Design and Analysis of a Combustion Chamber in a Gas Turbine

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Abstract;- **Gas turbines are preferred over new crucial movers for power generation due to its low specific fuel consumption. The gas turbine power plants and steam turbine bottoming cycle are used as co-generation technique for refining overall efficiency of the plant. Hence combustion chamber of gas turbine should provide obligatory chemical kinetics and species generation with effective cooling of flame tube. The paper deals with the design of a combustion chamber in a gas turbine engine and it has to be designed based on the constant pressure, enthalpy process. The approach deals with the computation of the initial design parameters of the combustion chamber. New computational analysis method are continuously developed in order to rectify the problems occur in gas turbine and the various analytical configuration of the combustor has to be calculated based on different realistic formulas. The air-fuel mixture, combustion turbulence, thermal and cooling analysis is carried out. The computational analysis of combustion chamber performed at various scenarios and compared by using k-€ Turbulence tool in ANSYS CFX software.**

Key Words: Combustion chamber, heat transfer, thermal and cooling analysis.

INTRODUCTION

A gas turbine, also called a combustion turbine, is a type of continuous combustion, internal combustion engine. The main elements common to all gas turbine engines are:

1. An upstream rotating gas compressor
2. A combustor
3. A downstream turbine on the same shaft as the compressor.

A fourth component is often used to increase efficiency (on turboprops and turbofans), to convert power into mechanical or electric form (on turbo shafts and electric generators), orto achieve greater thrust-to-weight ratio (on afterburning engines).

The basic operation of the gas turbine is **Brayton cycle** with air as the working fluid. Atmospheric air flows through the compressor that brings it to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates a high-temperature flow. This high-temperature high-pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor; the energy that is not used for compressing the working fluid comes out in the exhaust gases that can be used to do external work, such as directly producing thrust in a turbojet engine, or rotating a second, independent turbine (known as a power turbine) which can be connected to a fan, propeller, or electrical generator. The purpose of the gas turbine determines the design so that the most desirable split of energy between the thrust and the shaft work is achieved. The fourth step of the Brayton cycle (cooling of the working fluid) is omitted, as gas turbines are open systems that do not use the same air again.

COMBUSTION CHAMBER

A **combustor** is a component or area of engine where combustion takes place. It is also known as a burner, combustion chamber or flame holder. In a gas turbine engine, the combustor or combustion chamber is fed high pressure air by the compression system. The combustor then heats this air at constant pressure. After heating, air passes from the combustor through the nozzle guide vanes to the turbine. In the case of a ramjet or scramjet engines, the air is directly fed to the nozzle.

A combustor must contain and maintain stable combustion despite very high air flow rates. To do so combustors are carefully designed to first mix and ignite the air and fuel, and then mix in more air to complete the combustion process. Early gas turbine engines used a single chamber known as a can type combustor. Today three main configurations exist: can, annular and cannular (also referred to as can-annular tubo-annular). Afterburners are often considered another type of combustor.

Combustors play a crucial role in determining many of an engine's operating characteristics, such as fuel efficiency, levels of emissions and transient response (the response to changing conditions such as fuel flow and air speed

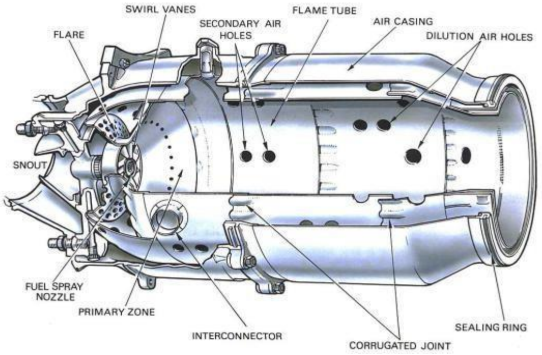

Fig -1 combustion chamber

FUNDAMENTALS OF COMBUSTOR

- Completely combust the fuel. Otherwise, the engine wastes the unbent fuel and creates unwanted emissions of un burnt hydrocarbons, carbon monoxide (CO) and soot.
- Low pressure loss across the combustor. The turbine which the combustor feeds needs high pressure flow to operate efficiently.
- The flame (combustion) must be held (contained) inside of the combustor. If combustion happens further back in the engine, the turbine stages can easily be overheated and damaged.
  Additionally, as turbine blades continue to grow more
  advanced and are able to withstand higher temperatures, the combustors are being designed to burn at higher temperatures and the parts of the combustor need to be designed to withstand those higher temperatures.
- It should be capable of relighting at high altitude in an event of engine flame-out.
- Uniform exit temperature profile. If there are hot spots in the exit flow, the turbine may be subjected to thermal stress or other types of damage. Similarly, the temperature profile within the combustor should avoid hot spots, as those can damage or destroy a combustor from the inside.
- Small physical size and weight. Space and weight is at a premium in aircraft
  applications, so a well- designed combustor strives to be compact. Non- aircraft applications, like power generating gas turbines, are not as constrained by this factor.
- Wide range of operation. Most combustors must be able to operate with a variety of inlet pressures, temperatures, and mass flows. These factors change with both engine settings and environmental conditions (I.e., full throttle at low altitude can be very different from idle throttle at high altitude).

