet engine

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Abstract

Jet engine is an energy conversion device. It converts chemical energy into a rotatory mechanical energy. It works on the concept of Brayton Cycle. In this work, a combustion chamber has been designed for a turbocharger-based jet engine. Calculations have been done for the designing of a combustion chamber in the engine. The system has also been modelled in CREO and proper materials have been selected. The system has been designed for sustaining the temperature of 1300 K. LPG is used as a fuel in the system and the demonstration has been carried out without any accidents and promising results have been attained.

1. Introduction

A turbocharger jet is the combined result of thermodynamics, fluid mechanics, heat transfer, and mechanical knowledge of various machine elements and components. In this paper, it has been thoroughly explained how a jet engine was fabricated using a safari car turbocharger (Sl. No – 01 869 0040, Type – K04 007 TELCO, License - Germany) along with the engineering analysis behind it. The CAD model for the turbocharger jet engine is also provided in this report. Furthermore, information regarding the history of jet engines, types of jet engines, requirements of jet engine, and function of various parts of the jet engine model is also mentioned.

In the jet engine, first a large amount of air is gushed in via the fan and the compressor, which is then pressurized and compressed by the compressor and delivered to the combustion chamber. In the combustion chamber, mixing of fuel and air occurs, followed by combustion of the fuel by the help of electric spark which lights the mixture. The temperature inside the combustion chamber of a typical commercial jet engine can reach up to 2000 degree Celsius. The work of the turbine is to force in the air to the combustion chamber to facilitate combustion. Fuel is supplied via the fuel spray nozzles. The burning gas produced at the combustion chamber, expands and is then forced out through the nozzle present at the back of the engine. Before the hot air is pushed out of the nozzle, it passes through another group of blades called the turbine, which is attached to the same shaft as that of compressor. The spinning of turbine causes the spinning of the compressor too. After this, in the final stage, the gas pushes itself backward, the engine and the aircraft are moved forward.

The thrust of the engine can be described as the forward force which is responsible for pushing the engine forward, thus resulting in the forward movement of airplane. When the air produced by the burning of air-fuel mixture is pushed backward out of the engine via nozzle, a thrust force is produced which causes the plane to move forward (every action has an equal and opposite reaction).

The purpose of a jet engine is to move the airplane with some amount of thrust, in the forward direction. Change in momentum of the flowing air in between the inlet and outlet section of the jet engine results in the generation of the required thrust force.

Usually a jet engine works on a fan, compressor, combustion chamber, turbine and a nozzle. But for a turbo jet engine, the necessity of a compressor and a turbine is replaced by a turbocharger.

The working of a turbo jet engine is similar to the conventional jet engine. The turbocharger's compressor is the fan shaped part inside it which allows the mixing of compressed air with the fuel and get burned. These hot gases escape from the back of the combustion chamber which then power's the compressor to bring in more air and to help the process continue for long time. Due to combustion the temperature of the air increases which helps in complete expansion. As the air leaves a large amount of thrust is generated, which pushes the airplane in the forward direction.

As the air passes through the fan some amount of air passes through the engine and some spread around the engine. This resolves in the formation of hot air and cooler air which then mix together at the exit of the engine.

A turbojet is a reaction type of engine where expansion of gases occurs against the front of the engine. The turbojet acts as a medium for compressing the air coming inside which is similar to the working of a conventional compressor. After the burning of gases in the combustion chamber, they expand and get released out of the rear of the exhaust, thus pulling the plane forward.

2. Methodology

Initially project was dedicated towards searching a suitable turbocharger to begin the project with. Then necessary calculations regarding the diameter of the primary, secondary and tertiary holes in the combustion chamber inner liner were done and in addition to that few other calculations were performed which helped in developing the actual project. Also, a 3D model of the project was made with the help of the software CREO.

Various other necessary items like battery, spark plug, nut bolts were purchased. Material to be used for combustion chamber, flame tube and air pipe were decided and purchased. Various components of the jet engine turbocharger like ignition chamber, fuel intake section, combustion chamber was designed. Holes were drilled wherever necessary. Components were cut and grinded to give them the appropriate shape according to the measurements. Proper finishing of all the components was done and rechecked.

After designing and constructing all the components separately, proper assembly of all the components were done to give the turbocharger jet engine its final shape. It was now ready for testing. A pressure of more than 60 psi was provided. LPG gas was provided at the air intake. Spark was generated and the functioning of the turbocharger jet engine was tested. Although at the initial attempt, it didn't work after a few corrections when it was re-tested the jet engine worked properly. It was re-tested a few more times to ensure its smooth and efficient working.

3. Components & Experimental Work

Jet engines being highly dangerous, safety is the main concern for which the temperatures of the components need to be regulated properly. The peak working fluid temperature was 1200K and the maximum operational temperature of 1300K. The actual temperature is expected to be less than 1200K to obtain full throttle.

Another safety concern is the operational safety. For this, the electronics are kept far away from the rest of the engine. The set-up box is attached to a battery of 12V and a spark plug by a small wiring that can be easily extended to any length which helps in safe and remote operation.

