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Combustion Acoustics Analysis of Gas Turbine Using CFD Package

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ABSTRACT

The combustion chamber in gas turbines and jet engines (including ramjets and scramjets) is called the combustor. The combustor is fed with fuel and high pressure air by the compression system thereby combustor burns the mix and feeds the hot, high pressure exhaust into the turbine. The tube-annular combustors are completely surrounded by the airflow that enters the liners through various holes and louvers. Due to the reduction of fuel consumption and new global emission limits, improvements to lean combustion technologies in aero engine combustors are unavoidable. Near to the lean limits, combustion tends to be unstable resulting in thermo acoustic instabilities, which pose a major threat to modern gas turbines. The use of acoustic dampers, like porous insert as a passive control, has proven useful for the mitigation of such instabilities. Usually passive methods are used instead of active controls, as they feature high reliability at low costs. In this thesis, design and acoustic analysis using CFD is performed for a tube-annular combustor of gas turbine and design of passive insert damper is investigated to compare the noise level with and without acoustic damper.

Key Words: Tube-annular combustor, Acoustic damper, 3D Modelling, 'Creo' and CFD

1. INTRODUCTION:

1.1 Combustor and it's Requirements:

The combustor or combustion chamber is fed with high pressure air by the compression system.

A combustor must contain and maintain stable combustion despite very high air flow rates.

1.2 Types of Combustors:

1.2.1 Annular Combustor

The primary compressed air is introduced into an annular space formed by a chamber liner around the turbine assembly. The space between the outer liner wall and the combustion chamber housing permit the flow of secondary cooling air from the compressor.

1.2.2 Tube-Annular Combustor

The combustion chambers are completely surrounded by the airflow that enters the liners through various holes and louvers. This air is mixed with fuel which has been sprayed under pressure from the fuel nozzles. The fuel-air mixture is ignited by igniter plugs, and the flame is then carried through the crossover tubes to the remaining liners. The inner casing assembly is both a support & a heat shield; also, oil lines run through it.

1.2.3 Can Combustors

Can combustors are self-contained cylindrical combustion chambers. Each "can" has its own fuel injector, igniter, liner, and casing. 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). The secondary air is then fed, usually through slits in the liner, into the combustion zone to cool the liner via thin film cooling.

2. LITERATURE SURVEY:

P. Sravan Kumar et.al [1] - had performed the "Design and Analysis of Gas Turbine Combustion Chamber" 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 (CH_4).

Ana Costa Conrado et.al [2] - had examined "Basic design principles for gas turbine combustor". This work shows a methodology for gas turbine combustor basic design. The methodology emphasis is on the practical rather than theoretical aspects of combustor design. Criteria for selecting a suitable combustor configuration are examined followed by design calculations for the dimensions of the casing, the liner, the diffuser, and the swirler. Calculations of gas temperature in the various zones of the combustor & liner wall temperatures in presence of film cooling are performed along with design calculations for dimensions of the air admission holes.

Georg A. Mensah et.al [3] - had done "Acoustic Damper Placement and Tuning for Annular Combustors: An Adjoint-Based Optimization Study". This paper discussed the principal challenges of the effective placement and the design of the impedance of acoustic dampers in annular chambers. This includes the choice of an appropriate objective function for the optimization, the combinatorial challenges with different damper arrangements, and the numerical complexities when using the thermo acoustic Helmholtz equation. As a key aspect, the paper proposes a new adjoint-based approach to tackle these problems. The new algorithm establishes algebraic models that predict the effect of acoustic dampers on the growth rates of the thermo acoustic modes. The theory is exemplified on the basis of a generic annular combustor model with 12 burners.