AIR FLOW DISTRIBUTION PATH

Primary air

This is the main combustion air. It is highly compressed air from the high- pressure compressor (often decelerated via the diffuser) that is suckled through the main channels in the dome of the combustor and the first set of liner holes. This air is mixed with fuel, and then combusted.

Intermediate air

Intermediate air is the air vaccinated into the combustion zone through the second set of liner holes (primary air goes through the first set). This air completes the response processes, cooling the air down and diluting the high deliberations of carbon- monoxide (CO) and hydrogen (H_2).

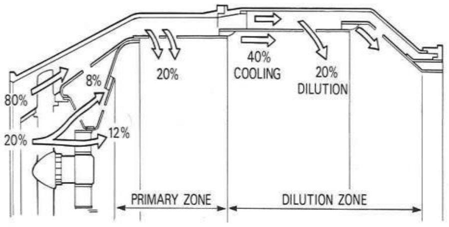

Fig -2 Air flow distribution Dilution air

Dilution air is airflow injected through holes in the liner at the end of the combustion chamber to help cool the air to before it reaches the turbine stages. The air is sensibly used to produce the uniform temperature profile preferred in the combustor. However, as turbine blade technology improves, allowing them to tolerate higher temperatures, dilution air is used less, permitting the use of more combustion air.

Cooling air

Cooling air is airflow that is inoculated through small holes in the liner to engender a layer (film) of cool air towards protect the liner from the combustion temperatures. The enactment of cooling air has to be carefully designed so it does not directly intermingle with the combustion air and process. In some cases, as much as 50% of the inlet air is used as cooling air. There are abundant different methods of injecting this cooling air, and the method can influence the temperature profile that the liner is bare.

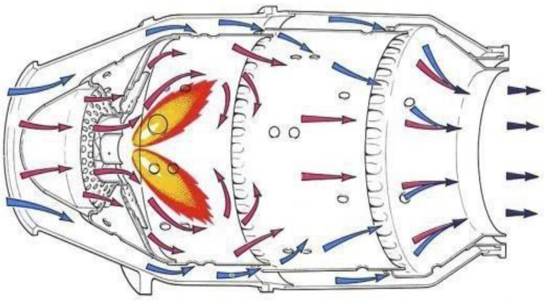

Fig-3 smoke ring

AERODYNAMIC INTENTION

Preliminary design procedure

The proposal of state-of-the-art low emission combustion chamber is based on a multitude of design rules.

By automating the combustor design process, the cohort of a new preliminary combustion chamber design can be done.

Initial design parameters

The initial design strictures are mostly the compressor exit and turbine inlet restraints, which is typically absorbed for any combustion chamber design. Others embracecusto-mer,specifications, constants, tentative values and limits.

Dimensions

Casing area:

calculates the reference area:

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Dimensions

Casing area:

calculates the reference area:

A_{ref} = 0.08217 m^2

Table-1 Initial desigN parameters

Parameters	values	Units
M3	28.7103	Kg\s
T3	743.352	K
P3	2083450	Pa
M	0.25818	kg\s

The combustor sectional area (A_L) can be calculated by

$A_L = 0.66\text{-}A_{ref}$

A= 0.05423 m^2

Annulus area:

The annulus area A_{an}, is the difference between A_{ref} and A_L and can be calculated from Equ.

$$A_{an} = A_{ref} - A_L$$

Pattern Fact:

The pattern factor is the difference between the maximum temperature in the CFD sector and the average combustor exit temperature and normalized by the average combustor temperature rise.

