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DESIGN AND ANALYSIS OF GAS TURBINE COMBUSTION CHAMBER

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ABSTRACT:

The design and analysis of gas turbine combustion chamber is based on combined theoretical and empirical approach and the design of combustion chamber is a less than exact science. This paper presents the design of combustion chamber followed by three dimensional simulations to investigate the velocity profiles, species concentration and temperature distribution within the chamber and the fuel considered as Methane (CH4). In this thesis, the combustion chamber is designed according to the ic engine specifications and analyzed for its heat transfer rate using Finite Element analysis software ANSYS. Modeling will be done in CREO parametric software. CFD analysis to determine the pressure drop, velocity, heat transfer rate and mass flow rate with different fluids (ethanol, methanol, ethelene, propyl and gasoil). Thermal analysis is to determine the heat transfer rate per unit area i.e. heat flux and temperature distribution for two materials steel and cast iron.

Keywords: **combustion chamber, *ANSYS, CREO.***

1. INTRODUCTION:

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

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response to changing conditions such as fuel flow and air speed). The objective of the combustor in a gas turbine is to add energy to the system to power the turbines, and produce a high velocity gas to exhaust through the nozzle in aircraft applications. As with any engineering challenge, accomplishing this requires balancing many design considerations, such as the following:

Components

Case

The case is the outer shell of the combustor, and is a fairly simple structure. The casing generally requires little maintenance.[4] The case is protected from thermal loads by the air flowing in it, so thermal performance is of limited concern. However, the casing serves as a pressure vessel that must withstand the difference between the high pressures inside the combustor and the lower pressure outside. That mechanical (rather than thermal) load is a driving design factor in the case.

Diffuser

The purpose of the diffuser is to slow the high speed, highly compressed, air from the compressor to a velocity optimal for the combustor. Reducing the velocity results in an unavoidable loss in total pressure, so one of the design challenges is to limit the loss of pressure as much as possible. Furthermore, the diffuser must be designed to limit the flow distortion as much as possible by avoiding flow effects like boundary layer separation. Like most other gas turbine engine components, the diffuser is designed to be as short and light as possible.

Liner

The liner contains the combustion process and introduces the various airflows (intermediate, dilution, and cooling, see Air flow paths below) into the combustion zone. The liner must be designed and built to withstand extended high temperature cycles. For that reason liners tend to be made from super alloys like Hostelry. Furthermore, even though high performance alloys are used, the liners must be cooled with air flow. Some combustors also make use of thermal barrier coatings. However, air cooling is still required. In general, there are two main types of liner cooling; film cooling and transpiration cooling. Film cooling works by injecting (by one of

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several methods) cool air from outside of the liner to just inside of the liner. This creates a thin film of cool air that protects the liner, reducing the temperature at the liner from around 1800 Kelvin's (K) to around 830 K, for example. The other type of liner cooling, transpiration cooling, is a more modern approach that uses a porous material for the liner. The porous liner allows a small amount of cooling air to pass through it, providing cooling benefits similar to film cooling. The two primary differences are in the resulting temperature profile of the liner and the amount of cooling air required. Transpiration cooling results in a much more even temperature profile, as the cooling air is uniformly introduced through pores Film cooling air is generally introduced through slats or louvers, resulting in an uneven profile where it is cooler at the slat and warmer between the slats. More importantly, transpiration cooling uses much less cooling air (on the order of 10% of total airflow, rather than 20-50% for film cooling). Using less air for cooling allows more to be used for combustion, which is more and more important for high performance, high thrust engines.

Air flow paths

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 fed 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 injected into the combustion zone through the second set of liner holes (primary air goes through the first set). This air completes the reaction processes, cooling the air down and diluting the high concentrations of carbon monoxide (CO) and hydrogen (H_2).

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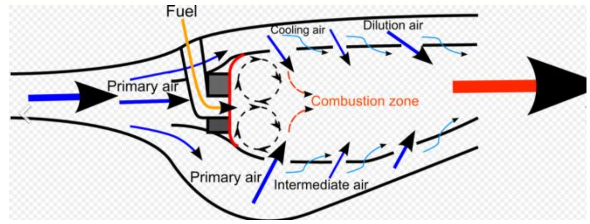
Dilution air

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 carefully used to produce the uniform temperature profile desired in the combustor. However, as turbine blade technology improves, allowing them to withstand higher temperatures, dilution air is used less, allowing the use of more combustion air.