Valter Bellucci et.al [4] – had done "Thermo acoustic Modelling of a Gas Turbine Combustor Equipped with Acoustic Dampers". In this work, the TA3 thermo acoustic network is presented and used to simulate acoustic pulsations occurring in a heavy-duty ALSTOM gas turbine. The combustion system is represented as a network of acoustic elements corresponding to hood, burners, flames and combustor. The multi-burner arrangement is modelled by describing the hood and combustor as Multiple Input Multiple Output (MIMO) acoustic elements. The MIMO transfer function (linking acoustic pressures and acoustic velocities at burner locations) is obtained by a three-dimensional modal analysis performed with a Finite Element Method. In particular, the flame transfer function model is based on the time-lag concept, where the phase shift between heat release and acoustic pressure depends on the time necessary for the mixture fraction (formed at the injector location) to be convected to the flame. By using a state-space approach, the time domain solution of the acoustic field is obtained. The non-linearity limiting the pulsation amplitude growth is provided by a fuel saturation term. Furthermore, Helmholtz dampers applied to the gas turbine combustor are acoustically modelled and included in the TA3 model.

Finally, the predicted noise reduction is compared to that achieved in the engine.

K. V. Chaudhari et.al [5] – had done "Design and CFD Simulation of Annular Combustion Chamber with Kerosene as Fuel for 20 kW Gas Turbine Engine". This paper discussed the challenges in designing high performance combustion systems with a more sophisticated analysis process. A technical discussion on combustion technology status and needs will show that the classic impediments that have hampered progress towards near stoichiometric combustion still exist.

3. PROBLEM DESCRIPTION:

Combustors running at lean conditions are prone to combustion instability. Due to the reduction of fuel consumption and new global emission limits, especially for the pollutant emissions of NOx, improvements to lean combustion technologies in aero engine combustors are unavoidable. Near to the lean limits, combustion tends to be unstable. It occurs when the unsteady heat release interacts constructively with the acoustic waves in the combustor.

3.1 Objectives of the present work:

- In the present work, attempt has been made to Design and carryout CFD Acoustic Analysis of Tube-Annular Combustor without damper to know the noise level.
- To study the effect of Porous insert damper made up of various materials in noise reduction using CFD Acoustic analysis
- To design a Tube-Annular combustor with Creo based on literature survey and design calculations.
- To carryout Modal Analysis of Tube-Annular Combustor with suitable materials using CFD

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➢ To do Thermal analysis of Tube-Annular Combustor with and without Acoustic Damper using Ansys.

4. RESULTS AND CONCLUSION

4.1 CFD-Acoustic Analysis Of Tube-Annular Combustor

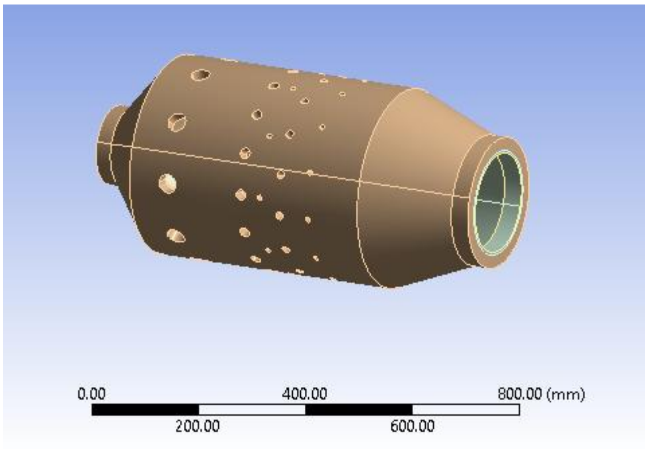


Fig. 4.1: - Tube-Annular Combustor (Imported)

