Journal of Engineering Sciences
Vol 10, Issue 10, OCT/2019
ISSN NO:0377-9254

DESIGN OF A MICRO GAS TURBINE USING AN AUTOMOTIVE TURBOCHARGER FOR DISTRIBUTED POWER GENERATION

Hemalatha Naidu [1], Gurrapu Sajeev [2], Mohammad Imamuddin [3]

[1]Assistant Professor Dept Mechanical, Mallareddy college of engineering for woman's, Hyderabad, T.S, India

[2]Assistant Professor Dept Mechanical, Mallareddy college of engineering for woman's, Hyderabad, T.S, India

[3]Assistant Professor Dept Mechanical, Mallareddy college of engineering for woman's, Hyderabad, T.S, India

ABSTRACT

Micro turbines are generators which are small that burn the fuels like liquid and gaseous , performing a Brayton cycle and 250 kW of less range. Such turbo-generators are exquisitely suitable for diffused generation applications because of their capability in equiping reliable and firm power in a stand unaided or parallel operation, they also are used as assisting power units on aircrafts. In relation to the Indian power set-up, microturbines can serve as a doable energy source for places without the grating due to their high power to weight ratio. Lowering costs and an efficient design can be achieved by consumption of off-the-shelf turbochargers in micro turbine.

1. INTRODUCTION

Indian power sector has made considerable progress in the last decade but there is a whole scope of exigent areas in the power sector that should be addressed by India on priority to convene its growth targets. The importance of electricity growth is very well acknowledged and to heighten the development of power system, the government of India has participated in a giantic way by creating an assortment of corporations such as, State Electricity Boards (SEB), NTPC Limited, NHPC Limited and Power Grid Corporation Limited (PGCL), etc. However, still there is power shortage.

Objective

This paper contains the plan and invention of a gas turbine engine in succession on a fuel of gaseous by using an automotive turbocharger. The design of combuster was based on the ideology of aircraft combustor development and was fictional entirely using available parts and materials that are local made. As the rotor assembly under provinsion of turbocharger, the other requirement was a lubrication system which was also made out of available parts locally.

2. LITERATURE SURVEY

The three core mechanisms in a gas turbine engine are the compressor, combustor, and turbine. The engine maneuver on standard of Brayton cycle, where air and fuel are mixed together and is squashed and constant pressure is preserved and then burnt in combuster. The high temperature and gas demands resulted is expanded through the turbine, force is applied for rotating turbine and the connecting shaft is used to power the compressor. The Brayton cycle depict the supreme recital of a gas turbine engine. The Brayton cycle's first law of competence is reliant on pressure proportion only and, a high pressure proportion is desired for improved efficiency. High precise exertion performance is also important, and is reliant on relative amount of temperature. Both pressure and temperature fraction need to be increased to pull off a high recital engine as a result of this interdependence. Higher temperatures of combustion explosively needed to amplify the power fashioned by a gas turbine engine. The high combustion warmth oblige incomparable presentation components of turbine, particularly the leading periphery and end barricade region of the nozzle steer vane of stage one. The knack of these vanes to hold out the callous thermal conditions precincts the power that the engine is able to turn out. Thus, turbine in effect limits the ceiling combustion temperature. The defy in maintaining turbine resilience include providing altercation to crash from thermal masses, exhaustion due to discrepancy in loading and thermal hassle, and deterioration due to the callous environment. Complex unruffled methods are required to warfare the effects of the thermal loads both on the turbine vanes and on combustor liner. Plan of these cooling systems are intricated further due to the non-uniformity of the gases in the combustor and the multifarious flow pasture in the turbine.

