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PERFORMANCE ANALYSIS OF COMBUSTION CHAMBER WITH CAVITY FLAME HOLDER

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Abstract:

This project involves the performance analysis of subsonic combustion of a gas turbine engine with cavity flame holder and stepped cavity fame holder. The fuel is injected upstream of the cavity and the cavity sustain the flame over a time. The provided cavity flame holder enhances the mixing and combustion efficiency. The same principle with same boundary conditions is applied to a combustion chamber of stepped cavity geometry. To improve the performance using cavity combustion chamber, this work discusses the solution of the flow field using CFD tools.

Key words: *Cavity flame holder, Mixing, Stepped cavity flame holder.*

INTRODUCTION

Combustion plays a major role in jet propulsion. There are many techniques such as micro flame holder, to improve the combustion efficiency and mixing. Micro flame holder sometimes fails to stabilize the flame due to total pressure loss in the combustor. So we are going to make a cavity in the combustion chamber in which the fame will be settling for a long time. Using K-ω model equation with smooth wall function, the problem is analyzed in computational fluid dynamics. Wu. M., Yetter and Yang V[1]., experimentally investigated the micro scale liquid propellant combustors, which utilized the vortex combustion concept. Singh .D , Carpenter. M and Drummond.J[2] investigated the Thrust enhancement in hyper velocity nozzles by chemical catalysis. Taha. A , Tiwari. S and Mohieldin. T[3] studied about the Pilot injection and flame characteristics of propane combustion in scramjet engine. Cheng .Z , Wehrmerer. J and Pitz. R[4] submitted the proceedings of Downstream interaction of lean premixed flame. Gruber . M , Mathur . T, Baurle. R and Hsu. K[5] studied about the cavity based flame holder concept for supersonic combustors. Ben – Yarker. A and Hanson. R[6] experimentally studied about the cavity flame holders for ignition and flame stabilization in scramjets. Hassa . C ,Carl. M, Forderman. N , Behrendt. T , Heinze. J , Fleing, C , Meier. U[7] investigated the planar combustor sector at realistic conditions experimentally and numerically. Aso . S.Yamanae. Y, Ando . Y , Umii. K , Tokunaga. K and Sakata. K[8] studied experimentally about the swept ramp injectors placed in supersonic mixed flow field. T.K.G Anavaradham, B.U Chandra. V, V.Babu and S.R Chakravarthy and S. Paneerselvam[9] did the experimental and numerical investigation of confined unsteady supersonic flow over cavities. Adela Ben – Yarkar and Ronald K. Hanson[10] studied about the ignition of cavity flame holders and flame stabilization in scramjet.

DESIGN AND ANALYSIS OF CAVITY FLAME HOLDER AND STEPPED CAVITY FLAME HOLDER

Gas turbine combustor with square cross section is designed using Catia. The dimensions are enlisted below and shown in figure 1and figure 2.

COMPONENTS	LENGTH (mm)	WIDTH (mm)
Inlet	30	30
Outlet	50	50
Fuel Inlet	3 (2mm projected inward)	
Cavity	48	17
Divergence angle of outlet	2 degree	

