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Experimental Investigate the Effect of Burner Geometry on the Operation Window of the Burner

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Abstract: The purpose of this paper is to conduct an experimental study of a swirl burner with different lengths for a fixed diameter. Three models of rim length (5 cm, 10 cm and 15 cm) were taken. The results show that any change in the ratio of length to diameter will affect the flame position and structure of the downstream. It turns out that the flame settles near the edge as the rim length increases. The result indicates that increasing the length of the burner neck will reduce the structure of the swirl and weaken it, thus increasing the incidence of flashback phenomenon. The operating window of three burner neck models was studied above. It was found that the 5 cm rim has an equivalent ratio of (0.38-0.82) and for the 10 cm rim that is equivalent ratio (0.39-0.84), as well as for the rim 15 cm in equivalent ratio (0.4-0.83) with air velocity stabilization. For the above three models. Through the equivalent ratio of the above models. It was found that the 10 cm rim gave a larger operating window and therefore higher stability than the other two models.

Keywords: Swirl, Flashback, Equivalent Ratio, Operating Window

Introduction

The increase in demand for power consumed by the increasing population in the world put a huge pressure on the power sector to provide the needed power. The cost of such power represents a change in climate which rings the bell in many places to produce a quick solution to reduce the emission around the world. Using gas or biofuels are submitted as a part of the future solution to reduce the syngases emission. However, switching to use gases or biofuels need to alter the classic combustion system to meet the safety issues that are needed to operate the power plants safely. The flame stability issues such as blow off and flashback are the main challenges in the way to switch fuel in main power plants. The blow off occurs when the flame leaves the burner rim and extinguished in downstream region and it is effected by the fuel type, flow velocity and mixing ratio (Lieuwen and Yang, 2005). In another hand, the flashback is a penetrate of the flame upstream into the fuel system. The flashback represents more disastrous damage in the combustion system. The flashback mechanisms are more complicated in their mechanism compared to blow off. The flashback reported being one of the following mechanisms: Core Induced Vortex Breakdown (CIVB), Boundary Layer Flashback (BLF) and Turbulent Core Flashback (TCF) Combustion Instabilities flashback (Lieuwen *et al*., 1999). The fuel type, equivalence ratio and flow type effect on the flashback mechanism, for example, the TCF, Combustion Instabilities and BLF occur on diffusion flow systems while CIVB is the mark of swirl flow beside the BLF. The swirl flow is more preferable in the combustion system duo the large reduction in NOx emission (Li *et al*., 2015). However, the swirl flame structure is complicated and parameters that have an influence on the swirling flame are not completely understood. The CIVB is dominant flashback mechanism in swirl burner, where a flame bubble is developed and the center of the flow and propagate upstream. Many techniques have been studied to avoid the CIVB (Konle and Sattelmayer, 2009). Bluff body is used to stabilizing the flame in downstream through increase the turbulence of the flow in recirculation zone witch help to reduce the tendency of a system to flashback (Lasky *et al*., 2019). Although the bluff body is sold geometry impeded in the central of the flow the bluff body could be used to produce a central fuel or air flow (Al-Fahham *et al*., 2017; Bauer *et al*., 2017). However, central injection of air or fuel in the combustion field, as well as the presence of the bluff body, will increase boundary layer flashback probability (Hoferichter *et al*., 1995). In boundary layer flashback the flame propagates upstream in the low-velocity region near burner walls or bluff body walls (Lovett and Mick, 1995). The techniques that are used to avoid boundary layer flashback focused on ensuring that the critical velocity gradient pushed towards the wall, where the heat transfer to surrounding

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extinguishes the flame and prevent the flame from propagating near wall (Heeger *et al*., 2010). Also, injecting air from side wall helps to push the flame to high velocity field and hence avoid the BLF (Marosky *et al*., 2013). In more recent work use stainless steel wire screen as a liner at the inner wall of burner rim to alter the boundary layer (Al-Fahham *et al*., 2017), from another hand the combination of the central injector and wire mesh produce more balanced effect between CIVB and BLF (Hatem *et al*., 2017). However, the aerodynamic characteristics of the burner rim and their effects on the burner stability still not clarified. In recent work, the effect of the burner length to diameter ratio (L/D) on the flame stability were studied. Three L/D ratio 1,2,3 where studied and the results were discussed.

Experimental Work

The experimental rig is a swirl burner shown in Fig. 2. The air is delivered tangentially from a blower. The maximum airflow rate around 160l/s. The air then mixed with LPG in the bottom of the burner then the mixture goes through a swriler plate to swirl the mixture and produce a premixed fuel. The rest of the burner geometry is a divergent shape which slows the flow to give the mixture the time to be fully mixing, then the premixed fuel accelerated through a convergent part and go through the burner rim. The burner rim diameter is 5 cm and the length of the rim is variable (5 cm, 10 cm and 15 cm) as shown in Fig. 1.