3. DESIGNING PROCESS:

This paper looks at the methodology of design we used prior to fabricating the gas turbine engine,

- the pick of the combustor brand
  - low Reynolds in the turbo tackle passage causing fairly high glutinous losses,
  - moderately sky-scraping slant clearances due the manufacturing tolerances and bearing precincts,
  - Large area-to-volume fraction resulting in lofty heat losses and unintended heat transfer to the compressor and high assisting system fatalities
- faltering design of the engine
- the turbocharger replica used and the pick of the design point
- Combustion chamber design process; including rock-hard modeling and flow simulations.
- Material selection justification

Journal of Engineering Sciences
Vol 10, Issue 10, OCT/2019
ISSN NO:0377-9254

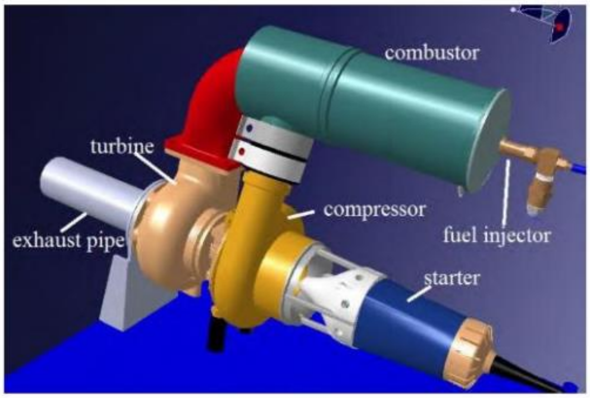

Fig. 1: The key mechanism of the gas turbine assembly;

Fig. 1 shows the gears of the gas turbine assembly as they were probable in the context of the contemporary paper. Of these components, the main part was the combustion chamber, which was to be designed and fabricated. Apart from this, the provision of turbocharger bearings with lubrication oil at around 55-65 psi, for which a motor pump congregation was to be made (not shown here)

The values found from compressor record and by the use of some thermodynamic calculations in table 1 are outlined. The maximum turbine inlet temperature is a manufacturer defined value.

Table 1 values found from the compressor plot

Parameter	Symbol	Value
Mass flow rate (in kg/s)	$\dot{m}_3$	.3175
Exit pressure (in kPa)	P_3	310
Compressor isentropic efficiency	η	73%
Compressor exit temperature (K)	T_3	452
RPM		103500
Maximum turbine inlet temperature(°C)	T_4	800

Combustion chamber design

The combustion chamber design encompassed the determination of the following:

1.) The outer casing diameter

2.) Flame tube/holder diameter

3.) Hole area for the diverse zones of the blaze tube

4.) Length of the a likeness of zones of the flame tube

5.) Hole area distribution

This design chart is used as follows:

A suitable combustion efficiency is chosen (we took a value of 90 to 95%).The value of Ө corresponding to that value is read (taken as here) .Using the values from table 1 and using the fact that we have a uniform cylinder as the outer casing (and hence and are related), we find the reference diameter.

Vol 10, Issue 10, OCT/2019
ISSN NO:0377-9254

Table 2: The casing diameter values

Approach type	D_{ref} (in mm)	D_{ref} (in inches)
Aerodynamics based	95	3.74
Combustion efficiency based	186	7.32

Before ruling the magnitude of the holes and various zones length of the flame tube, a appraisal of the local market was conducted to test out the availability of the pipes toning our requirements and the values of the casing diameter and the diameter of flame tube were altered according to the available pipes.

Table 3 shows the old and the amended values

Component	Design value (in inches)	Available value (inner dia. of the pipe in inches)
Outer casing	7.32	7.98
Flame tube	6.12	6.06

Hole area calculation for various zones The design point assumes an overall equivalence ratio of .5 (in actual practice much leaner mixtures are used) with an airflow equal to the amount required for a stoichiometric reaction entering the primary and the secondary zone and the rest entering the tertiary zone for the cooling.

Table 4 shows the airflow distribution in various zones of the combustor.

	Overall	Primary zone	Secondary zone	Tertiary zone
Equivalence ratio (Φ)	.5	.6	.4	-
Airflow (%)	100	30	20	50
Bleed ratio(μ)	-	.3	.2	.5

The length distribution among various zones The primary zone length can be taken within 2/3 to 3/4 of the flame tube diameter. The latter value is related with better combustion efficiency and has been chosen. A value of .5 times the flame tube diameter is suggested for the secondary zone. A length of 1.5 times the flame tube diameter is recommended for the tertiary zone.

The total hole area of various zones found was distributed as given in table 5. The hole diameters were chosen so as to:

1.) Help the flame survive in the primary zone

2.) Lower the primary zone temperature by the use comparatively higher penetrating jets and hence burn the CO and soot coming from the primary zone.