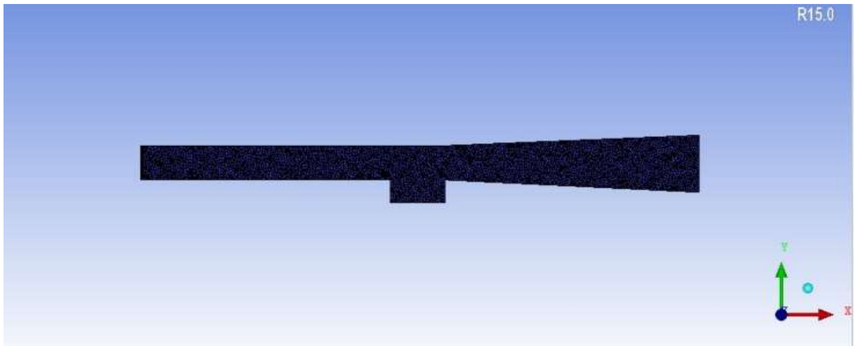

Figure 1: Mesh surface of combustion chamber with cavity holder

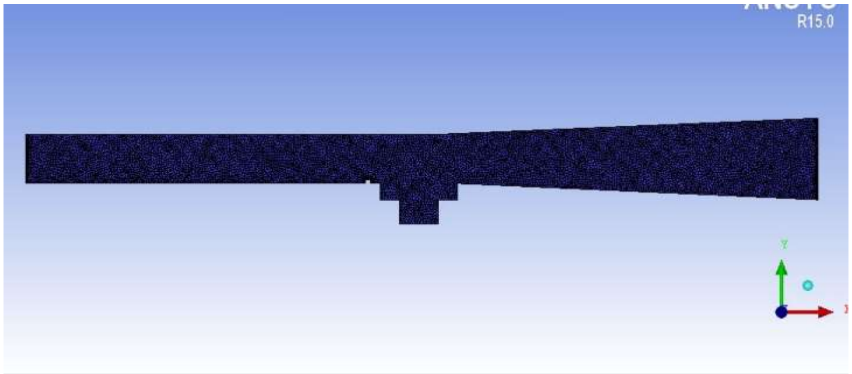

Figure 2: Mesh surface of combustion chamber with stepped cavity holder

The very next stage after the design stage is creating the mesh into the surface. Discretizing the given structure into small volumes is called creation of mesh in computational fluid dynamics. Our aim is to create fine mesh in order to capture the cavitieseffectively.Using ICEM fine mesh is created and elements used here is tetrahedral.

The interactive process in the entire section is the simulation. We are going to simulate our problem in CFX-PRE, in which effective results are gained. Our solver use three types of models such as Eddy dissipation model, P1radiation model and laminar flamelet model.

RESULTS AND DISCUSSION

From the distribution mass fraction of CH_4as shown in figure 3,4 and figure 11,12, the fuel air is very well mixed in stepped cavity flame holder as compared to cavity flame holder. From the graphical representation, fuel inlet located 400 mm from the inlet and the distribution of methane is plotted. It drastically increases at the fuel inlet and mixed with air in regular a regular manner. A sharp decrease in methane in stepped cavity shows the thorough distribution of fuel.

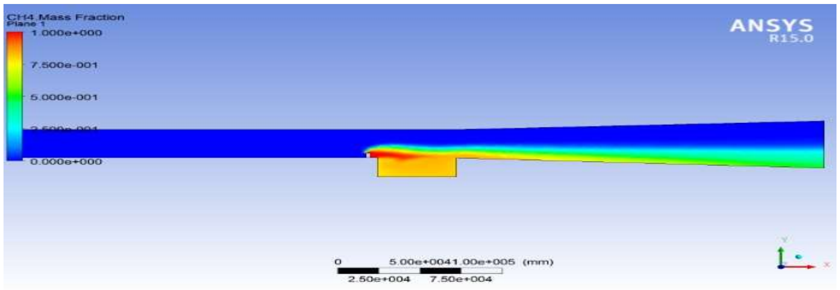

Figure 3 : Distribution of CH_4 mass fraction of combustion chamber with cavity flame holder

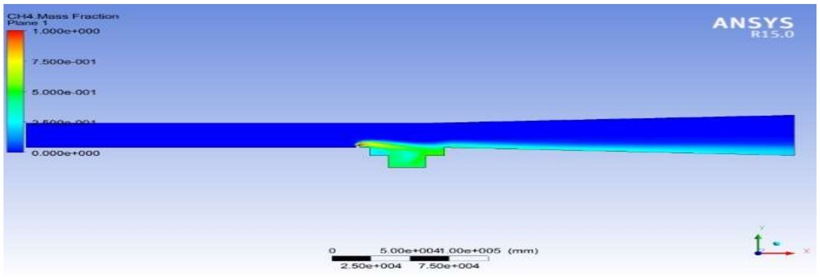

Figure 4: Distribution of CH_4 mass fraction of combustion chamber with stepped cavity flame holder

