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NOTCHED FLAME HOLDERS FOR JET ENGINES

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ABSTRACT

An extensive investigation has been carried out to outline the reattachment point, reverse flow region, stay period of reverse flow and vortex size crafted by conical and hemispherical flame holder models in a transparent water flow channel. Six types of models with base length of 60 mm were carved from the wood. Surface of each model were grooved triangular (teeth) and semi-circular (arc). The depth of each groove is 10 mm. The flow visualisation was carried out for all six models at Reynold's numbers (Re) ranging from of 9000 to 20000. It was observed that conical model is more efficient compared to hemispherical model at all Reynold's number tested. Among all the models conical model with teeth type groove exhibits it efficiency at all the Reynold's numbers studied. As much as 350% increment in wake length was noticed at Re 15000.

Keywords: Conical, hemispherical, groove, vortices, Reynold's number.

I.INTRODUCTION

Flame holding, flame stabilization and mixing enhancement are the fundamental aspects of the combustion chamber and crucial for development of an air breathing propulsion engine. In general, flame holding and flame stabilization can be achieved by the following techniques: (i) by organizing of the recirculation area where the fuel and air can be mixed partially at low velocities (ii) by interaction of mass entrainment with partially or fully mixed fuel and oxidizer. (iii) by formation of coherent structures containing unmixed fuel and air where the diffusion flame occurs as they are convicted downstream [3]. Using a bluff body is another method to stabilize high-speed flows which influences the drag coefficients and analysis of wake aerodynamics on stability boundaries [4]. The bluff-body effects the stabilized flame combustor by central jet having higher momentum than air jet, in turns it penetrates through recirculation zone and affects its size [5].Strut based flame holders decelerate the flow, providing more time for fuel air mixing and combustion. Although, this exposes the strut to very high as well as spatially varying pressure and heat flux giving rise to high temperature and stress across its structure [11]. Research was carried out on flame holder device having ring with a continuous cross section of revolution in the shape of a U or V. The plurality of flame holder arms having a continuous cross section in the shape of a U or V and radiating from one of the flanks of the ring. According to the study, each arm is attached to the ring by means of gussets which provide slight spacing of the arm from the ring in order to prevent local overheating of the ring due to the recirculation of combustion gases

[2]. A flame holder for an afterburner duct of a jet engine, including an arm in the form of a gutter forming a cavity. It is a shield for protecting the cavity of the arm from heat, and an air supply baffle housed in the cavity, is disclosed. The arm, the protective shield, and the air supply baffle are held together by a one-piece spacer shoe [1]. The v-gutter has a boundary layer that develops from the small-radius leading edge. The thickness of the boundary layer is a function of the Reynolds number of the incoming air. It was also found that for the square shape flame holder, the boundary layer thickness is function of the Reynolds number, but its initiation and development starts from the corners of the leading face. The scale of the v-gutter and square flame holders can also be used to study the effects of the development length on the stability [10].The flame stability limit, lift off and blow out can be affected by the burner geometry in the combustion system installation. Consequently a flame holder has to be put in to hold the flame as big as possible on a stable condition. The flame holder could disturb the air and fuel flow. The fluid flow blockage by the flame holder will generate vortex and this vortex end up with a turbulence condition. This turbulence condition will shift the critical stability limit and will produce a perfect combustion [12]. The effect of increasing the swirl will improve the mixing and flame stability. Mostly only one swirl is incorporated in the combustor, increase in number of swirls actually reduces the turbulence level and flame stability. Excessive swirl also had the disadvantage of forcing the flame to move upstream to a position closer to the burner walls, resulting in excessive wall heating [6].