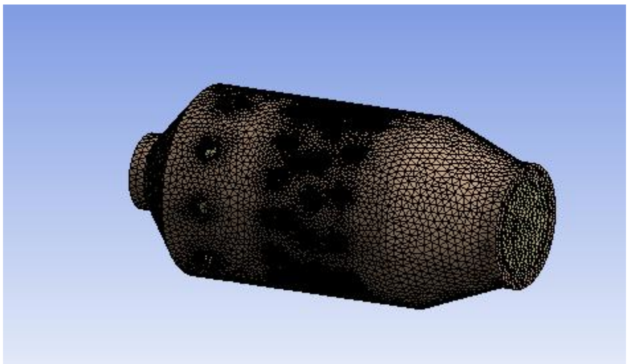
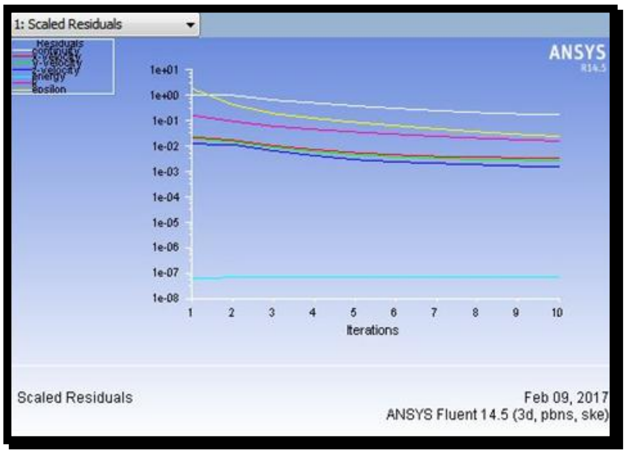


Fig. 4.2: - Tube-Annular Combustor (Meshed)



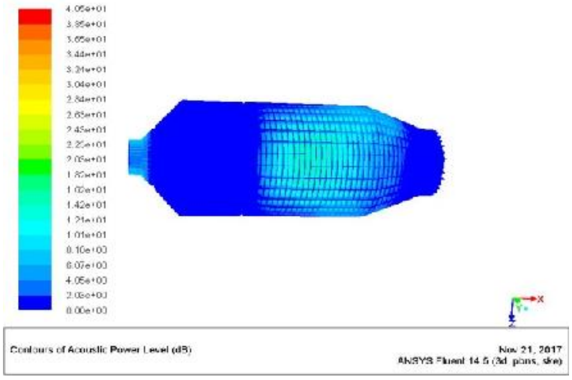


Fig 4.4: - Tube-Annular Combustor (Acoustic power level)

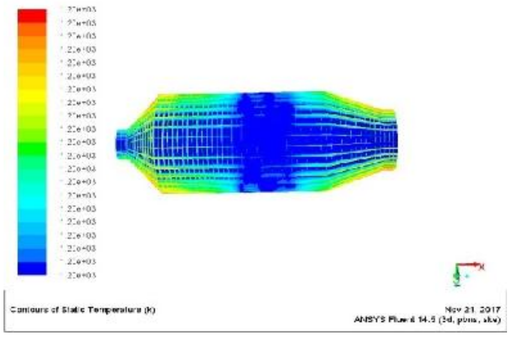


Fig. 4.5 : - Tube-Annular Combustor (Temperature)

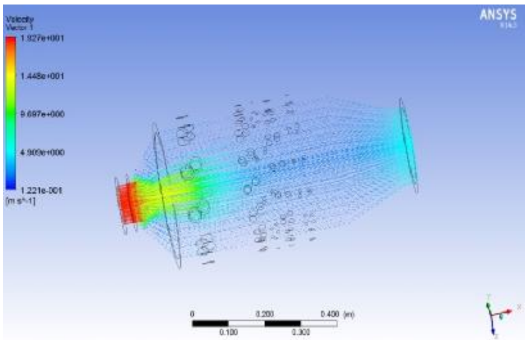


Fig. 4.6 : - Tube-Annular Combustor (Velocity)

4.2 Thermal Analysis:

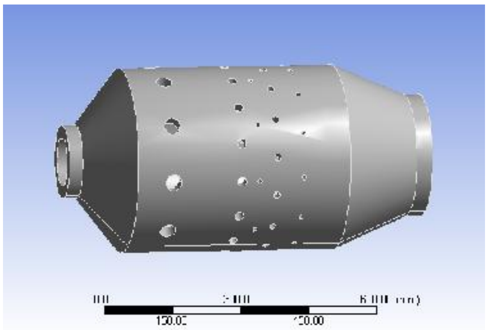


Fig. 4.7:- Tube-Annular Combustor (Imported)