To ensure L/D ratios (1,2 and 3). A pilot flame is produced by a secondary ignition system consist from a central nozzle with an adjustable length, where it is ensured that the top of the pilot ignition system nozzle lay at the same level of the burner rim top edge. The flame stability is captured using a 1000 fps camera. The LPG is supplied from a pressurized cylinder through a high-pressure plastic hose connected to a bank of rot meters.

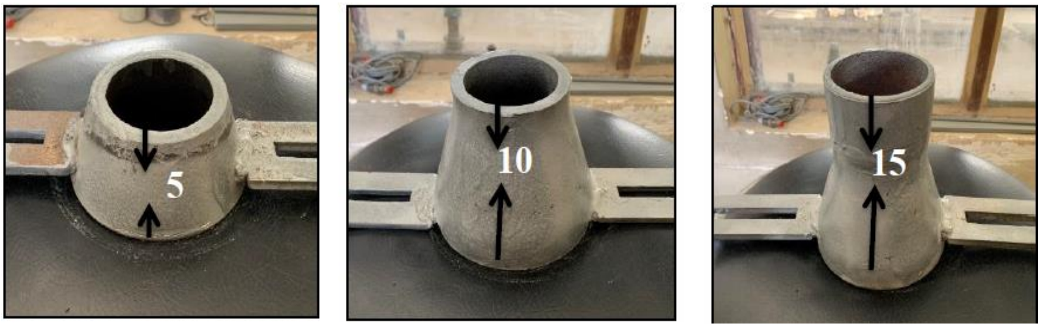

Fig. 1: Rim burner section

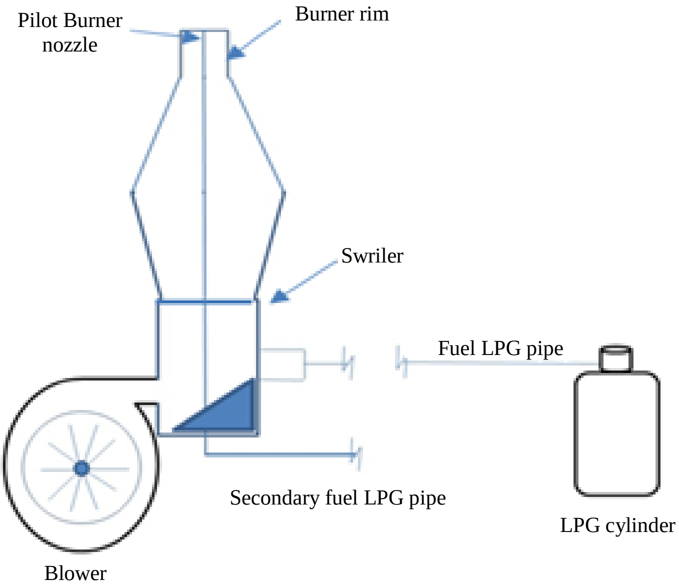

Fig. 2: Sketch of the experimental rig

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Results and Discussion

The experimental tests focused in the first stage on the effect of the rim Length (L) to the Diameter (D) the results show that for a stable flame. The equivalence ratio (ϕ) of the mixture was taken to be 0.84 where the system is stable and far away from blow off and flashback. The position of stabilization downstream is effected significantly by the L/D ratio. The burner with L/D equal 1 the flame stabilized increase in L/D will stabilize the flame closer to the burner rim. The increase L/D ratio cause the flame front moves towards the upstream and stabilizing closer to the rim Fig. 3. The increase of rim length in internal swirl flow caused to increase the swirl decay which reduces the flow turbulence. The increase of turbulence in the downstream flow will increase the residual time which gives more time to complete the combustion. The completed combustion will reduce the amount of emission. Also, the decay in swirl strength will influence on the coherent of the flow (Kitoh, 1991).

The coherent of the flow will improve the combustion. The overall picture of operation window for the three geometries is shown in Fig. 4.

(a) (b) (c)

Fig. 3: The flame front height at different rim length (L) (a) 5 cm (b) 10 cm (c) 15 cm