Stabilization methods of turbulent flames often involve mixing of reactants with hot products of combustion. For stabilizing combustion product, enthalpy and chemical composition plays vital role [7].The flame blowout limit initially increases and then decreases with an increase in plate length. The flame blowout process demonstrates that, the flame is extinguished due to "pinch-off phenomenon" at high inlet velocity. Smaller blowout limit is due to the shorter distance between upper and lower flame fronts [8]. Unpremixed combustion can be understood by combustion process and flame stabilization study [13].The flame is affected by the total fuel equivalence ratio. The structure of the flame was investigated by using the PLIF technology. It was observed that cavity flame holder flame can be stabilized near the bottom wall, aft wall and free shear layer. The heat release region and combustion zone were also illustrated. [14]. Researchers emphasized that the dual-cavity flow path is always smaller than that of the single cavity as the equivalence ratio was increased [9].

II.EXPERIMENTAL SETUP

The experiments were conducted in the Aeronautical Department of Tagore Engineering College using water flow channel made up of acrylic sheet so that visualising the flow around notched cylindrical models with the support of Introduction to fluid mechanics by R.K. Bansal [12].

2.1 Water Flow Channel

The water flow channel was fabricated from acrylic sheet which consists of right angled triangle wedge to settle the flow. Meshes are used to make the flow streamlined as shown in Fig. 1. The design parameters of water flow channel are as follows:

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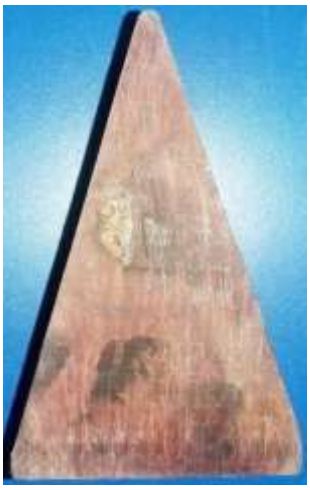
Tank Volume	0.3x0.15x0.1 m
Wedge distance from tank	0.08 m
No of meshes	2
Test section dimensions	0.3x0.3 m
Coloured solution used	Black Ink

An adjustable stand (1.24m x 0.3mx 0.1m) was built to place the setup. Adjustable provision makes stand to level for any uneven surface. Water supply with sock arrangement to avoid turbulence was connected to tank. The wake region was measured with the help of the scale placed at the side walls and the flow was recorded with the help of camera and the report on Computational analysis of flow over slotted cylinder.

Figure 1. Artistic view of acrylic water flow channel



(a)

(b)

Figure 2. A pictorial view of plane (a) cone (b) hemispherical

(a)

(b)

Figure 3. An artistic view of cone (a) teeth (b) arc

III.EXPERIMENTAL PROCEDURE

Models were placed in test section of water flow channel (WFC) and tested for flow velocities 0.09m/s, 0.18m/s,0.21m/s, 0.24m/s and 0.23m/s. The coloured solution of potassium permanganate crystals was ejected through the needle to visualise the wake region behind the models as shown in figure. Wake region is non-dimensionalized with base length of the model and flow velocity is converted to Reynolds Number. The distance between flow separation and reattachment is considered as wake region. Measuring scale is fixed to the side wall of WFC to measure the wake region. Time period of the flow reaching the base of the model in the direction opposite to the flow from the reattachment point is noticed, which is termed as reverse flow. Stay period of the wake is calculated by recording time during of wake stay in the flow channel. The length of the wake is measured after the wake stabilises, with the measuring scale fixed to the vertical wall of WFC. The wake region behind the model has been observed and compared with the different shapes of notches. The flow pattern was visualised and vortex formation was captured by the camera. It is well established fact that wake regions are responsible for drag formation. Farthest the reattachment point, more the drag penalty as illustrated in comparative analysis of experimental and numerical flow visualisation by Ristic S., Isakovic, et al in 2006[15]. Also it was found that reattachment point keeps changing with change in shape and size of notch. A provision of measuring angle of inclination of wakes region is provided in the form of protractor, placed at the bottom of WFC and the method is incorporated in this study with Flow visualisation water tunnel, operating maintenance and instructions by ELD in 1984[16]. The effectiveness of model is defined as smaller region of wake behind the model. The results have been illustrated by plotting the graph Reynolds Number (Re) versus normalised reattachment distance (X/D) as illustrated in flow visualisation in a water channel report by Cimbala [17].

