DESIGN OF ANNULAR COMBUSTION CHAMBER WITH DIFFERENT TYPES OF SWIRL TO PERFORM PRESSURE DROP

J. Sumendran, Kamal Raj Chandra Shekar, G. Jegadeeswari, B. Kirubadurai

Abstract: This work is measured to be a foremost factor in the growth of an annular combustor. For measure the values for the annular geometry, an analytical approach is used. The dissimilar dimensions of the combustor are gritty dependent on dissimilar mathematical equations. The CATIA V5R20 software is worn to design and fabricating the additional combustor model used in mathematical methods. The template is combined with numerous swirl types and then the investigation of the combustor is performed in the ANSYS code. The difference in pressure drop is calculated for two models premeditated with different types of swirl. It is also studied the mixture of air-fuel, combustion-turbulence. The model evaluated for different models.

Keywords: Annular Combustor, Swirl, Pressure Drop Variation, Optimized Design

1. INTRODUCTION

Gas turbines are continuously refining and emerging to create consecutively ended an inclusive kind of functioning conditions conceivable. Consequently, the gas turbine's incineration chamber layout plays a vital part in the gas turbine's steady process. Modern trend proves the annular combustion chamber design to be highly efficient design. Thus, the annular combustor design is undertaken in this work for the purpose of understanding the pressure drop study in the combustor and to get the optimized design. Conventional gas turbine consists of an inlet diffuser, fuel injectors, Swirler and three combustion zones namely, primary, secondary and dilution zones. Basically, the design of the combustor involves empirical relations and numerical modelling of the design. The design's goal is to deliver a satisfactory clarification to an extensive choice of design challenges. The challenges faced during the combustor's new design are the combustion efficiency, pressure drop, combustor limitations, combustor interaction with components such as turbine and compressor, and the various types of fuel that can be used in the engine. The aim of this paper is to control the various configuration of the twirl combined with the annular combustor and to associate the different design of the combustor with the CFD method in order to accomplish the best conceivable design with a least pressure drop. Thus, the optimum plan is developed which would be further steady state under a widespread choice of operational conditions. Hence, the optimum prototype is attained which would be additional good and robust under a wide choice of operating conditions.

- *J. Sumendran, PG Research Scholar, Department of Aeronautical Engineering, Vel Tech Dr. Rangarajan Dr. Sagunthala R&D Institute of Science & Technology, Chennai, India.
- Kamal Raj Chandra Shekar, PG Research Scholar, Department of Aeronautical Engineering, Vel Tech Dr. Rangarajan Dr. Sagunthala R&D Institute of Science & Technology, Chennai, India.
- Jegadeeswari .G, Assistant Professor, Department of Electrical and Electronics Engineering, AMET Deemed to be University, Chennai, India. Email: jegadeeswari.dharan@gmail.com
- Kirubadurai.B, Assistant Professor, Department of Aeronautical Engineering, Vel Tech Dr. Rangarajan Dr. Sagunthala R&D Institute of Science & Technology, Chennai, India. Email: bkirubadurai@gmail.com

There are various types of approach done which the methodology of the design of the combustor designs are approved. They are empirical methodology, semi-empirical methodology, analytical methodology and semi-analytical methodology. Separate type of methods has its specific advantages and drawbacks and it is the designer's comfort of selecting the category of approach essential. The method adopted for the design were the empirical methodology. Within this methodology a series of statistical data of the successful combustion systems is taken as a base line through which the basic parameters of the combustor are established. The foremost benefit of this approach is the robust calculations which is worn to control the simple parameters of the combustor with benefit of inlet conditions based in mission and engine cycle analysis.

A) ANNULAR DESIGN CALCULATION

i) Casing and liner diameter

The value of D_{ref} and D_L can be calculated from A_{ref} and A_L which gives the result of,

D_{ref} = 200 mm

D_L = 150mm

D_{in} = 50.6 mm

ii) Liner length

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

$$L_L = \frac{-D_L}{0.05\frac{\Delta P_L}{q_{ref}}\ln(1-PF)}$$

Where, $\Delta P_L / q_{ref}$ =17.5

$$PF = \frac{T_{max}-T_4}{T_4-T_3}$$

PF = 0.25

L_L=300 mm

B) CATIA MODELLING

In the design of the annular combustor prototype, the simple dimensions of the combustor found using the design calculation were worn. In the CATIA V5R20 code, three CATIA models fulfilling the specification of the project work are modelled for the purposes of the work related to this paper. The designed models were shown in the CATIA wireframe design to better understand the various structural designs.

