



New Innovation of Combustion Chamber by Rotating Components Using CFD Tool

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ABSTRACT

Fuel conservation is very important and popular subject given today's concern for the operating cost economics in the aviation industry. Several techniques based on energizing the performance, or using in-time modifications of the engine combustion chamber will be studied in this project. This second approach on new designing of combustion chamber by rotational component seems to be promising. Considering a commercial aircraft for example, enhancing the engine regime by using combustion chamber by new innovative ideas and thereby increasing air fuel mixing ratio would most likely lead to fuel economy. Then the various dimensions of the combustor are calculated based on different empirical formulas. The air mass flow is then distributed across the zones of the combustor. The whole combustion chamber is modeled using Gambit, a modeling software and presented. The model is then analyzed using various parameters at various stages and levels to determine the optimized design. The aerodynamic flow characteristics are simulated numerically by means of fluent software suite. This project focuses on the design of a structure for an experimental combustion chamber, which will be studied using the computational fluid dynamic analysis.

Key Terms: Engines, Aircraft, Combustion Chamber

1. INTRODUCTION

A combustor is a component or area of a gas turbine, ramjet, or scramjet 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. (also referred to as can-annular turbo-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).

2. COMPONENTS

2.1 Case

The case is the outer shell of the combustor, and is a fairly simple structure. The casing generally requires little maintenance. 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.

2.2 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

2.3. Liner

The liner contains the combustion process and introduces the various airflows zone. The liner must be designed and built to withstand extended high temperature cycles.

2.4 Fuel Injector

The fuel injector is responsible for introducing fuel to the combustion zone and, along with the swirler, is responsible for mixing the fuel and air. There are four primary types of fuel injectors, pressure-atomizing, air blast, vaporizing, and premix/pre-vaporizing injectors.

3.TYPES

3.1 Can Type

Can combustors are self-contained cylindrical combustion chambers. Each "can" has its own fuel injector, igniter, liner, and casing [5]. The primary air from the compressor is guided into each individual can, where it is decelerated, mixed with fuel, and then ignited. The secondary air also comes from the compressor, where it is fed outside of the liner (inside of which is where the combustion is taking place).

3.2 Can-Annular Type

The next type of combustor is the cannular combustor; the term is a portmanteau of "can annular". Like the can type combustor, can annular combustors have discrete combustion zones contained in separate liners with their own fuel injectors. Unlike the can combustor, all the combustion zones share a common ring (annulus) casing. Each combustion zones no longer has to serve as a pressure vessel. The combustion zones can also "communicate" with each other via liner holes or connecting tubes that allow some air to flow circumferentially

3.3 Annular

The final, and most commonly used type of combustor is the fully annular combustor. Annular combustors do away with the separate combustion zones and simply have a continuous liner and casing in a ring (the annulus). There are many advantages to annular combustors,

including more uniform combustion, shorter size (therefore lighter), and less surface area. Additionally, annular combustors tend to have very uniform exit temperatures. They also have the lowest pressure drop of the three designs (on the order of 5%). The annular design is also simpler, although testing generally requires a full size test. An engine that uses an annular combustor is the CFM International CFM56. Almost all of the modern gas turbine engines use annular combustors; likewise, most combustor research and development focuses on improving this type.

4. PROBLEM IDENTIFICATION

One of the driving factors in modern gas turbine design is reducing emissions, and the combustor is the primary contributor to a gas turbine's emissions. Generally speaking, there are five major types of emissions from gas turbine engines: smoke, carbon dioxide (CO₂), carbon monoxide(CO), unburned hydrocarbons (UHC), and nitrogen oxides (NO_x). Smoke is primarily mitigated by more evenly mixing the fuel with air. As a result of this close relation, a combustor that is well optimized for CO emissions is inherently well optimized for UHC emissions, so most design work focuses on CO emissions. Carbon monoxide is an intermediate product of combustion, and it is eliminated by oxidation. Like CO, Nitrogen oxides (NO_x) are produced in the combustion zone. However, unlike CO, it is most produced during the conditions that CO is most consumed (high temperature, high pressure, long residence time). This means that, in general, reducing CO emissions results in an increase in NO_x and vice versa. This fact means that most successful emission reductions require the combination of several methods. The emissions are reduced by increasing the efficiency of the combustion.