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Figure 4. A view of flow over a plane cone

Figure 5. A view of flow over a teeth cone

IV.RESULTS AND DISCUSSION

Initially cone and hemispherical models of flame holders are analysed to verify the effectiveness. It was observed that conical flame holder is more effective and capable of producing more wake region as high as X/B =2.4 at Re. 17,000. At the same Re. hemispherical model gives X/B=1 as shown in Fig.6

Another study for wake size was conducted for the conical hemispherical flame holder models. Again it was observed that there was gradual increase in wake size with Reynold's number for the models. But conical model proved to be better that hemispherical model. It was found that conical model maximum, wake size W/B = 0.065 at Re 20000 at the same time hemispherical model has W/B = 0.028 as shown Fig.8

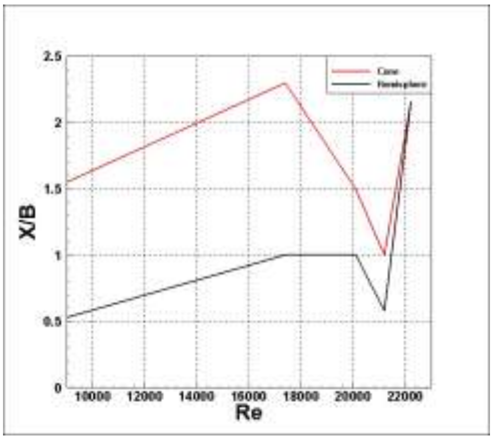

Figure 6. Reattachment location at different Reynold's numbers

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To authenticate the above results the models were tested for time taken by reverse flow to reach back to the base of the model. It is clear from Fig.7 that conical model takes more time to reach the base, there it may regarded as beneficial for mixing enhancement. However gradual decrease can be noticed by increase in Reynold's number.

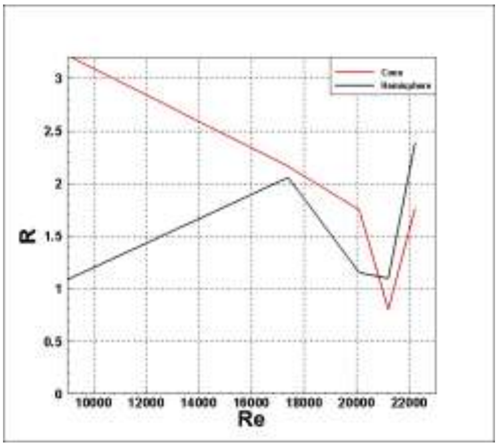

Figure 7. Reverse flow at different Reynold's numbers

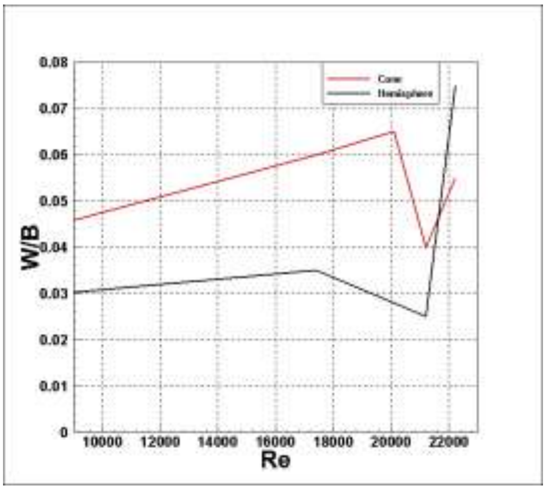

Figure 8. Wake length at different Reynold's numbers

Also it was noticed that in turbulent flow the wake size decreased, and there was sudden jump in the wake size, this may attributed to the transition region i.e change form laminar flow to turbulent flow which is associated with high energy. Therefore wake size is re-energized.

