Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2013
(ICMERE2013) 1-3 May 2014, Chittagong, Bangladesh

ICMERE2013-PI-228

CONSTRUCTION OF A GAS TURBINE/JET ENGINE WITH AN AUTOMOBILE TURBOCHARGER

Deshbandhu Halder

Department of Mechanical Engineering, Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh
mechdb15@gmail.com

Abstract-*Gas turbine/Jet engine is an internal combustion engine, used to propel vehicles (war tanks, Destroyer ships), produce electricity and which has changed the aviation sector as one of the main propulsion system. Both gas turbine and jet engine have the same working principle but during gas turbine shaft power is used and for jet engine it's jet thrust is used. Adding a combustion chamber between compressor outlet and turbine inlet of a turbocharger, an inexpensive gas turbine/jet engine can be constructed. This work deals with a better understanding of the jet engine for educational purpose.*

Keywords: Gas turbine, Jet engine, Turbocharger, Combustion chamber, Stoichiometric mixture.

1. INTRODUCTION

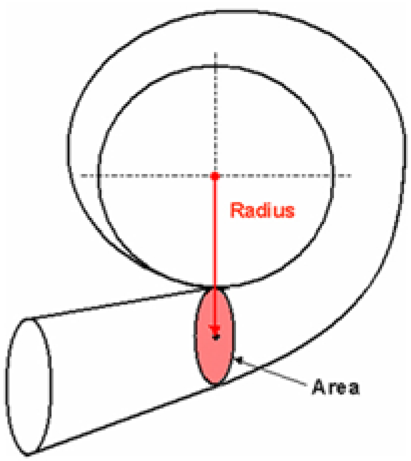
A gas turbine is constant flow, shaft work machine composed of three components- a compressor, a combustor and a turbine. A turbocharger is a device which is used to increase engine horsepower using exhaust gases. It comprise of two components (compressor & turbine). So there needs a combustor between compressor outlet & turbine inlet of the turbocharger to be physically similar to gas turbine. A combustion chamber functions like a heat exchanger & can be modeled as a constant pressure device where chemical potential energy is converted into thermal energy. When the compressed Air from the compressor reaches combustion chamber, mixed with fuel and ignited, the combustion takes place in this chamber creating high pressure combusted gas for exhaust for turbine outlet to produce positive shaft power or jet thrust.

2. REQUIRED PARTS

Turbocharger, a combustion chamber, Propane tank, ignition System, Digital mass flow meter, leaf blower.

3. SELECTING THE TURBOCHARGER

It is the main component of the engine. The performance of the engine is highly dependent on A/R ratio of the compressor and turbine of the turbocharger. A/R ratio describes a geometric characteristic of all compressor and turbine housings. Technically, it is defined as: the turbine inlet or for compressor outlet cross-sectional area divided by the radius from the turbo centerline to the centroid of that area (See Figure 1).



.

Fig.1: Area and Radius for A/R ratio.

3.1 Performance Variation Due to A/R Ratio

A/R ratio has different effect on the compressor and the turbine. Compressor performance is increased for lower A/R ratio. Because of lower A/R ratio compressors can produce more compressed air, increasing the compressor efficiency. On the contrary, larger A/R ratio increases the turbine efficiency only when exhaust discharge rate in high, increasing the shaft power.

4. Designing the Combustion Chamber

The combustion chamber is just a cylindrical tube. But there is another cylindrical tube inside the combustion chamber called flame tube, which has to be made of stainless steel. This tube helps the air to enter into the center of the combustion chamber but keeps the flame held in place so that it must exit to the turbine side only, not the compressor side. A flame tube has many holes in it, which may be classified of three types-Primary holes, Secondary holes & Tertiary or Dilution holes (See Figure 2). These three holes have their individual purposes. Primary Holes: Supply air inside the flame tube for air & fuel mixing where the burning process begins. Secondary Holes: Supply air to continue the combustion and complete the combustion process. Tertiary Holes: Provide air to cool the combusted gases before leaving the combustion chamber preventing overheating of the turbine blades of the turbocharger.

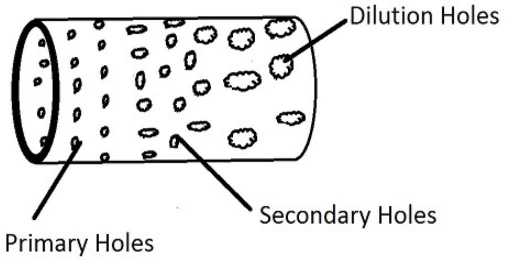


Fig.2: Flame tube.

