PSYCHOLOGY AND EDUCATION (2016) 53(1): 34-38
ISSN:1553-6939

Computational Fluid Dynamics Strut Flame Holder Efficiency ffor Supersonic Combustion

AG.MALLIKARJUNA, Associate Professor & Head of H&S Dept., St.Johns College of Engineering and Technology, Yemmiganur, Kurnool(Dist.). E_mail Id: mallipraveena1023@gmail.com

S VEERA REDDY,Research schloar of Rayalseema university.,Associate Professor & H&S Dept., St.Johns College of Engineering and Technology, Yemmiganur, Kurnool(Dist.)KURNOOLE_mail Id: veerakuppagallu@gmail.com

Abstract : For hypersonic vehicles, the ramjet engine's supersonic burning process is considered a suitable propulsion technology. The flow in the combustor has an extremely short residence time (milliseconds) due to the supersonic combustion. Fuel-air mixing and combustion efficiency have been evaluated using both normal and tangential fuel injection.. Shocks and vorticity created in the combustor keep the flame in place and prolong its stay in there. For CFD analysis, the commercial numerical programme ANSYS FLUENT 15 is used. ICEM CFD is used for geometry and meshing, whereas FLUENT is used for analysis. Simulated flow field of hydrogen-fueled scramjet combustor has been used to the finite-rate/eddy-dissipation reaction model. Fuel injector count is being investigated at different Combustor inlets with a Mach number of 2.0 and fuel being introduced under sonic circumstances. Combustion efficiency is measured as a function of the total mass of H2O in the combustor. Aiming for a better fuel-air combination in the combustion chamber and achieving optimum combustion efficiency were the main goals of the work done.

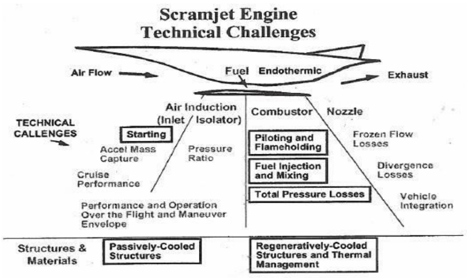
***IndexTerms* - Combustion, Flame, Holder, Ramjet, Engine, Strut.**

I. INTRODUCTION

This Turbojets and ramjets are the air-breathing engines that can fly at a maximum speed of Mach 6 in the atmosphere. However, rockets have been utilised for a wide variety of applications, from missiles to lunar missions, all the way up to speeds exceeding Mach 20. Even while rockets have fulfilled their purpose well so far and will continue to do so for some time to come, the drawback of bringing oxygen on board with the fuel is a significant one. There is no need to transport big oxygen tanks when there is so much free ambient oxygen accessible in the environment. According to recent research, aircraft and multistage rocket transportation vehicles typically have a 15% and 4% payload weight fraction, respectively. Researchers throughout the world have been inspired by this issue to seek for a better answer. The intake, isolator, combustor, and exhaust nozzle are all parts of the Scramjet engine. Through a sequence of oblique shockwaves, the input warms and slows the flow. Allowing additional flow slowing, Isolator helps to isolate combustor from engine's intake port. Free-stream supersonic air is combusted with fuel in the combustor, increasing pressure and temperature. This is accomplished by expanding the flow via the use of nozzles, which offers a mechanism for converting the increase in pressure into forward propulsion.

In Fig. 1, the primary technical problems of scramjets are shown as a schematic. The study of combustion in supersonic flows has recently been boosted by scramjet engine research and development in recent years. The scramjet engine powered by hydrocarbon fuel is continuously being studied and researched. Ground testing facilities, numerical simulation, and combustor mixing are all crucial to the development of the scramjet engine.