5. DESIGN

The design was done in GAMBIT for this study. GAMBIT is a software package designed to help analysts and designer build and mesh models of computational fluid dynamics and other scientific applications. Different CFD problems require different mesh types, and GAMBIT gives us all the options us need in a single package. GAMBIT's meshing toolkit lets us decompose geometries for structured hex meshing or perform automated hex meshing with control over clustering. Triangular surface meshes and tetrahedral volume meshes can be created within a single environment, along with pyramids and prisms for hybrid meshing. GAMBIT builds on Fluent's established leadership in tools for automated meshing combined with user control. We have done a design and mesh by using the GAMBIT software. Here we have chosen an annular combustion chamber for design and analysis purpose. We have taken co-ordinates for annular combustion chamber and imported into gambit. Then the co-ordinates will be designed by various tools.

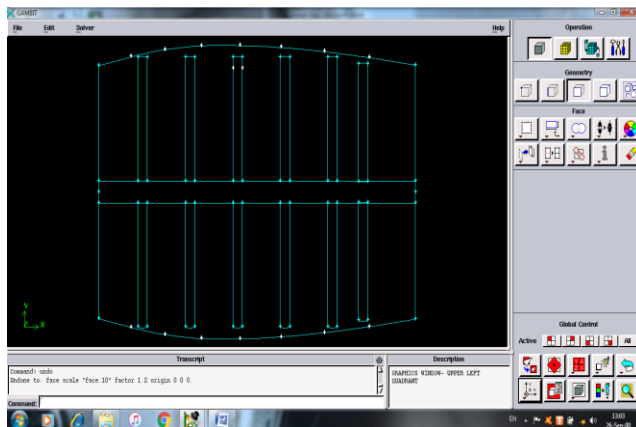


Fig 1 6stage blade in combustion chamber

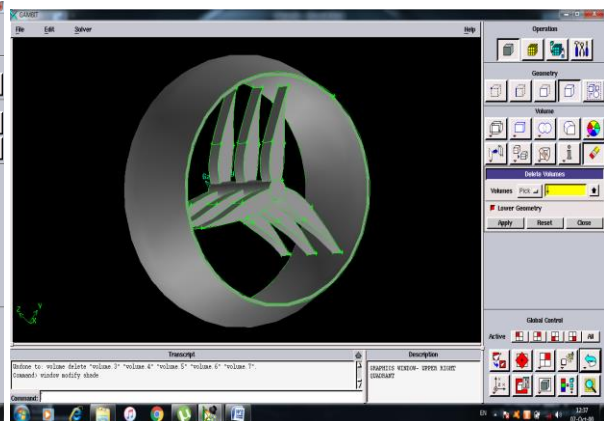


Fig 2 Solid model designed in GAMBIT

6. ANALYSIS

The analysis was carried out in GAMBIT-FLUENT module for the results. The model or the design of the combustion chamber made was set into the module with the necessary characteristics.