5. ASSEMBLING THE CONFIGURATION

One side of the flame tube will be closed (the primary holes side/left side). But the closed side will have two holes. One for fuel supply and another is for ignition. The flame tube is to be placed in such a way that primary holes side will be near to the compressor side and the dilution holes side will be near to the turbine side. So that the combusted gases must flow to the turbine side only. Fuel nozzle and the igniter are to be place to their positions (See Figure 3).

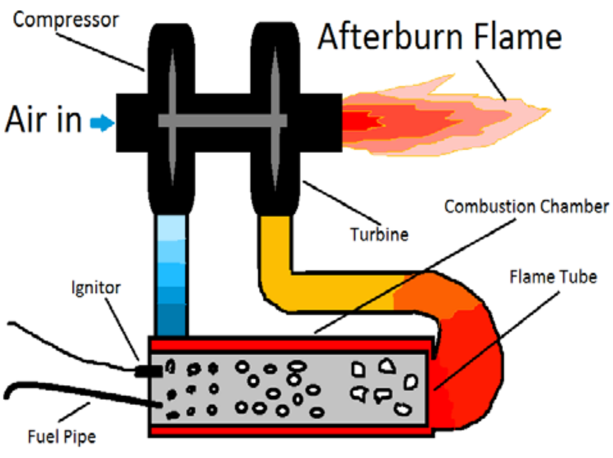


Fig.3: Gas Turbine/Jet Engine After full assembly & During Runtime.

6. Stoichiometric Mixture

In the combustion chamber air-fuel mixture should create Stoichiometric mixture for combustion. Stoichiometric combustion is the ideal combustion process where fuel is burned completely. A Stoichiometric combustion burns all C to CO_2, all H to H_2O and all S to SO_2 (i.e. No fuel molecule lefts unburned).There is two types of Air-Fuel mixtures-

1. Fuel-Lean (Air content is higher than stoichiometric ratio).
2. Fuel-Rich (Air content is less than stoichiometric ratio).

7. Calculations for Making Stoichiometric Mixture

Kerosene, ATF, propane, octane etc. can be used as fuel in this engine. As propane is being used as fuel in this engine, all calculations are being done with respect to propane.

Reaction equation of propane with oxygen:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Atomic weight of C=12.01

Atomic weight of O=16.00

Atomic weight of H=1.008

So, Molecular weight of C_3H_8 = 44.094

Molecular weight of O_2 =32

Ratio of O_2 & C_3H_8 mixture by mass= {(5*32)/44.094}=3.629

That means at least 3.629 Kg of oxygen is needed to burn 1 Kg of propane completely. But 23.2% of air is actually oxygen (by mass).

So, Ratio of air-propane mixture by mass= 15.5**:**1 [(3.6/23.2)*100=15.5]

We got from the calculation that to make Stoichiometric mixture percentage of air should be at least 15.5 times the mass of fuel (Propane).

8. STARTING THE ENGINE

First of all start the leaf blower, calculate the volumetric flow rate and convert it to mass flow rate. Now attach the blower with the compressor inlet so that air flows from compressor to combustion chamber and then exits from turbine. That means air flow rotates the shaft. Let the propane flow to the combustor. There is a digital mass flow meter connected between propane tank and the combustor so that propane mass flow rate can be observed. Ensuring air and propane mass flow rate is (15.5:1) or higher (Fuel-lean mixture), engine can be ignited. When the engine is started the blower can be removed. Increasing the fuel supply, the turbine will produce more shaft power as a result the compressor will automatically regulate the air supply.

9. ANALYSIS of THE ENGINE CONFIGURATION

When the engine runs at full throttle, it creates a high pressure at compressor outlet and as the turbine sucks air at it's inlet, there creates a low pressure. As a result the combusted gases always intend to go out through the turbine side only.

Again, as the flame tube is closed at compressor side and fully open at turbine side, although there are some holes in the left side of the flame tube, the combusted gases are force to come out through the turbine, creating a one way out configuration.

The material of the flame tube should be chosen with the consideration that the material must be capable of enduring the extreme temperature of the combustion with the consideration of what is being used as fuel.

10. CONCLUSION

This work is limited to this point. Although it can be taken a little bit further by using compressor map of the specific turbocharger used. From which engine horse power can be calculated by measuring shaft r.p.m. & presser ratio at the compressor.

11. REFERENCES

[1] Keane T. Nishimoto, Design of an automobile turbocharger Gas Turbine Engine, B.Sc Thesis, Massachusetts Institute of Technology, 2003.

[2] Gas Turbine Engineering Handbook by Meherwan P. Boyce.

[3] http://www.diyturbinejet.com