i) Annular Combustor Model

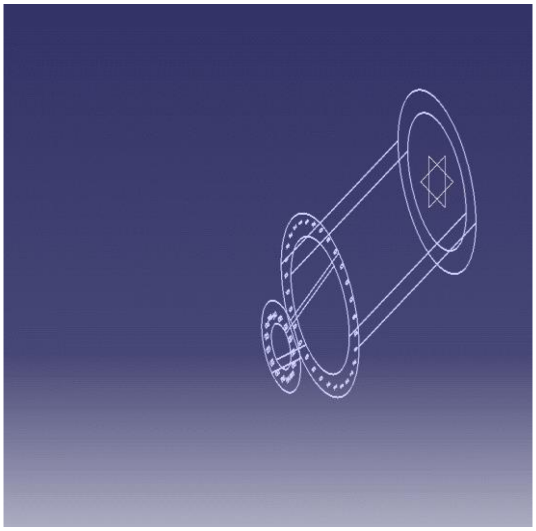

Fig 1. *Wireframe CATIA model of general Annular Combustor*

ii) Annular Combustor Model with Flat Swirl

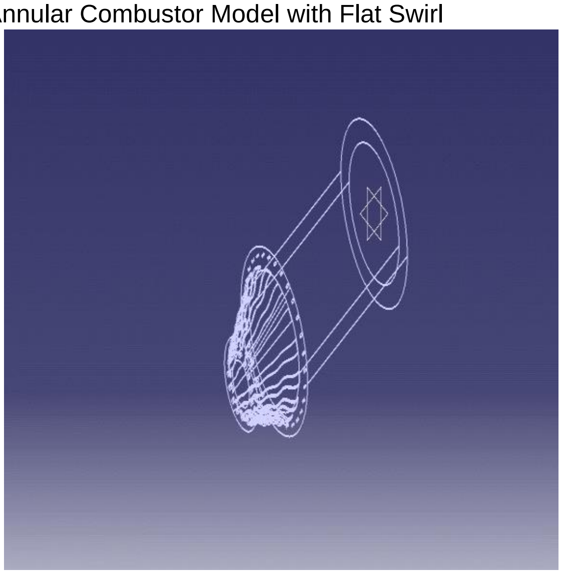

Fig 2. *Wireframe CATIA model of Annular Combustor Model with Flat Swirl*

iii) Annular Combustor Model with Curved Type Swirl

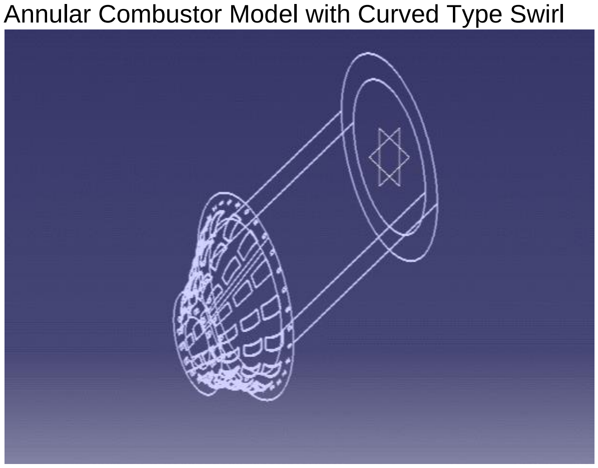

Fig 3. *Wireframe CATIA model of Annular Combustor Model with Curved Type Swirl*

C) CFD FLUENT ANALYSIS

The designed CATIA system was imported into the CFD fluent development framework in the ANSYS WORKBENCH. The prototype was meshed in the software's mesh component.

3. CFD MODEL

This section provides a detailed view of the analysis in the ANSYS software. These involve meshing the annular combustor CATIA models designed in conjunction with the fluent simulation process carried out in the ANSYS workbench. In the research process, it was complicated to conduct a comparative analysis on the pressure drop in the different built models and to find the optimal configuration suitable for the modern aircraft engines based on the results obtained.

A) MESHING

Meshing is the method of separating the geometry into smaller and smaller components so that it is possible to apply the governing equations to all these sub-domains. The various designed CATIA framework has been incorporated into the ANSYS software design system. Once importing the model into the development model, the imported CATIA models are converted from the CAT component format to the STP file type. The geometry is ready for the mesh workbench to be transferred. The geometry was attached in the mesh workbench and then the model was finely split into very fine tetrahedral type meshes. The fine tetrahedral type mesh of the various geometry of the annular combustor designed are shown below:

i) Annular Combustor Model

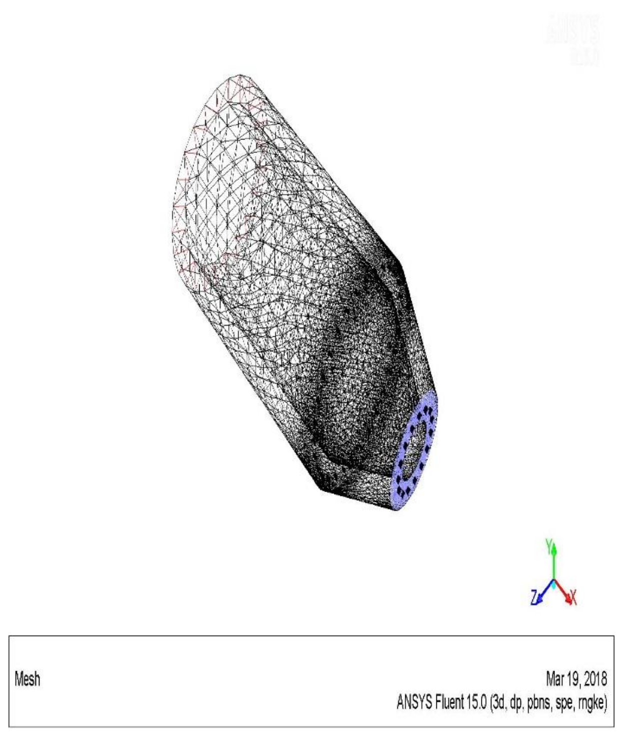

Fig 4. *Mesh diagram of general Annular Combustor Model*

ii) Annular Combustor Model with Flat Swirl

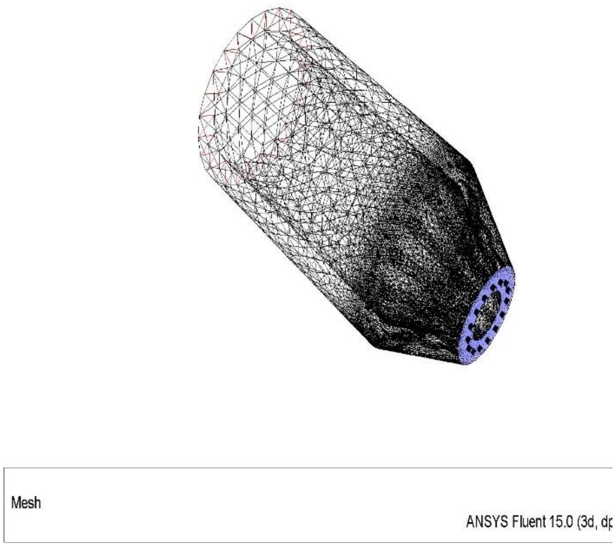

Fig 5. *Mesh diagram of Annular Combustor Model with Flat Swirl*

iii) Annular Combustor Model with Curved Type Swirl

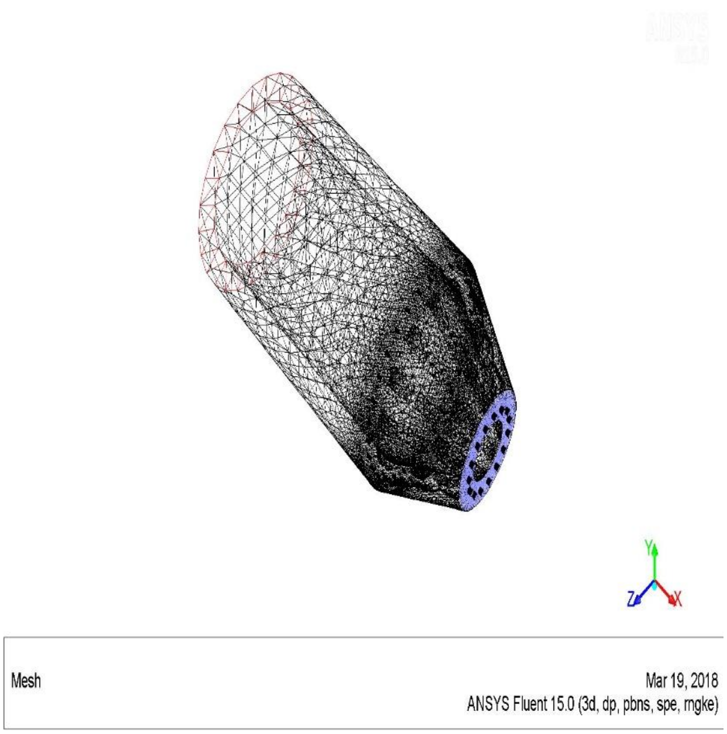

Fig 6. *Mesh diagram of Annular Combustor Model with Curved Type Swirl*

B) FLUENT NUMERICAL SOLUTION

The geometry mesh was then used for analysis in the ANSYS fluent portion of the CFD. The method of fluent simulation involved evaluating the different models of the combustor meshed under the equation analysis of the species transport type. The simulation turbulence model focused solely on the realizable model K-π. The solver worn in the resolution process was based on strain using the Semi Implicit Stress Linked Equations algorithm.