Cooling air

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



2. RELATED STUDY:

A. A Review on use of Computational Fluid Dynamics in Gas Turbine Combustor Analysis and its Scope, H. A. Bhimgade, S. K. Bhele, International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, 6 June 2013 In this paper the CFD application and its scope, is mainly focused on gas turbine combustor (generally can or tubular, annular and tuboannular type of combustor used in gas turbines for higher efficiency). In many practical combustion applications like gas turbine and diesel engine, the combustion takes place in turbulent flow field. Therefore it is important to model the effects of turbulence and mixing interactions including all related processes either physical or chemical. In the present the emphasis is on how the turbulence leads to increased mixing in order to be used to compensate for the inaccurate prediction for the chemical reaction rate. However this has to be treated numerically and physically. Both ways are referring to the incomplete mixing process that may lead to ignite the fuel vapour before the auto-ignition delay time or out of the main reaction zone. Physically, the mixing process tends to speed up the overall reaction rate by stretching and wrinkling of the preheating zone. In addition the simulation of turbulent spray combustion remains quite a hard task because many problems may occur due to strong coupling that exists between predicted vapour mass fraction and the chemical reaction. . The experimental results and the semi empirical correlations for calculating CO, UHC, NOx, exhaust gases temperature and inner liner wall temperature as a function of different operating parameters are useful for design and further development of design, of gas turbine combustor is possible. Even with existing physical models, CFD can offer cost-effective solutions for many complex systems of interest to the power generation, aero-engines and process industries. B. Thermal mapping of a can type gas turbine Combustion chamber using cfd , SachinBhalerao., Dr. A.N.Pawar. International Journal of Emerging trends in Engineering and Development, ISSN 2249-6149 The literature review reveals that the increase in the exhaust temperature of the combustor increases the gas turbine efficiency. In this article efforts taken to conduct simulation of the thermal flow behavior of the combustion chamber using CFD and their results are discussed. The combustor under study is a typical can type combustion chamber. The overall length of combustor is 567 mm including the diffuser section at outlet. A mesh of 557K nodes is designed after a set of trials which showed that further refinement in either direction does not change the velocity and scalar variables at any point in the combustor considerably. The domain is discretized with 3 million full tetrahedral volume cells. The grids are generated by a mesh generator. 2-D quadrilateral grids are chosen to approximate the domain. Figure 5 shows the different views of the meshed geometry. Figure 6(a) shows the temperature distribution along the length of the combustion chamber.

DESIGN OF COMBUSTION CHAMBER

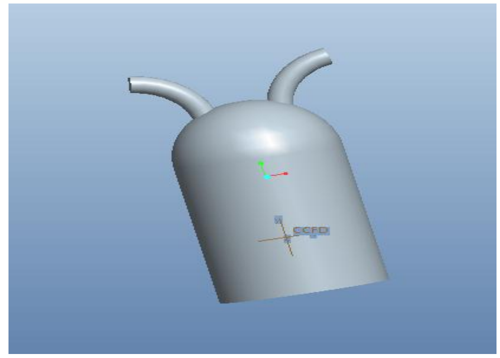
INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

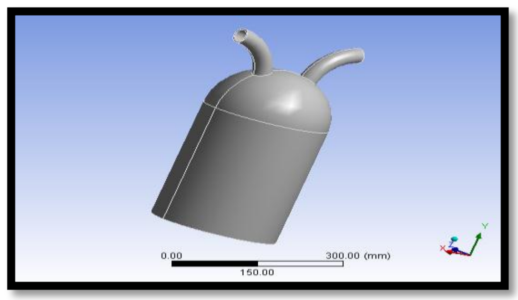
The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assembly modeling, 2D orthographic views for technical drawing, finite element analysis and more

CREO parametric modules:

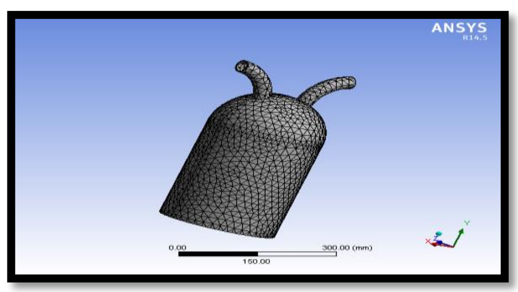
- Sketcher
- Part modelling
- Assembly
- Drafting