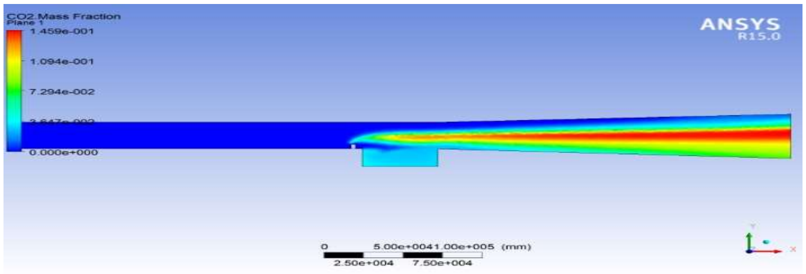

Figure 5: Distribution of CO_2 mass fraction of combustion chamber with cavity flame holder

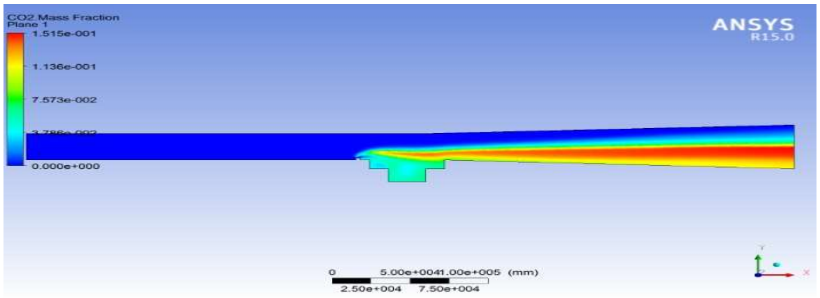

Figure 6: Distribution of CO_2 mass fraction of combustion chamber with stepped cavity flame holder

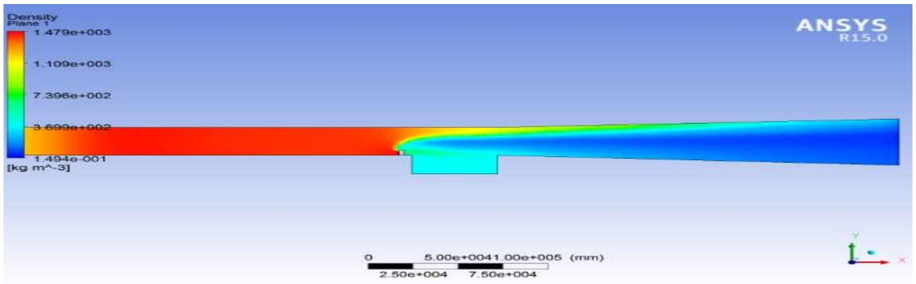

Figure 7 : Distribution of Density of combustion chamber with cavity flame holder

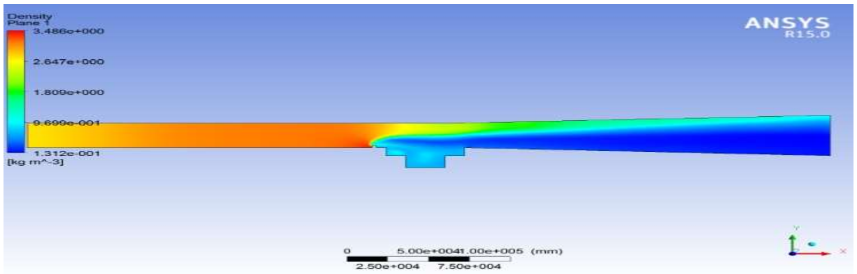

Figure 8 : Distribution of Density of combustion chamber with stepped cavity flame holder

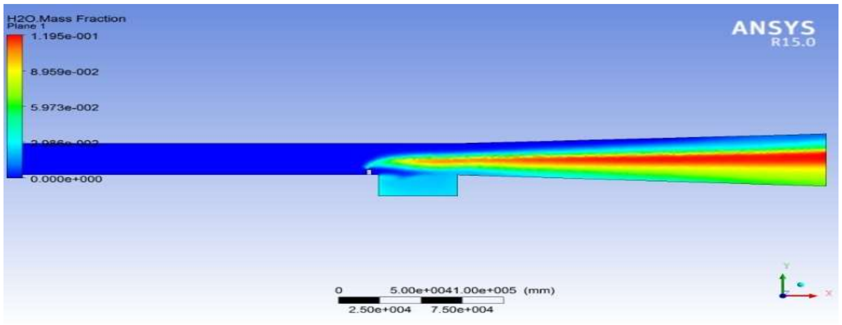

Figure 9: Distribution of H_2O mass fraction of combustion chamber with cavity flame holder