4. RESULTS AND DISCUSSION

The practical model developed was analyzed based on species transport equation model. The analysis was carried out with higher accuracy using the combustion-turbulence interaction model and the result shows the comparative studies between the different annular combustor configuration were obtained. The various models pressure contour, turbulent intensity obtained are shown below.

A) PRESSURE CONTOUR

i) Annular Combustor Model

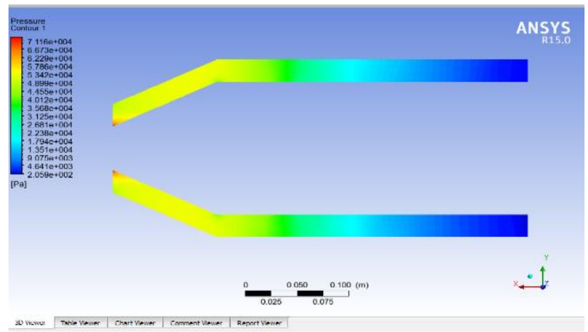

Fig 7. *Pressure contour of general Annular Combustor Model*

ii) Annular Combustor Model with Flat Swirl

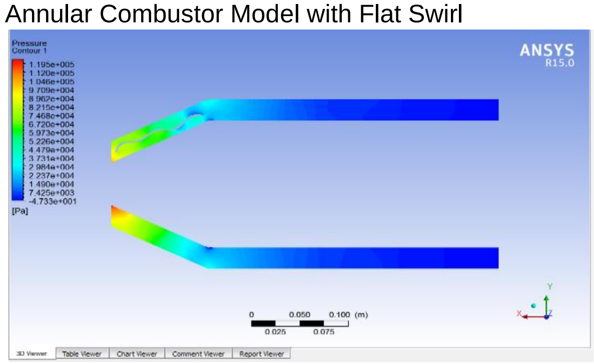

Fig 8. *Pressure contour of Annular Combustor Model with Flat Swirl*

iii) Annular Combustor Model with Curved Type Swirl

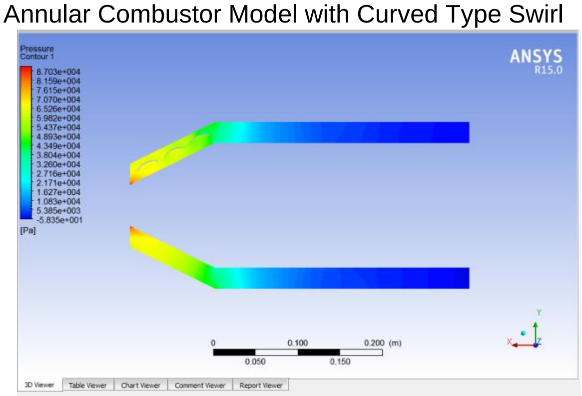

Fig 9. *Pressure contour of Annular Combustor Model with Curved Type Swirl*

B) TURBULENCE INTENSITY

i) Annular Combustor Model

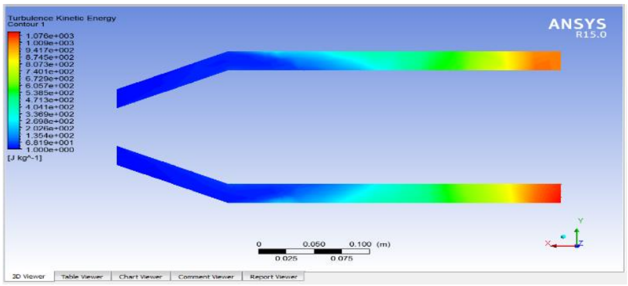

Fig 10. *Turbulent kinetic energy of Annular Combustor Model*

ii) Annular Combustor Model with Flat Swirl

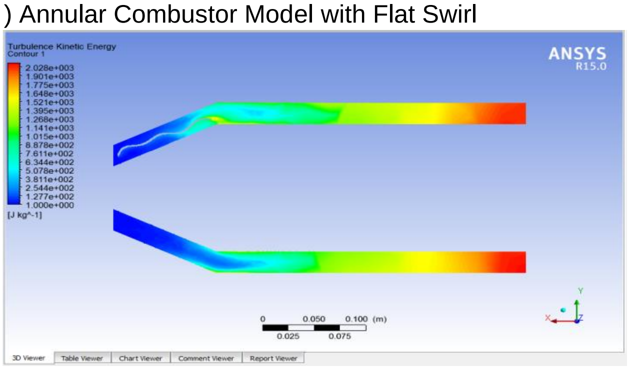

Fig 11. *Turbulent kinetic energy of Annular Combustor Model with Flat Swirl*

iii) Annular Combustor Model with Curved Type Swirl

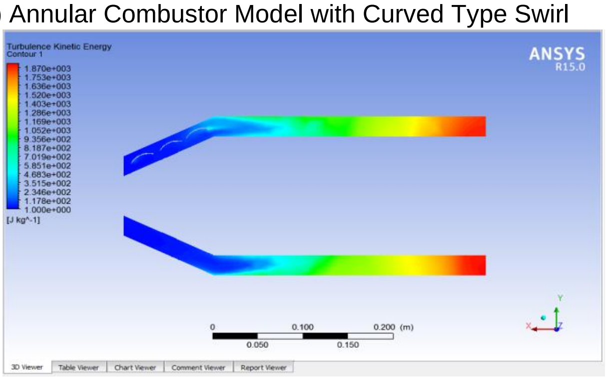

Fig 12. *Turbulent kinetic energy of Annular Combustor Model with Curved Type Swirl*

5. CONCLUSION

Efficient estimation and simulation of the annular combustor system's different configuration. Also produced was the simplified design required to evaluate the different combustor configuration. At the design point, the model was then subjected to aerodynamic analysis and the result-based optimized design was obtained. The flow field comparison for the different types of annular combustor model resulted in a high turbulence intensity that produced a high mixing efficiency of the kerosene fuel with the air and increased the reaction between the air and the fuel. The analysis of the pressure drop was performed in the different configuration of the combustor system. The findings have thus resulted in an efficient design of the combustion chamber that can be used in the modern aircraft engine.