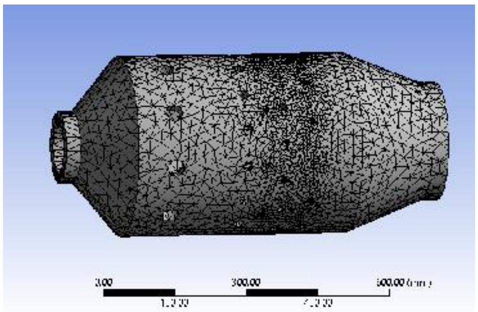


Fig. 4.8:- Tube-Annular Combustor (Meshed)

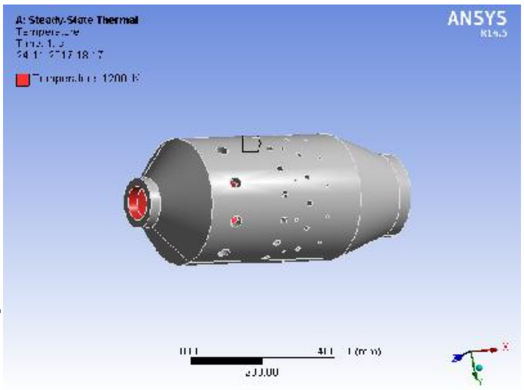


Fig. 4.9:- Tube-Annular Combustor (Temperature)

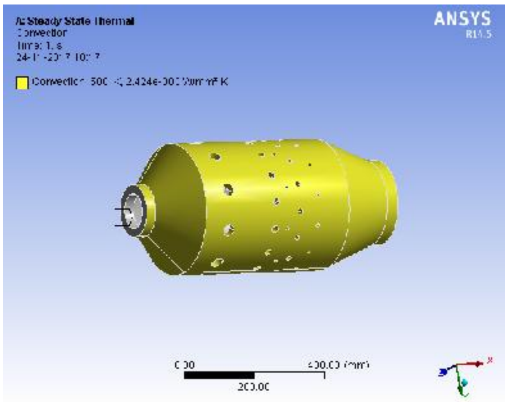


Fig. 4.10:- Thermal analysis (Convection)

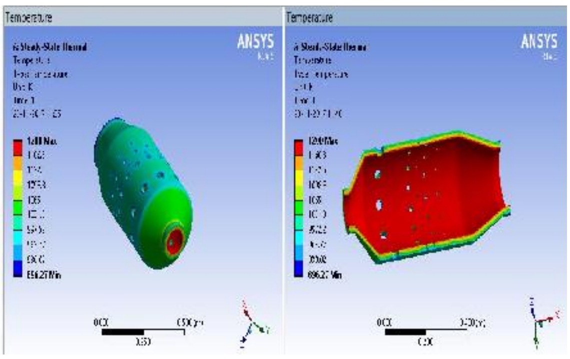


Fig. 4.11:- steady state thermal analysis (Temperature)

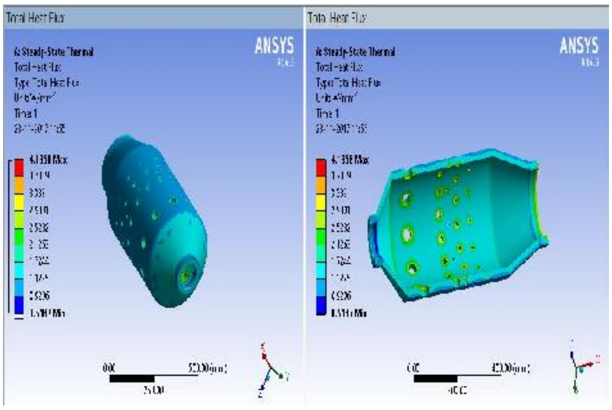


Fig. 4.12:- steady state thermal analysis (Total heat flux)

4.3 Conclusions:

Made the Comparison about reduction in noise level apart from combustion temperatures and heat flux and it is obvious that reduction in noise is observed with use of porous insert dampers.

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