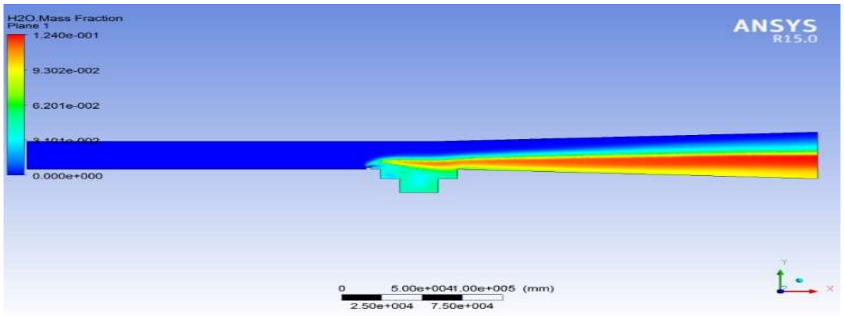

Figure 10: Distribution of H_2O mass fraction of combustion chamber with stepped cavity flame holder

From the distribution of CO_2as shown in figure 5, 6 and figure 13, 14, it is evident that the flame is stabilized till the end of the process and the upcoming flame will enhance the reaction while restoring it.
The density distribution in figure 7,8and graphical representation in figure 15,16 reveals that the air and fuel is mixed at constant proportions and burned completely because the density of hot air is lesser than the cold air. The cavity hold the air fuel mixture in some amount and the flame is stabilized also if the Mach number in the combustion chamber is further increased.

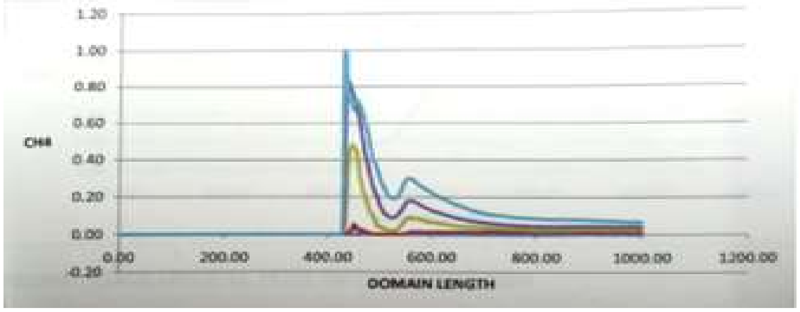

Figure 11: Graphical representation of CH_4 mass fraction of combustion chamber with stepped cavity flame holder

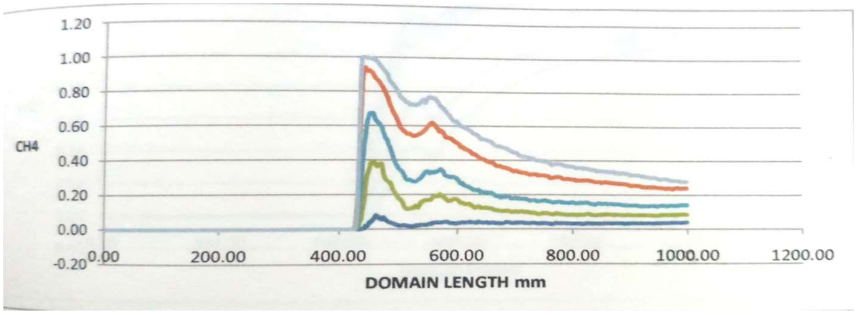

Figure 12: Graphical representation of CH_4 mass fraction of combustion chamber with cavity flame holder