1. REFERENCES

2. [1] H. Cohen, G.F.C. Rogers, H.I.H. Saravanamuttoo, Gas Turbine Theory, Fourth ed., Longman Group Limited, Essex, England,1996.
3. [2] Mellor, A.M. and Fritsky, K. J,1990," Turbine Combustor Preliminary Design Approach," J. Propul.Power,6(3), pp.334-343.
4. [3] Durst F, Wennerberg D,1991, Numerical Aspects of Calculation of Confined Swirling Flows with Internal Recirculation.Int.J. Numerical methods Fluid,12, pp.203-224.
5. [4] Jones.B,2010, Gas Turbine Combustor Design, Gas Turbine Combustors Short Course, Cranfield University, Cranfield.
6. [5] Gupta, A.K. Lilley, D.G. and Syred, N,1984, Swirl flows, Abacus, Tunbridge Wells, UK.
7. [6] Mohd Jaafar MN, Eldrainy YA, Ahmad MF,2009, Investigation of Radial Swirler Effect on Flow Pattern inside Gas Turbine Combustor. Model Appl.Sci.,3(5), pp.21-30.
8. [7] G. Ofualagba, The, The modelling and Simulation of a Microturbine Generation System.int, J.sci. Eng. Res.2,2012, pp.1-7.
9. [8] Yehia AE, Hossam SA, Khalid MS, Mohd Jaafar NM,2010, A Multiple Inlet Swirler for Gas Turbine Combustors.Int.J. Mechanical Syst.Sci. Eng,2(2), pp.106-109.
10. [9] Melconian, J.W. Modak, Combustors Design, Saywer's Gas Turbine Engineering Hand Book: Theory and Design, Vol.1,1985.
11. [10] G.C. Krieger, S. Paulo, F.L.S. Filho, R.C. De Souza, A Swirler Stabilized Combustion chamber for a Micro Gas Turbine Fuelled with Natural Gas, J.Braz.Soc.Mech.Sci.Eng.34,2012, pp.441-449.
12. [11] Ilker and Yilmaz,2013," Effect of Swirl Number on Combustor Characteristic in Natural Gas Diffuser Flame", Journal of Energy Resources Technology, Vol.135.
13. [12] C. Priyant Mark and A. Selwyn," Design and Analysis of an Annular Combustion Chamber of a Low Bypass Turbofan Engine in a Jet Trainer Aircraft", 2018
14. [13] A.R. Sivaram, R. RajaveL, K. Umanath, S. Ruban kumar & S. B. Narayana swamy, A technical review on emulsion fuel with nano additives, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Vol. 8, Special Issue 7, Oct 2018, 1196-1200