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Fabrication and Testing of Gas Turbine Engine's Combustion Chamber

Sathish D

Assistant Professor, Department of Aerospace Engineering Periyar Maniammai University, Thanjavur, Tamil Nadu, India

ABSTRACT

Mini and micro-gas turbine engines offer advantage over the other technologies for small-scale power generation. This project explains modelling, fabrication and experimental details of the annular combustion chamber of the micro gas turbine engine. As we know combustor is the heart of any engine, where incoming pressurized air is heated by burning of fuel. A combustor of micro gas turbine should be compact, simple, inexpensive and robust in construction. This is capable of sustaining variation in fuel flow rate. The material selection and flame stabilization, precautions have been taken. Design is economically and assembly is made also less complicated, purchasing of the requirement has less journey and the project is completed in minimum duration. The specialty of this combustor is that the fuel is liquefied petroleum gas. The swirl vanes is designed in such a manner that flow turns at 30o from the previous path. This combustor has provision for flame tube cooling also; one row of holes on both the inner and outer domes is made parallel to the axis of the combustor compared to the other rows of holes, which are at 30o angle. The exit of the combustor has number of holes in place of the slit for overcome from the fabrication complications. A separate plate having holes, which are bolted at the exit for the combustor exhaust is started with and without exit plate to check the burning performances. The exit temperature is determined for the various air pressures and gas pressures.

KEYWORDS : combustion, fuel injection, swirl vanes, flame tube, exit temperature.

I. INTRODUCTION

The current trend towards miniaturization, portability and more in general ubiquitous intelligence, has led to the development of a wide range of new products such as laptops, cellular phones, PDAs, etc. However, the power requirements of such systems have received much less attention: typically, traditional battery-operated electronic systems are used. Nevertheless, the energy density of most fuel types is still 100 times more than that of the most performing batteries, which makes the use of a fuel-based micro power unit interesting. Such power units can be based on a wide range of operating principles, ranging from fuel cells and thermo-electric devices, to combustion engines and gas turbines. While fuel cells are expected to offer the highest efficiency, micro gas turbines are expected to offer the highest power density. Gas turbines are amongst the most advanced systems as they combine extreme conditions in terms of rotational speed with elevated gas temperatures (up to 2100 K for military engines). Miniaturization of such a system poses tremendous technical problems as it leads to extremely high rotational speeds (e.g. 10^6 rpm). Moreover scaling down the system unfavorably influences the flow and combustion process. Fabricating such devices requires new materials to be explored and requires three-dimensional micro manufacturing processes.

II. BASICS OF COMBUSTION CHAMBER

Heat input to the gas turbine Brayton cycle is provided by a combustor. The combustor accepts air from the compressor and delivers it at an elevated temperature to the turbine (ideally with no pressure loss). Thus, the combustor is a direct-fired air heater in which fuel is burned almost stoichiometrically with one-third or less of the compressor discharge air. Combustion products are then mixed with the remaining air to arrive at a suitable turbine inlet temperature. There are many types of combustors, but the three major types are tubular, tubo-annular, and annular. Despite the many design differences, all gas turbine combustion chambers have three features: (1) a recirculation zone, (2) a burning zone (with a recirculation zone which extends to the dilution region), and (3) a dilution zone. The function of the recirculation zone is to evaporate, partly burn, and prepare the fuel for rapid combustion within the remainder of the burning zone. Ideally, at the end of the burning zone, all fuel should be burnt so that the function of the dilution zone is solely to mix the hot gas with the dilution air. The mixture leaving the chamber should have a temperature and velocity distribution acceptable to the guide vanes and turbine. Generally, the addition of dilution air is so abrupt that if combustion is not complete at the end of the burning zone, chilling occurs and prevents completion. However, there is evidence with some chambers that if the burning zone is run over rich, some combustion does occur within the dilution region. Combustor inlet temperature depends on engine pressure ratio, load and engine type, and whether or not the turbine is regenerative or non-regenerative especially at the low-pressure ratios. The new industrial turbine pressure ratio's are between 17:1, and 35:1, this means that the combustor inlet temperatures range from 850 F (454 C) to 1200 F (649 C). The new aircraft engines have pressure ratios, which are in excess of 40:1. Regenerative gas turbines have combustor inlet temperatures, which range from 700 F (371 C) to 1100 F (593 C). Combustor pressures for a full-load operation vary from 45psia (3.1 Bar) for small engines to as much as 588 psia (40.5 Bar) in complex engines. Fuel rates vary with load, and fuel atomizers may be required for flow ranges as great as 100:1. However, the variation in the fuel-to-air ratio between idle and full-load conditions usually does not vary by more than a factor of three. During transient conditions, fuel-to-air ratios vary. At light off and during acceleration, a much higher fuel-to-air ratio is needed because of the higher temperature rise. On deceleration, the conditions may be appreciably leaner. Thus, a combustor that can operate over a wide range of mixtures without the danger of blowouts simplifies the control system. Combustor performance is measured by efficiency, the pressure decrease encountered in the combustor, and the evenness of the outlet temperature profile. Combustion efficiency is a measure of combustion completeness. Combustion completeness affects fuel consumption directly, since the heating value of any unburned fuel is not used to increase the turbine inlet temperature. To calculate combustion efficiency, the actual heat increase of the gas is rationed to the theoretical heat input of the fuel (heating value). The loss of pressure in a combustor is a major problem, since it affects both the fuel consumption and power output. Total pressure loss is usually in the range of 2-8% of static pressure. This loss is the same as a decrease in compressor efficiency. The result is increased fuel consumption and lower power output that affects the size and weight of the engine. The uniformity of the combustor outlet profile affects the useful level of turbine inlet temperature, since the average gas temperature is limited by the peak gas temperature. This uniformity assures adequate nozzle life, which depends on operating temperature. The average inlet temperature to the turbine affects both fuel consumption and power output. A large combustor outlet gradient will work to reduce average gas temperature and consequently reduce power output and efficiency. Thus, the traverse number must have a lower value-between 0.05 and 0.15 in the nozzle. Equally important are the factors that affect satisfactory operation and life of the combustor. To achieve satisfactory operation, the flame must be self- sustaining, and combustion must best able over a range of fuel-to-air ratios to avoid ignition loss during transient operation. Moderate metal temperatures are necessary to assure long life. Also, steep temperature gradients, which cause warps and cracks, must be avoided. Carbon deposits can distort the liner and alter the flow patterns to cause pressure losses. Smoke is environmentally objectionable as well as a fouler of heat exchangers. Minimum carbon deposits and smoke emissions also help assure satisfactory operation.