PF =0:25

Liner length:

The liner length provides the total length of the zones. It can be calculated from equ,

$$=$$

L_l=0.15719 m

Primary zone length:

The primary zone length can be calculated

L_{PZ} = 0.03020 m

Secondary zone length:

The length of the secondary zone can be calculated as,

Liner area:

$L_{PZ} = 0.03020$ m

Dilution zone length:

The length of the dilution zone can be calculated as,

$L_{DZ} = D_L\ 3.83 - 11.83PF + 13.4PF^2$ $L_{DZ} = 0.06933$ m

Case and liner diameter:

The locus length D_{ref} for annular combustor configuration. The value of D_{ref} is wary from A_{ref} and D_L is calculated from A_L and it must be chosen such that it accommodates the aerodynamic consideration in every functional ailment.

Dref =0.061m DL =0.04026 m

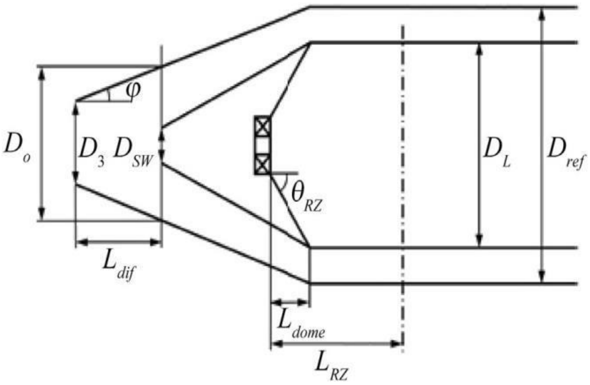

Fig-4 Fronted and geometry of combustor

Gas temperature profile

Adiabatic flame temperature:

In the study of combustion, there are two types of **adiabatic flame temperature** depending on how the process is completed: the constant volume and constant pressure*;* both of which describe temperature that combustion products theoretically can reach if no energy is lost to the outside environment.

The constant volume adiabatic flame temperature is the temperature that results from a complete combustion process that occurs without any work, heat transfer or changes in kinetic or potential energy. Its temperature is higher than the constant pressure process because no energy utilized to change the volume of the system (i.e., generate work).

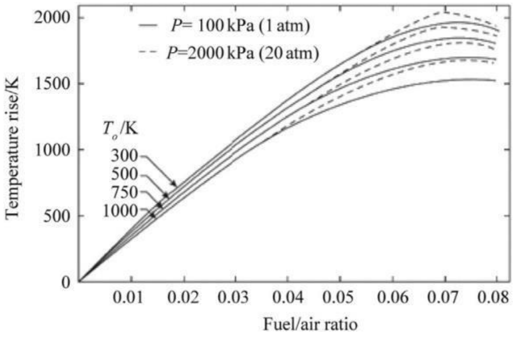

Fig – 5 Fuel/ air ratio

Analytical models

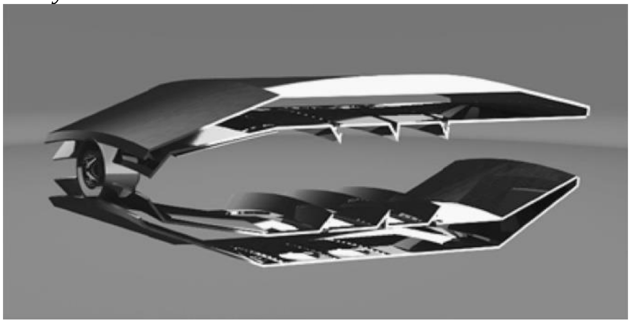

Fig- 6 the analytical model Table -2 parameters

Parameters	**Values**
Discretization	te volume method
Domain	bustor- eddy dissipation
Meshing model	Advancing front
Total element	2906742
Total nodes	5921257

The combustor is divided into four zones: recirculation zone, primary zone, secondary zone and dilution zone. For each zone, the local temperature is assumed to vary linearly between the zone inlet temperature (T_{in}) and zone outlet.