Fig.1. Schematic diagram of scramjet engine



For the numerical simulation of the flow field of the hydrogen fuelled scramjet combustor with cavity flameholder, Wei Huang[1] employed k-turbulence and finite-rate/eddy-dissipation reaction models. The boundary layer and the oblique shock wave have a complicated shock wave/shock wave interaction. Because it is a flame support for supersonic combustion, no specific cavity design has been offered despite this fact. Cavities with steeper ramp angles have lower drag coefficients and shorter residence periods than cavities with longer lengths and sloped back walls, as discovered by M.R.Gruber et al. [2] in their experimental and computational studies of the non-reacting flow. Larger cavities (L/D=7) exhibited a much greater drag coefficient than smaller cavities (L/D=3), according to Ben – Yakar and Hanson[4]. Reduce the rear wall angle below 90 degrees to increase drag. An increase in the amplitude of vorticity suggests that the flowfield is more efficient in mixing air and fuel, according to the findings of Hyungseok SEO et al [5]. Vorticity is increased and fuel-air mixing is improved by increasing the cavity size. No matter how much fuel is injected at an angle, the combustor's overall pressure distribution remains the same. Consequently, the combustor's cavity shape has the largest impact on the distribution of pressure in the combustion chamber. EunjuJeong et al [6] found that the rear-cavity oblique shock had a greater impact on total heat release than the cavity effect. With struts, fuel may be injected directly into the centre of a supersonic flow without the need for a high fuel supply pressure. There is an inherent increase in overall pressure losses and drag when struts are used instead of non-intrusive techniques. Having access to gasoline No improvement in penetration height was found by Chung-Jen Tam et al [7] because fuel tends to be pushed lower at the trailing edge owing to flow expansion.

II. MATERIALS AND METHODS

For many applications, the SCRAMJET Combustor is an isolator-starting rectangular duct with a constant-area isolator to create a flow with a uniform divergent section for effective thrust generation. Supersonic flow makes mixing and combustion almost impossible. With increased pressure and temperature comes oblique shocks that restrict velocity flow. This is why the current study uses a strut flame holder.

Modeling:

According to KM Pandey et al [8], the geometry for this issue has been derived from Fig.2, Fig.3., and Fig.4. and Fig.5. ANSYS ICEM CFD is used to develop the geometry.

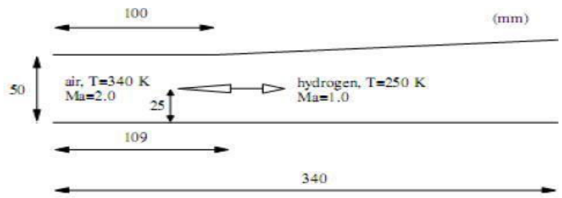


Fig.2. Schematic diagram of scramjet engine

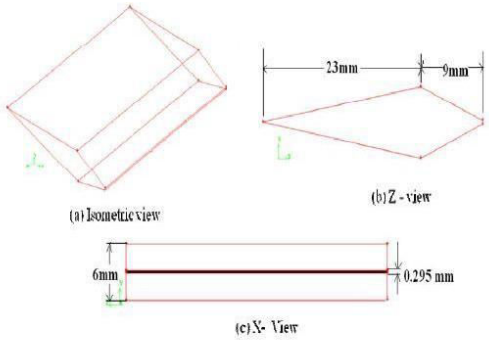


Fig.3. Strut Dimensions (Courtesy KM Pandey et.al. 2011)

Boundary conditions:

The problem's complexity and the starting inputs are defined by boundary conditions. When the right circumstances aren't met, the issue becomes divergent, and erroneous outcomes follow. KM Pandey [8] provides the initial boundary conditions, as given in Table-I [8].

Table-I Boundary conditions

Variable	**Air**	**Fuel (H_2)**
Mach	2	1
Pressure (Pa)	101325	101325
Velocity (m/s)	730	317
Temperature (K)	340	250
Density (Kg/m^3)	1.125	0.0097
Oxygen mass fraction	0.232	0
Nitrogen mass fraction	0.736	0
Hydrogen mass fraction	0	1

Different cases tested in CFD are shown in Table-I.

Table-I Different cases selected for CFD Analysis

Case	**Mach Number**	**Injectors**
1	2	1,3 Tangential
2	2	1,3 and 5 Normal

III. RESULTS AND DISCUSSION

Using ANSYS CFD POST results of the present analysis are extracted with H_2 and H_2o mass fractions. Because the mixing efficiency of fuel is known by Hydrogen mass fraction and combustion efficiency is known by H_2o mass fraction along the combustor.