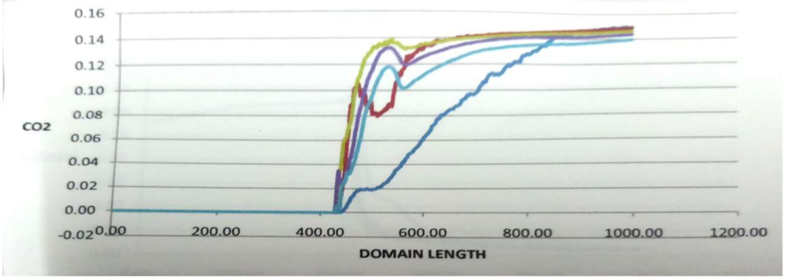

Figure 13: Graphical representation of CO_2mass fraction of combustion chamber with stepped cavity flame holder

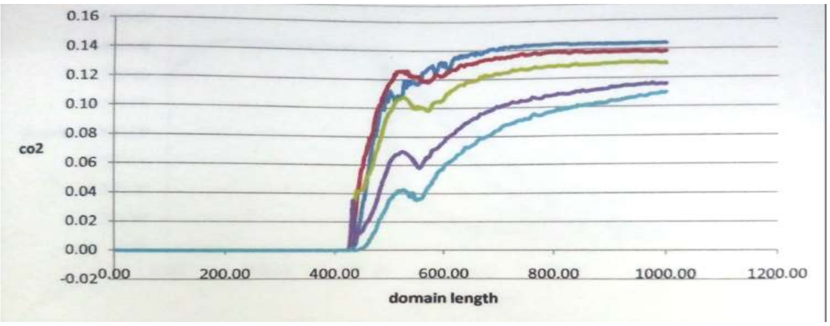

Figure 14: Graphical representation of CO_2 mass fraction of combustion chamber with cavity flame holder

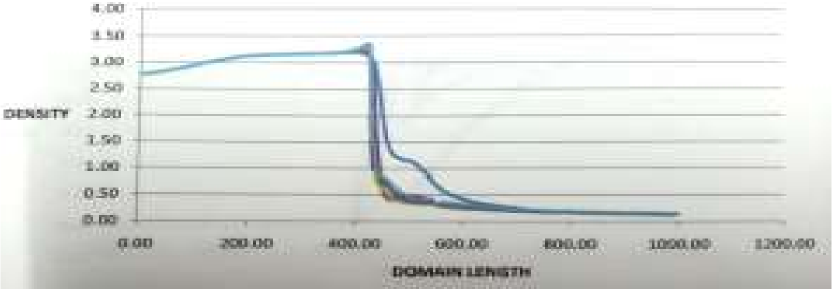

Figure 15: Graphical representation of Density of combustion chamber with stepped cavity flame holder

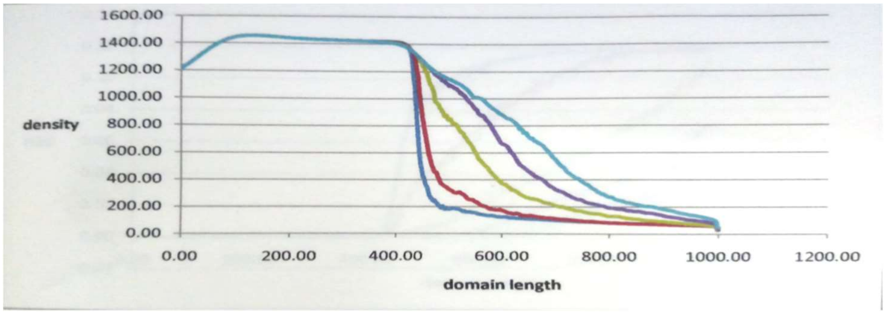

Figure 16: Graphical representation of Density of combustion chamber with cavity flame holder

Due to the multiple stepped cavity, the fuel air mixture find hard to escape from the cavity against due to gravity. The only way to escape from it is the upcoming mixture should replace it and the fresh mixture will stay for some seconds. The process is going on continuously and the flame is stabilized.

In the stepped cavity, due the corners of the step a wake like turbulence formed. It mixes with the fresh mixture and the process is continuous in nature.

Conclusion

Performance of cavity combustion chamber and stepped cavity combustion chamber was studied. From the analysis it is revealed that combustion chamber with stepped cavity flame holder stabilize the flame more efficiently than the combustion chamber with normal cavity of same geometry size.

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