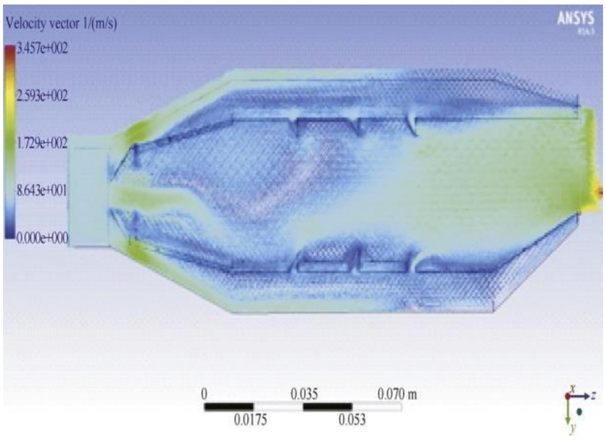

Fig-7 velocity path model

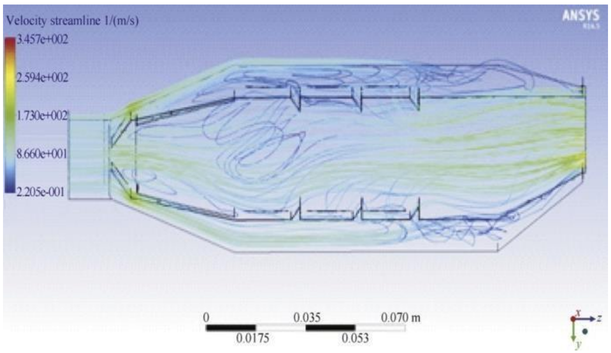

Fig- 8 velocity streamline model

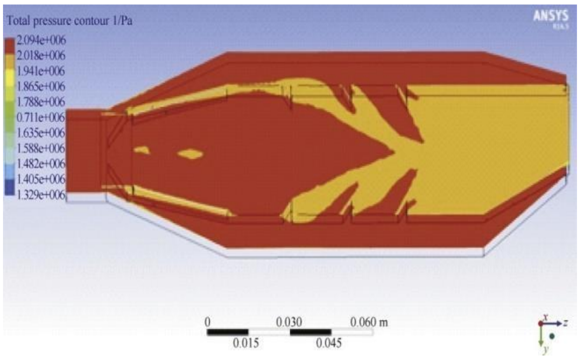

Fig -9 Total pressure delineation model

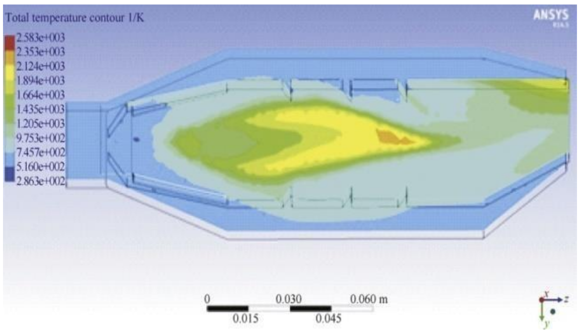

Fig-10 Total temperature delineation model

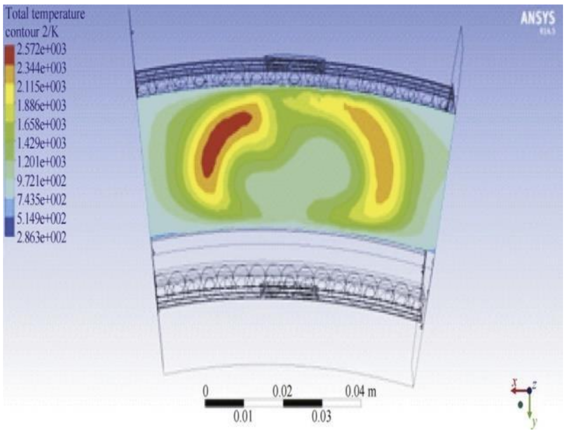

Fig-11 Temperature delineation at the outlet

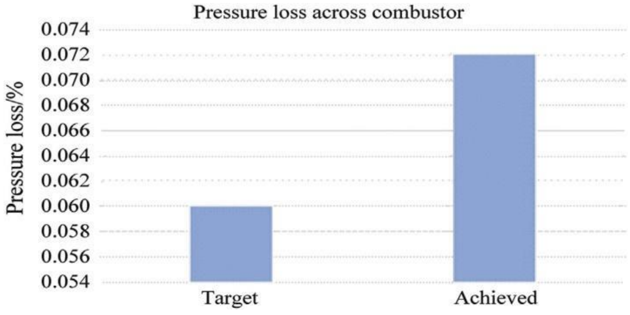

Fig –12 pressure loss

RESULTS AND DISCUSSION

The complete combustor design using theinitial parameters has been evidentlydiscussed in this paper.this is more sophisticated design approach which can be used for the preliminary design.By using this practise a practical design can be illustrated. Based on theoretical calculation and obtained results, the design point combustor exit temperature was achieved within 96% efficiency. Thus the design is capable of reaching higher temperatures.

CONCLUSION

The design was efficaciously calculated and modeled. The mandatory simpler model for exploration was also created. Then the model was aerodynamically analyzed at design point and the geometry was enhanced based on the results. This has delivered one of the most efficient combustion chamber design that can be used in the gas turbine engine.

REFERENCE

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2) Design and analysis of gas turbine combustion chamber.
3) The JET ENGINE – rolls- royce
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