Further experiments were conducted by notching the conical model as teeth (V-cut) and arc cut (Semicircle). Results were compared for reattachment location, reverse flow timing and wake size.

Fig. 9 shows reattachment location of conical, teeth conical and Arc conical. It is demonstrated from the plot that in laminar flow conical model prove d to be better mixing enhancer. But in turbulent region teeth cone is better mixing enhancer compared to other models. Because the gain in reattachment location enhances rapidly in

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turbulent zone compared to other two models tested. It may be noted that the nature is always turbulent. Therefore it is suggested to utilize teeth cone models as a flame holder in jet engine combustor. It was observed that increment in (X/B) is 475% with teeth model, where as 100% and 108% with plane and arc cone respectively. It may be taken as an advantageous for mixing point of view.

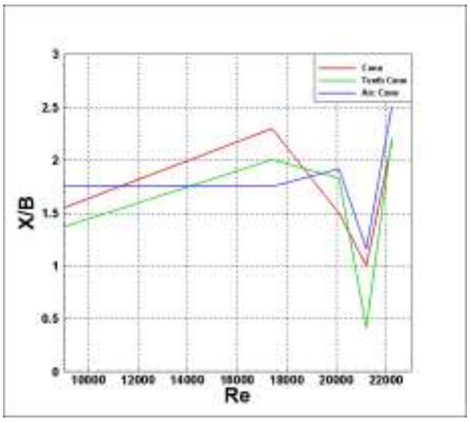

Figure 9. Comaparison of reattachment location of plane, teeth and arc cone at different Reynold's numbers

Fig. 10 illustrates time taken by flow to reach to the base of model (which is called reverse flow). Also it may be noted that more time taken by the flow is beneficial for mixing enhancement. At all the Reynold number teeth cone flame holder is more efficient than other two flame holders tested. The maximum time taken by flow to reach base of the model is approximately 2.9 seconds at Re 20000. However due to re energy in the transition period reverse flow take less time to reach back to the base as clearly evident in the Fig. 10.

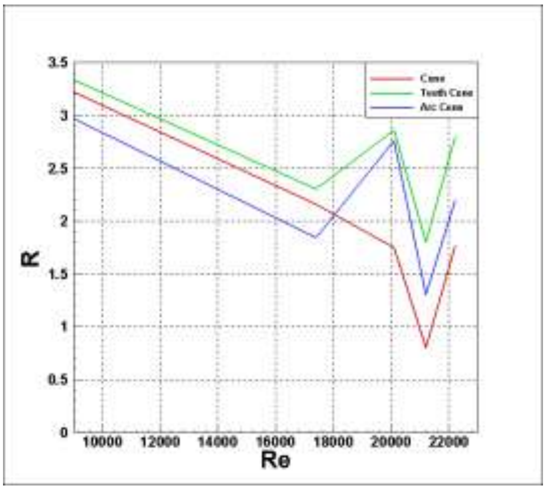

Figure 10. Comaparison of reverse flow timing of plane, teeth and arc cone at different Reynold's numbers

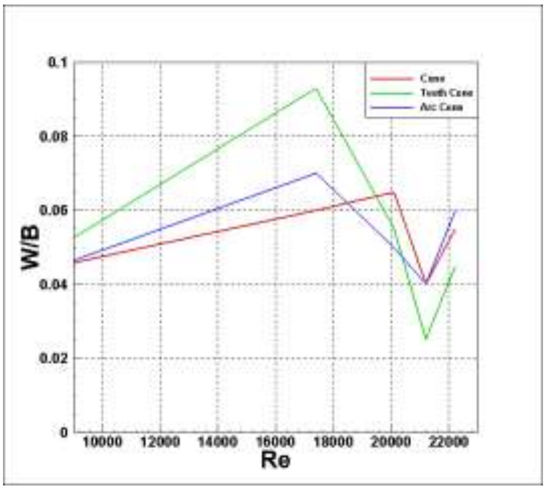

Figure 11. Comaparison of wake size for plane, teeth and arc cone at different Reynold's numbers

From Fig. 11 it is clearly seen that teeth cone model behaves efficiently in laminar zone as high as 63.63% increment in was size was observed. Similarly 44.44% and 37.77% was notified with arc cone and flame cone respectively. The wake size of teeth cone diminishes with increase in Reynolds number. It may be attributed breaking of large wake into small eddies. From literature it is the well established fact that small eddies are always better mixing promoters.