Case-1: variation of H2 mass fraction for M=2 with 1, 3 tangential injectors

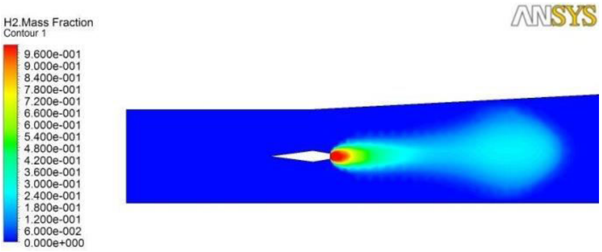


Fig.6. H_2 mass fraction for M=2 with 1 tangential injector

It is shown in the Fig.6. that fuel H_2 is injected from the base of the strut at X≅110mm and mixing is completed at X ≅250mm

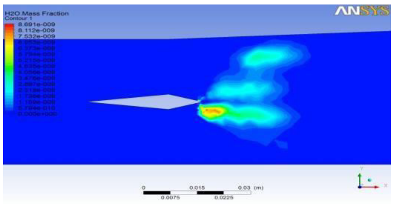


Fig.7. H_2O mass fraction for M=2 with 1 tangential injector

It is observed that the combustion is completed at X≅ 180mm and maximum mass fraction of H_2O 8.691$\times 10^{-9}$ is reached at X≅155mm.

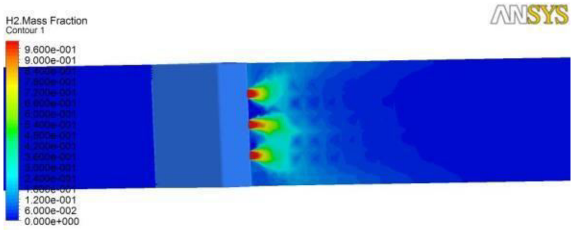


Fig.8. H_2 mass fraction for M=2 with 3 tangential injectors

It is shown that fuel is injected from the base of the strut at X ≅ $110m$ it is observed that mixing is completed at X≅142mm

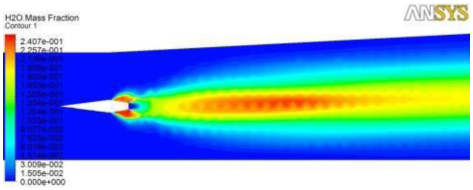


Fig.9. H_2O mass fraction for M=2 with 3 tangential injectors

From the Fig.9. it is observed that the combustion is completed at X≅ 250mm and maximum mass fraction of H_2O is 0.2407 which is reached at X≅225mm

With single injector the distribution of fuel or fuel air mixing is delayed leading to delay in combustion as shown in above figures. Single injector with red line combustion is late when compared to 3 injectors with green and blue lines.

Case 2: M=2 with 1,3 and 5 Normal Injectors

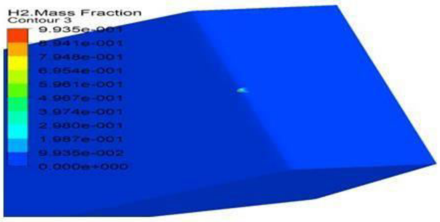


Fig.10. H_2 mass fraction for M=2 with 1 normal injector

It is observed that maximum mass fraction of H_2 obtained at X≅ 100mm and the mixing is completed at X≅ 107mm.

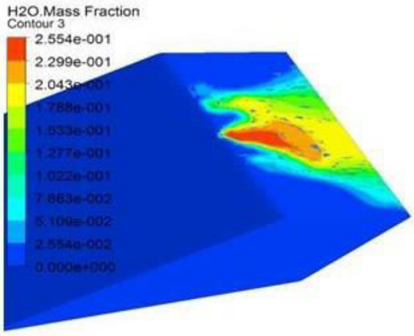


Fig.11. H_2O mass fraction for M=2 with 1 normal injector

From the Fig.11. it is observed that the maximum mass fraction of H20 obtained at X≅ 109mm for M=2 with 1 normal injector is 0.2554 whereas minimum is 0.0255

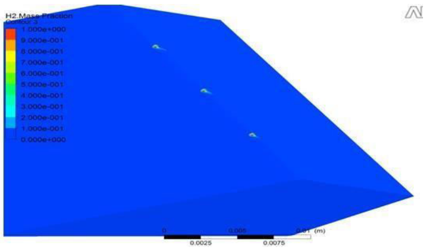


Fig.12. H_2 mass fraction for M=2 with 3 Normal injectors

From the Fig.12. it is observed that maximum mass fraction of H_2 obtained at X≅ 100mm and the mixing is completed mostly at X≅ 105mm.