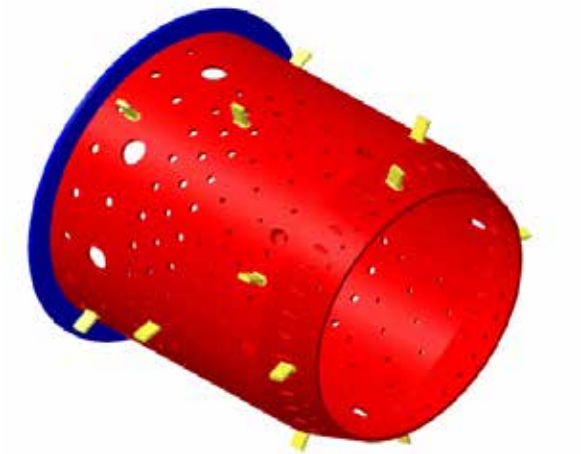


Fig.1 Model of outer flame tube



Fig.2 Fabricated outer flame tube



Fig.3 Model of inner flame tube



Fig.4 Fabricated inner flame tube

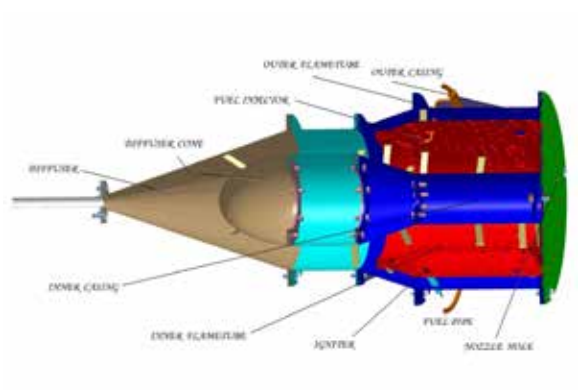


Fig.5 Cross section of test rig



Fig.6 Other fabricated components



Fig.7 Full assesmbly of test rig

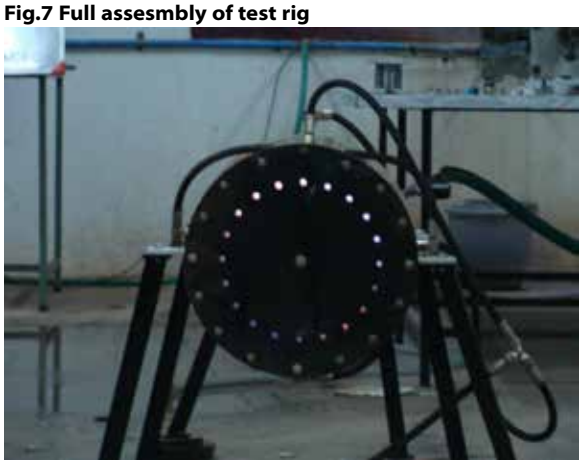


Fig.8 Testing of combustion chamber

IV. RESULTS

Exp.No	Air Pressure (bar)	Gas pressure (bar)	Exit Temperature (k)
1	4	3	502
2	5	4	585
3	6	5.8	695

In the first experiment, the fuel pressure level had been taken as 3 bar and the air pressure as 4 bar corresponding exit temperature is noted as 500k. During the next experiment both the pressure of air and pressure of fuel are increased gradually to 6 bar and 5.8 bar corresponding exit temperature is noted as 695k. As with the increase in pressure of the working fluid, exit temperature of the combustion chamber is also increases. Thus, the result shows that our estimated calculation is achieved.

V. CONCLUSION

According to the Results, we have seen that pressure of the fuel is an important parameter of a combustion chamber and it is concerned with the exit temperature. These experimental evaluations have major role in the selection of turbine blade material. This project fully explains experimentally the relation between working fluid of the combustion chamber and temperature. Finally the result obtain will be helpful for the entire selection of the engine components material.

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