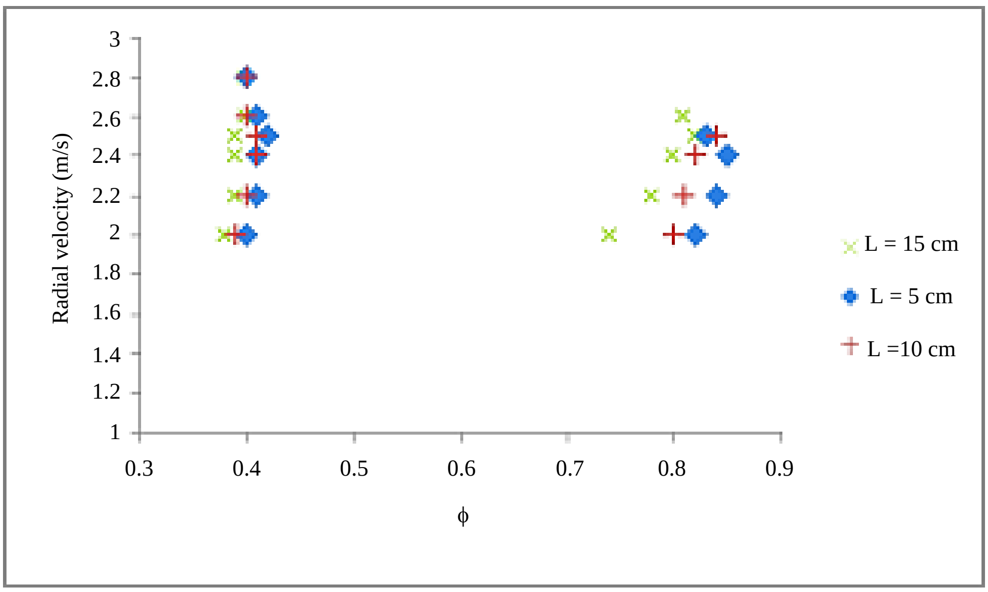

Fig. 4: Operation window for all cases

Conclusion

The main point that concluded from the experiments that the increase in the length of the burner rim causes more decay in swirl strength which reduce the coherence of the flow downstream, such weakness in flow structure will move the flame front closer to the rim and make the system more vulnerable to the flashback issues.

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Author's Contributions

The Authors have been working on this paper and the corresponding author was responsible on experimental work and the other two authors were cooperated as supervisor.

Ethics

The authors are clarify that this work has no ethics issues.

References

Al-Fahham, M., F.A. Hatem, A.S. Alsaegh, A. Valera Medina and S. Bigot *et al*., 2017. Experimental study to enhance resistance for boundary layer flashback in swirl burners using microsurfaces. Proceedings of ASME Turbo Expo: Turbomachinery Technical Conference and Expansion, Jun. 26-30, Charlotte, NC, USA2017.

Bauer, S., B. Hampel and T. Sattelmayer, 2017. Operability limits of tubular injectors with vortex generators for a hydrogen-fueled recuperated 100 kw class gas turbine. J. Eng. Gas Turbines Power, 139: 082607-082607-8. DOI: 10.1115/1.4035842

Hatem, F.A., A.S. Alsaegh, M. Al-Faham and A. Valera-Medina, 2017. Enhancement flame flashback resistance against CIVB and BLF in swirl burners. Energy Proc., 142: 1071-1076. DOI: 10.1016/j.egypro.2017.12.358

Heeger, C., R. Gordon, M. Tummers, T. Sattelmayer and A. Dreizler, 2010. Experimental analysis of flashback in lean premixed swirling flames: Upstream flame propagation. Exp. Fluids, 49: 853-863. DOI: 10.1007/s00348-010-0886-0

Hoferichter, V., C. Hirsch and T. Sattelmayer, 1995. Prediction of confined flame flashback limits using boundary layer separation theory. J. Eng. Gas Turbines Power, 139: 021505-021505-10. DOI: 10.1115/1.4034237

Kitoh, O., 1991. Experimental study of turbulent swirling flow in a straight pipe. J. Fluid Mech., 225: 445-479. DOI: 10.1017/S0022112091002124

Konle, M. and T. Sattelmayer, 2009. Interaction of heat release and vortex breakdown during flame flashback driven by combustion induced vortex breakdown. Exp. Fluids, 47: 627-627. DOI: 10.1007/s00348-009-0679-5

Lasky, I.M., A.J. Morales, J. Reyes, K.A. Ahmed and I.G. Boxx, 2019. The characteristics of flame stability at high turbulence conditions in a bluff-body stabilized combustor. AIAA SciTech Forum: American Institute of Aeronautics and Astronautics.

Li, Y., R. Li, D. Li, J. Bao and P. Zhang, 2015. Combustion characteristics of a slotted swirl combustor: An experimental test and numerical validation. Int. Commun. Heat Mass Tran., 66: 140-147. DOI: 10.1016/j.icheatmasstransfer.2015.05.021

Lieuwen, T.C. and V. Yang, 2005. Combustion Instabilities in Gas Turbine Engines: Operational Experience, Fundamental Mechanisms and Modeling (Progress in Astronautics and Aeronautics). 1st Edn., American Institute of Aeronautics, ISBN-10: 156347669X, pp: 657.

Lieuwen, T., H. Torres, C. Johnson and B.T. Zinn, 1999. A mechanism of combustion instability in lean premixed gas turbine combustors. J. Eng. Gas Turbines Power, 123: 182-182. DOI: 10.1115/1.1339002

Lovett, J.A. and W.J. Mick, 1995. Development of a swirl and bluff-body stabilized burner for low-nox, lean-premixed combustion.

Marosky, A., V. Seidel, T. Sattelmayer, F. Magni and W. Geng, 2013. Impact of cooling air injection on the combustion stability of a premixed swirl burner near lean blowout. J. Eng. Gas Turbines Power, 135: 111501-111501. DOI: 10.1115/1.4025043