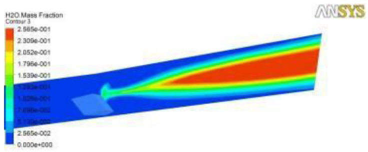


Fig.13. H_2O mass fraction for M=2 with 3 Normal injectors

It is observed that the combustion is completed at X≅ 327mm and maximum mass fraction of H_2O is 0.2565 which is reached at X≅279.46mm.

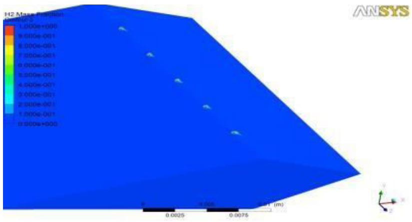


Fig.14. H_2 mass fractions for M=2 with 5 Normal injectors

III. CONCLUSIONS

It is necessary to look at the planer strut flame holding mechanism in supersonic flow using the three-dimensional coupled implicit RANS equations, conventional k- turbulence model, and finite-rate/eddy-dissipation response model. Under various variables, such as the number of fuel injectors and Mach number, the flow field of the hydrogen fueled scramjet combustor with a strut flame holder is studied. Compared to Tangential injection, normal-direction injection provides greater mixing of fuel and air, resulting in a more efficient combustion process.

REFERENCES

[1]. Wei Huang, Shi-bin Luo, Mohamed Pourkashanian, Lin Ma, Derek B.Ingham, Jun Liu and Zhen-guo Wang Numerical simulations of a Typical Hydrogen Fueled Scramjet Combustor with a cavity Flameholder WCE 2010, June 30-july2, 2010, London.

[2].Gruber MR, Baurle RA, Mathur T and Hsu KY. Fundamental studies of cavity-based flameholder concepts for supersonic combustors. Journal of Propulsion and power, 17(1): 146-153,2001.

[3].Wei Huang, Zhen-guo Wang, Shi-bin Luo and Jun Liu Effect of cavity flame holder configuration on combustion flow field performance of integrated hypersonic vehicle Sci China Tech Sci, 53:pp. 2725-2733, 2010.

[4].Adela Ben-Yakar and Ronald K. Hanson Cavity Flame-Holders for Ignition and Flame Stabilization in Scramjets: An Overview JOURNAL OF PROPULSION AND POWER Vol. 17, No. 4, Aug 2001.

[5].Hyungseok SEO, Hui JEONG, Jaewoo LEE and Yunghwan BYUN " A Study of the mixing Characteristics for cavity sizes in Scramjet combustor" Journal of the Korean Physical Society, Vol. 55, No. 5, pp. 2180~2186, Nov 2009.

[6].EunjuJeong, Sean O'Byrne, In-seuckJeung and A.F.P. Houwing "Investigation of Supersonic combustion with Angled injection in a Cavity-Based Combustor" JOURNAL OF PROPULSION AND POWER Vol.24, No. 6, Nov-Dec 2008.

[7].Chung-Jen Tam, Kuang-Yu Hsu, Mark R. Gruber, Charbel N. Raffoul Fuel/Air mixing Characteristics of Strut Injections for Scramjet Combustor Applications 5th Applied Aerodynamics Conference, Honolulu, Hawaii, Aug 2008.

[8].K.M.Pandey and T.Sivasakthivel CFD Analysis of Mixing and Combustion of a Scramjet Combustor with a Planer Strut Injector International Journal of Enviromental Science and Development, Vol. 2, No. 2, April 2011.

[9].K.M. Pandey and A.P. Singh Numerical Analysis of Supersonic Combustion by strurt flat duct length with a Turbulence model IACSIT International journal of Engineering and Technology, Vol. 3, No 2, April 2011.

[10].K.M. Pandey, B.K. Azad, S. P.Sahu and M. Prajapati Computational Analysis of Mixing in Strut Based Combustion at Air Inlet Mach number 2 International journal of Enivironmental Science and Development, Vol 2, No 1, Feb 2011**.**