V.CONCLUSIONS

The current study demonstrated that conical flame holder with teeth cut (V-cut) is more influential for mixing air at all Reynold's numbers investigated. Also it was authenticated that small eddies are contributed the teeth cone in turbulent region, which in turn play very crucial role in mixing enhancement.

REFERENCES

[1] Jacques Marcel Arthur BUNEL, Yann Francois Jean-Claude Vuillemenot, Flame holder for an afterburner duct of a jet engine with a spacer shoe, afterburner duct, and jet engine comprising an afterburner duct, US 8307658 B2

[2] Gerald J.P. Bayle Laboure, Marc F.B. Buisson, Roger A.J. Vandenbroucke, Flame holder devices for combustion chambers of turbojet engine afterburner tubes, US 4259839 A

[3] Ben-Yakar, Hanson, R.K. ,Cavity flameholders for ignition and flame stabilization in scramjets, review and experimental study. AIAA 98-3122 (1998)

[4] M. V. Herbert, Aerodynamics influences on flame stability, progress in Combustion Science and Technology (1980) 61.

[5] R. S. Tankin, W. M. Roquemore, H. H. Chiu and S. A. Lottes , A study of a bluff-body combustor using laser sheet lighting, *Exp Fluids*, 4 (1986) 205.

[6] V. Tangirala, R. H. Chen & J. F. Driscoll, Effect of Heat Release and Swirl on the Recirculation within Swirl-Stabilized Flames.

[7] Bruno Coritona, Jonathan H. Frank, Alessandro Gomez, Interaction of turbulent premixed flames with combustion products, Combustion and Flame Volume 170, August 2016, Pages 37-52

[8]Wan, Jianlong, Fan,Aiwu, Yao, Hong, Effect of the length of a plate flame holder on flame blowout limit in a micro-combustor with preheating channels, Combustion and Flame Volume 170,August 2016, Pages 53-62

[9] MacKenzie *J.*, Performance and Operability of a Dual-Cavity Flame Holder in a Supersonic Combustor, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio Thursday, 01 April 2010

[10] Barry Kiel1 and Amy Lynch , Influence of Flame-Holder Shape on Flame Dynamics, Air Force Research Laboratory Wright-Patterson Air Force Base, OH 45433

[11] Anupam Purwar, Thermo-Structural Design of Strut Based Flame Holder for Scramjet Combustor, Springer Singapore

[12] Rudy Soenoko, The Effect of a Flame Holder Shape Modification toward the Diffusion Flame Stability Zone Shift, World Applied Sciences Journal 8 (3): 339-344, 2010 ISSN 1818-4952 © IDOSI Publications, 2010

[13] Jeong, E.J., Byrne, S.O., Jeung, I.S., et al.,Cavity flame-holder experiments in a model scramjet engine,AIAA 2006-7918 (2006)

[14] Brandstetter, A., Rocci Denis, S., Kau, H.P., et al.: Flame stabilization in supersonic combustion. AIAA 2002-5224 (2002)

[15] Ristic S, Isakovic, Sreckovic, Matic D, 2006. Comparative analysis of experimental, numerical flow visualization,FME Transactions

[16]ELD, 1984,Flow Visualisation Water Tunnel, operating maintenance and Instructions.

[17] Zdravkovich M , 2003, Flow around Circular Cylinders: Vol 2: Applications, Oxford University Press, Oxford.