3.) Achieve maximum penetration levels and cool the hot gases before they enter the turbine. A region in each zone was left without any holes, this was done in order to promote homogeneity within the gaseous flow.

Table 5 total hole area of various zones

	Primary	Secondary	Tertiary
Total area(mm^2)	740	426	1065
Hole diameter calculated (mm)	5.9	7.8	11.65
Hole diameter used (mm)	6	8	12
Total no. of holes	27	9	10
No. of rows	3	1	1

The used hole diameters are the diameters closest to the calculated value for which drill bits were easily available.

4. COMBUSTOR MODEL DESIGN

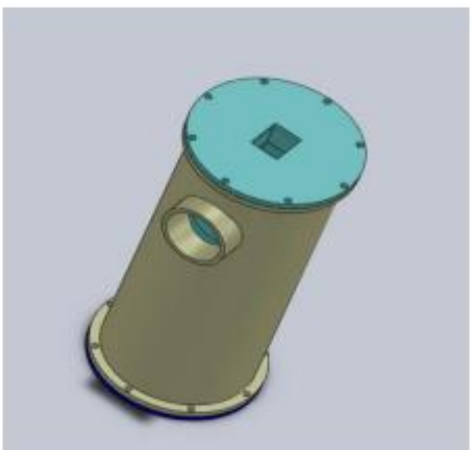

Fig 2 Assembled view

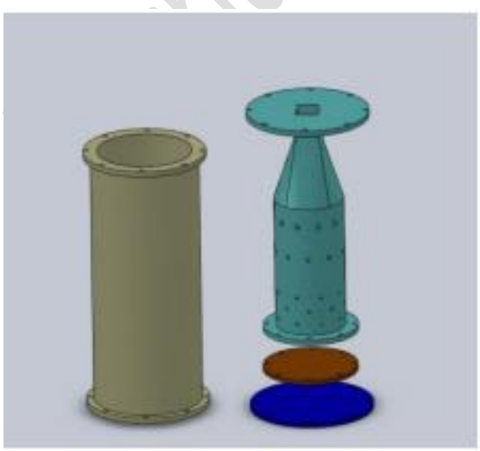

Fig 3 An exploded view

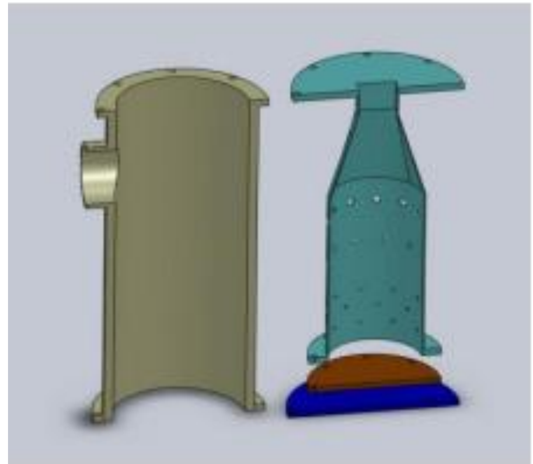

Fig 4 A sectional view of the components

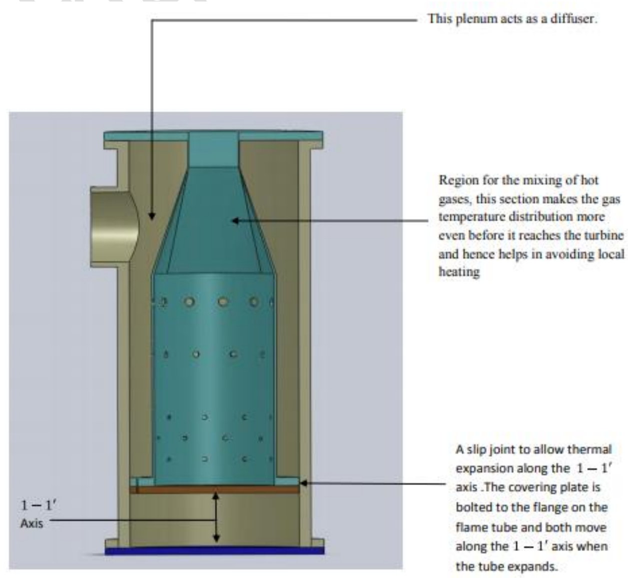

Fig 5: Key design features of the combustor assembly.