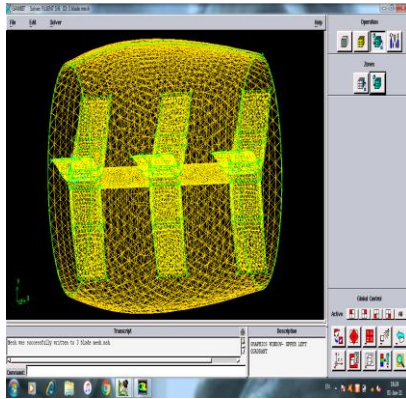


Fig 3 Meshing in CFD

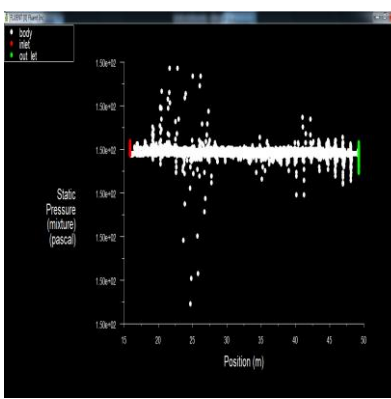


Fig 4 Pressure Track

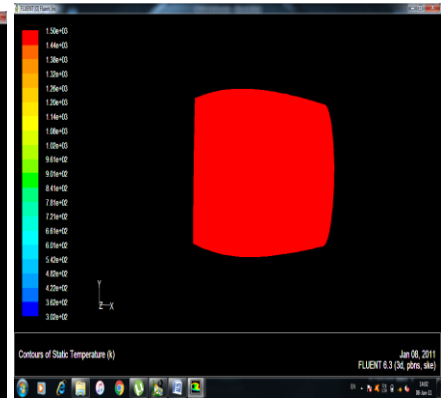


Fig 5 Temperature

7. RESULTS AND DISCUSSION

Mass flow rate

1. 17.779 kg/ min
2. 20.6703 kg/min
3. 24.3684 Kg/ min

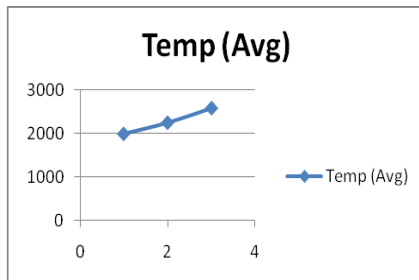


Fig 6 Average Temperature

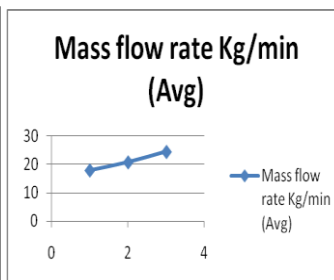


Fig 7 Average Mass Flow Rate

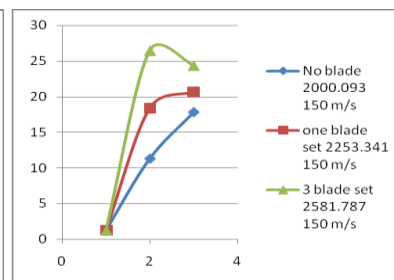


Fig 8 Comparison between blade set

8. CONCLUSION

As we pace towards a much automated habitat, we always tend to look for faster and better automotive products for which industries compete with each other. As far as the combustion systems are considered the industries focus more on increased efficiency and better emission results. This second approach on new designing of combustion chamber by rotational component seems to be promising. Considering a commercial aircraft for example, enhancing the engine regime by using combustion chamber by new innovative ideas and thereby increasing air fuel mixing ratio would most likely lead to fuel economy. Then the various dimensions of the combustor are calculated based on different empirical formulas. The air mass flow is then distributed across the zones of the combustor. In the concerned project, we have undergone study to improve the efficiency of the combustion chamber by designing a new type of combustion chamber based on the annular type combustion chamber. Thus by the results it is evident we have achieved good amount of increased and improved efficiency of the combustion chamber.

REFERENCE

- [1] Cai wen-xiang, Experiment analysis of combustion performance in pulse jet engine. (sep 2016)
- [2] C. Priyant Mark, A. Selwyn(2016).Design and analysis of a low bypass turbofan engine in a jet trainer aircraft.vol-5 (2016)
- [3] P. Saravana Kumar, P.Punna Rao Design and analysis of gas turbine combustion chamber
- [4] Yize Liu , Xiaoxiao Sun Review of modern low emission combustion technology for aero gas engines
- [5] Kevin Peieur, Daniel Durox, Strong azimuthal combustion instabilities in - a spray annular chamber with intermittent partial blow off.
- [6] Ana Costa Conrado, Pedro Teixeira Lacava Basic Design Principles For Gas Turbine Combustor(Dec 2004)
- [7] A.H. Lefebvre,D.R.Ballal, Gas Turbine Combustion, Third ed., CRC Press,Florida,USA,2010.
- [8] S.R. Turns, An Introduction to Combustion Concepts and Applications, Second ed.,Mc Graw Hill Book Co., USA, 2000.
- [9] K.S. Kaddah, Discharge Coefficients and Jet Deflection Angles for Combustion Liner Air Entry Holes, M.Sc. dissertation,College of Aeronautics,Cranfield,England,1964.
- [10] S. Venkataraman ,Design and Development of Combustion Systems for an Aero Gas Turbine