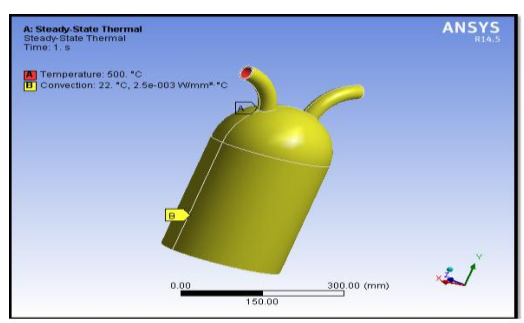


THERMAL ANALYSIS OF COMBUSTION CHAMBER

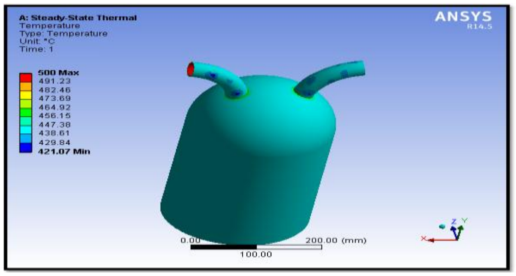


Meshed model

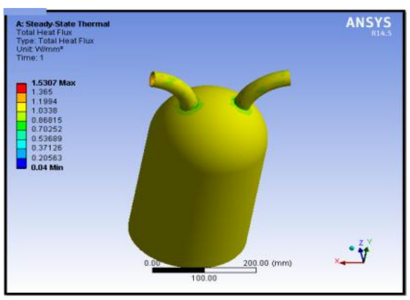




TEMPERATURE



HEAT FLUX



CFD ANALYSIS RESULTS TABLE

VELOCITY 120m/s

fluids	Pressure(pa)	Velocity(m/s)	Heat transfer coefficient(w/m2-k)	Heat transfer rate(W)	Mass flow rate(kg/s)
ethanol	3.07e^{+06}	1.48e^{+02}	7.90e^{+04}	3172116.5	15.739029
methanol	2.87e^{+06}	1.69 e^{+02}	8.09e^{+04}	2666271.2	11.90834
ethelene	8.41e^{+03}	1.59 e^{+02}	6.99 e^{+02}	1297.443	0.018528
propyl	3.71e^{+06}	1.76 e^{+02}	2.09 e^{+05}	3400758.7	13.964752
Gas oil	1.195e^{+07}	1.586 e^{+02}	3.578 e^{+04}	2324893.4	13.03038

fluids	Pressure(pa)	Velocity(m/s)	Heat transfer coefficient(w/m2-k)	Heat transfer rate(W)	Mass flow rate(kg/s)
ethanol	4.6e^{+06}	2.0e^{+02}	9.780e^{+04}	3634251.9	17.86530
methanol	4.565e^{+06}	1.960 e^{+02}	1.002 e^{+05}	3884644.9	17.865326
ethelene	1.402e^{+04}	1.904 e^{+02}	7.462 e^{+02}	2815.9748	0.022484
propyl	5.997e^{+06}	1.851 e^{+02}	2.479 e^{+05}	4448207.7	19.316803
Gas oil	1.102e^{+07}	1.877 e^{+02}	4.261 e^{+04}	3434600.6	19.312317

MATERIAL	TEMPERATURE(k)		HEAT FLUX(W/mm²)
	MIN	MAX	
STEEL	421.07	500	1.5307
CAST IRON	`410.52	500	1.4979

CONCLUSION

The combustion process increases the internal energy of a gas, which translates into an increase in temperature, pressure, or volume depending on the configuration. In an enclosure, for example the cylinder of a reciprocating engine, the volume is controlled and the combustion creates an increase in pressure. In a continuous flow system, for example a jet engine combustor, the pressure is controlled and the combustion creates an increase in volume. This increase in pressure or volume can be used to do work, for example, to move a piston on a crankshaft or a turbine disc in a gas turbine. By observing the CFD analysis the pressure drop, velocities and heat transfer rate values are increasing by increasing the velocity. The thermal analysis is to determine the heat flux of the combustion chamber the heat flux more for steel compare with cast iron material. So it can be concluded the heat transfer rate more for propylene fluid, when heat transfer rate will more than the engine efficiency will increase.

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