An assembled view showing the outer casing, compressor inlet (2” dia.) and the turbine outlet (2.5”×2”).The air inlet has no offset. Offset inlets induce tangential flows along the axis of the tube which are detrimental. An exploded

Vol 10, Issue 10, OCT/2019
ISSN NO:0377-9254

view showing the outer casing, flame tube, flame tube flanges and the covering plates. It is worth noticing that the turbine inlet is considerably smaller than the flame tube and hence the converging pipe.

5. FLOW SIMULATIONS

Based on the data obtained from the previous section, a preliminary model was generated and was put into ANSYS FLUENT to get an initial idea of the validity of the design. Two simulations were carried out:

1.) Cold flow simulation

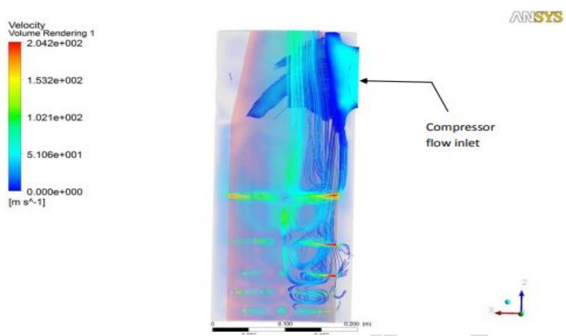

Fig.6: A cold flow simulation depicting air paths and velocities

1.) This simulation shows recirculation patterns and low penetration in the primary zone with slightly higher velocity and penetration in the secondary zone. Compressor flow inlet 63

2.) The tertiary jets are penetrating till the core

3.) Low annulus velocities

4.) Steep jet admission angles The flow patterns obtained from this simulation; though without combustion, were pretty encouraging.

2.) Combustion simulation

For this simulation, a fuel flow rate of propane was taken as 10.242 Kg/s. The zone wise equivalence ratio and airflow percentages are summarized in table 3.4 A radially spewing fuel injector was considered as the fuel inlet.

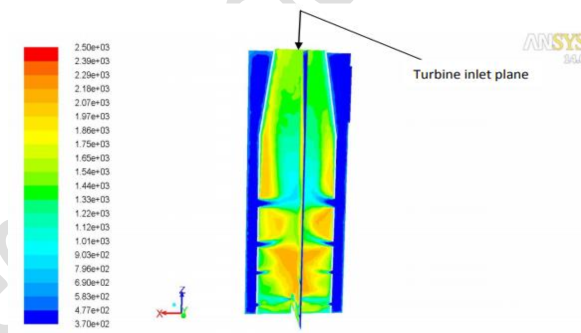

Fig.7: Temperature distribution in the combustor

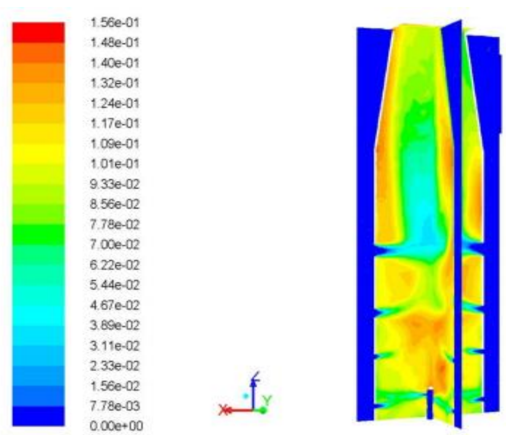

Fig. 8: Mass fraction distribution of carbon dioxide in the combustor

1.) At the chosen design point, the turbine inlet temperature value is higher than the recommended turbine inlet temperature but it

Vol 10, Issue 10, OCT/2019
ISSN NO:0377-9254

should be remembered that in actual practice the engine would run at much leaner mixtures, giving lower temperatures.(leaner, but mixtures leading to temperatures at which the flame can sustain.)

2.) The temperature distribution at the turbine inlet plane seems pretty homogenous, signifying a good amount of mixing.