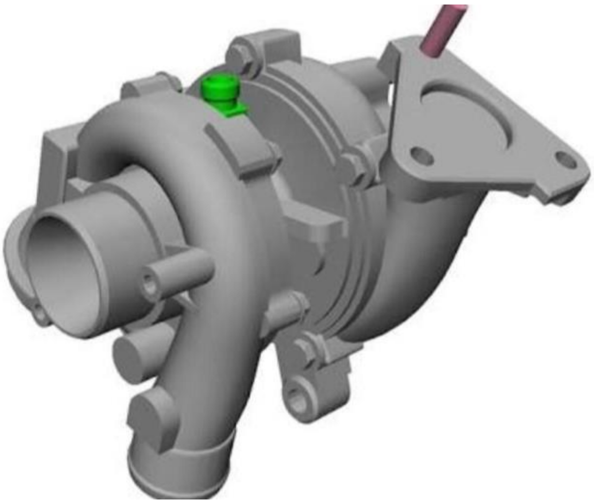

Figure 1 Turbocharger

Battery of 12V capacity is coupled with primary and secondary coil for conduction of electricity. Spark plug of Honda Activa (109 cc) is used here for initiating proper ignition for the turbocharger jet engine.

Figure 2 Compressor and Turbine section

The fuel is supplied by a fuel injection pipe of length 7 inch (17.78 cm) and diameter 1 cm. The material of the fuel injection pipe is copper.

Experimental Setup

- Outer Tube- Diameter of the outer tube of the combustion chamber is 3 inch or 7.62 cm. Length of the outer tube of the combustion chamber is 6.5 inch or 16.51 cm.
- Inner Tube/Flame Tube- Diameter and length of the flame tube are 2 inch (5.08 cm) and 6 inch (15.24 cm). Total number of holes in the flame tube are 27. The size of small holes is 4 cm. The size of medium holes is 8 cm. The size of large holes is 1 inch and 8 cm, i.e. 10.54 cm.
- Extra bend pipe diameter- The pipe used for connecting the different parts of the jet engine with the turbocharger has an extra bend diameter of 2 inch or, 5.08 cm.
- Fuel Injection Pipe Size- The fuel injection pipe is made of copper and has its length and diameter as 7 inch (17.78 cm) and 1 cm respectively.
- Ignition System- The required amount of ignition is provided by a spark plug and the required amount of electricity is generated by a battery of 12V.
- Assembling of the combustion chamber- For proper instalment of the combustion chamber, construction rings are created which not only help in bolting the ends but also centre the flame tube

in the chamber. Six bolt holes are drilled around the ring in a circular pattern for the mountings of the ends. Bolts can be threaded properly by welding the nuts on the back of these holes. The diameter and thickness of the end rings are 3 inch (7.62 cm) and 2 cm respectively. The bolts are of size number 8. Three more bolts and nuts of size 12 number are used for joining turbocharger and the combustion chamber. The hole size obtained during the connection of the turbocharger and the combustion chamber is 2 inch (5.08 cm). A circular plate is used in installing the spark plug and the injector pipe. The diameter and thickness of this tube is 3 inch (7.62 cm) and 2 mm respectively. Another circular plate is used for combining the combustion chamber and the turbocharger whose diameter and thickness are 3.5 inch (8.89 cm) and 2 mm respectively.

- End rings welding- Ends rings are required to be welded on the combustor housing. The housing is cut according to the proper shape using the dimensions mentioned above and the ends are squared up so that there is proper alignment.
- Calculation of flame tube- The flame tube diameter is obtained by doubling the diameter of the turbocharger's inducer. The length of the flame tube is obtained by multiplying the diameter of the inducer of the turbo by six.
- Calculating the dimensions of the combustion chamber- flame tube should fit inside the combustion chamber and thus, the chamber housing needs to be of large diameter than the flame tube. Here, the flame tube diameter is 2 inch and that of the housing of the combustion chamber is 3 inch, thus a minimum space of 1 inch around the flame tube needs to be maintained; the length of the flame tube and the combustion housing remaining the same.
- Primary zone holes- Total area of holes in primary zone is 30% of the compressor inlet area. Inducer area = ΠR^2, where R(inducer) = 25.4 mm. Inducer area = 2026. 82 mm^2. Total area of holes in Primary zone = Inducer Area * 0.3 = 608. 04 mm^2. Since there are 17 holes in the primary zone, 608.04/17 = 35.76 mm^2. Area = ΠR^2, R (primary holes) = 3.37 mm = 0.1326 inches.
- Sizing Holes for Secondary Zone- Total area of holes in secondary zone is 20% of the compressor inlet area. Inducer Area = 2026.82 mm^2. Total area of holes in Secondary zone = Inducer area * 0.2 = 405. 36 mm^2. Since there are 5 holes in Secondary zone, 405.36/5 = 81.07 mm^2. Area = ΠR^2, R (secondary holes) = 5.07 mm = 0.1996 inches.
- Sizing Holes for Tertiary Zone- Total area of holes in tertiary zone is 50% of the compressor inlet area. Inducer area = 2026.82 mm^2. Total area of holes in Tertiary zone = Inducer area * 0.5 = 1013.41 mm^2. Since there are 5 holes in tertiary zone, 1013.41/5 = 202.68 mm^2. Area = ΠR^2, R (tertiary hole) = 8.03 mm = 0.316 inches

4. Results and Conclusion

The project was successful in its way and the engine performed well. The fuel (LPG) and air was mixed together in the combustion chamber and upon igniting the mixture, flame was found at the exhaust. This flame provides enough thrust to make an actual engine run.

Although at the initial attempt after the assembly of the components, the outcome wasn't as expected and the engine didn't run; few advancements were made and error was rectified, thus making it run successfully in the second attempt. Initially, the diameter of the fuel injection pipe was too small. As a result of which, enough fuel wasn't reaching the combustion chamber and hence proper combustion of the mixture wasn't occurring. So finally, fuel injection pipe of a bit bigger diameter (1 cm) was used, so that enough fuel was reaching the combustion chamber and proper combustion was happening.

All in all, the project worked out as per the expectations.

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