3.) The air cushion that protects the flame tube from melting can also be clearly seen

Material selection justification

We decided to use stainless steel (SS 302) for the combustion chamber based on its successful use in similar applications before. To confirm its efficacy at elevated temperatures we decided to run a structural simulation in a horizontal position. Refer to fig. 9 and 10

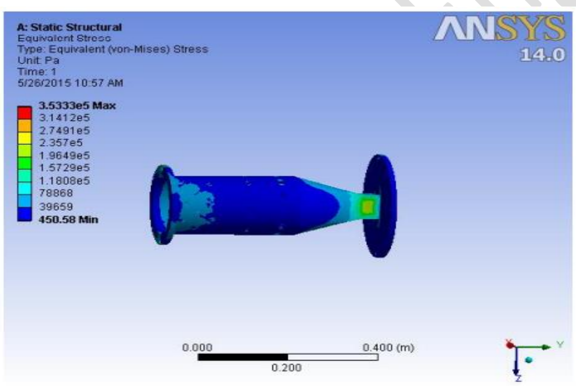

Fig.9: Stress distribution in the flame tube in a horizontal position

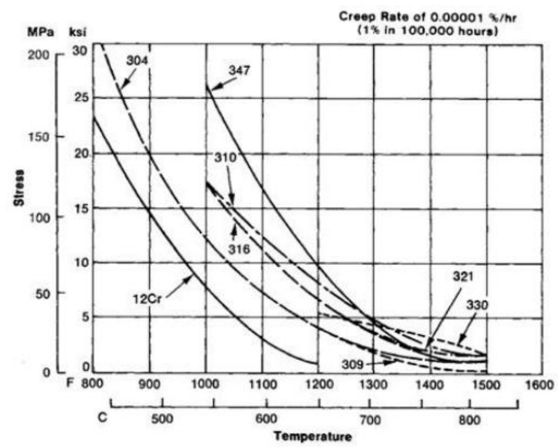

Fig.10: Creep rate curves for several types of steels

CONCLUSION

Aggravated by the current power set-up in the country, a micro gas turbine engine was premeditated and made-up for strewn power generation and to cater area. The turbocharger lended a hand us in purging several design problems and was cost effective as well. The plan was verified using numerical analysis tools and the results from the testing of the fabricated engine showed good agreement. The stable working of the engine is showed by test results as the compressor efficiency was in the 70-72% range and the turbine outlet temperatures were maintained under 600°C. Apart from that, the liner tempering colors suggested a temperature distribution along the flame tube which met our design expectations.

REFERNCES

1. William W. Bathie, Fundamentals of Gas Turbines, 2nd Ed. p. 7

2. The Lend Lease Agreement was an agreement between Great Britain and the United States. It was a means by which the US could circumvent previous isolationist/neutrality legislation that barred its transfer of military goods to other nations.

3. William W. Bathie, Fundamentals of Gas Turbines, 2nd Ed. p. 10

4. W J Watson, "The 'Success' of the Combined Cycle Gas Turbine" Opportunities and Advances in International Power Generation, University of Durham Conference Publication, March 18-20, 1996, London: Institution of Electrical Engineers, 1996. p 88.

5. Frank J. Brooks "GE Gas Turbine Performance Characteristics" GE Power Systems Schenectady, NY GER-3567H

6. S.M. Correa and W. Shyy, "Computational models and methods for continuous gaseous turbulent combustion", Progress in Energy and Combustion Science, vol. - 13, no.- 4, pp. 249-292,1987

7.W. Shyy, M.E. Braaten and D.L. Burrus, "Study of three-dimensional gas-turbine combustor flows", International Journal of Heat and Mass Transfer, vol.- 32, no.- 6, pp.1155-1164, June 1989

8. Arthur H. Lefebvre, "Gas Turbine Combustion", ISBN - 1-56032-673-5, Taylor & Francis, 1998, 2nd Edition

9.S N Singh, V Seshadri, R K Singh and T Mishra, "Flow Characteristics of an Annular Gas Turbine Combustor Model For Reacting Flows Using CFD", Journal of Scientific and Industrial Research, vol.-65, pp. 921-934, November 2006

10. A. M. Mellor, "Design of Modern Turbine Combustors", ISBN - 0-12-490055-0, Academic Press, 1990