

Flashback Avoidance Analysis using Geometrical Constrictions in a Tangential Swirl Burner

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The flashback analysis in Gas Turbines for Power Generation has been of great concern for manufacturers and researchers in the last decade. This is due to the increased interest in using biofuels and enriched hydrogen combustibles for emission reduction and economical alternatives to fossils. This paper analyses experimentally and numerically the phenomenon in a Tangential Swirl Burner under different conditions in order to increase the understanding of the phenomenon to reduce its impacts in real gas turbines.

Introduction

Swirl flame stabilization of lean premixed fuels has been studied and applied to gas turbines for a number of years, giving considerable benefits in terms of reduced pollutant emission, especially of NO_x. However, there are still problems that can occur during the combustion process including those related to flashback (especially with hydrogen enriched fuels) and combustion induced instabilities. Swirl numbers of the primary system are optimized to minimize pressure drop, flame contact with the injectors and swirl system, whilst avoiding flashback. Pure hydrogen or hydrogen enriched fuels give rise to especial problems owing to the high flame speed of hydrogen, potential for flashback in conventional or simply modified combustors and often requirement for multi fuel operation. Solutions adopted commercially are normally compromised, leaving considerable room for improvement.

Theory

Swirling flows have been studied for decades, with detailed descriptions in the work of Syred [1] and Gupta et al. [2]. The recognition of several coherent structures and interaction between them has been studied for the last years employing Diagnostic Techniques capable of showing the close correlation between them. Essentially, the behaviour of a Central Recirculation Zone, External Recirculation Zones and a Precessing Vortex Core have been of main interest due to their influence in the definition of the final flow field under isothermal and combustion cases [3].

According to previous studies [4-5], flashback can occur not only by the increase in turbulent flame speed and reduced velocity near the wall, but also by the

negative effect of the central recirculation zone. This advances upstream the stability region at stronger energies caused by increased radial pressures or high combustion. The recirculation moves farther upstream producing flashback even if the turbulent flame speed is less than the flow velocity.

Experimental

This paper describes a combined practical and modelling approach to study and reduce the effect of flashback in practical swirl burners using both a flexible experimental combustor, coupled with extensive CFD modelling to guide experimental progress. Of especial importance is the location of the central recirculation zone (CRZ) downstream of the swirl burner exhaust. Unless due care is taken it is perfectly possible for the CRZ to extend upstream around the fuel injector, both causing physical damage as well as a pathway for flashback at burner loading beyond that which would be normally expected.

Different geometries and a great variety of flows have demonstrated a change in straining rates comprised by compressive and stretching regions that may define the flame shape and the recirculation zones [6]. This, coupled with the negative axial pressure produced by the increasing Swirl number and Re, plus the change in time delay caused by the use of different injection systems and fuel quantities [7], lead to a deep study of a vast number of configurations, using passive constrictions such as different nozzles and injectors in a wide range of premixing and diffusive cases to analyze the resistance of flashback on the tip of the injection system and complete flashback inside of the burner.

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This study focused on natural gas combustion experimentally and different blends CFD models. Use of various diagnostic techniques allowed the detection of the Central Recirculation Zone (CRZ), occurrence and suppression of the Precessing Vortex Core (PVC) and flame lifting caused by shear flow interaction with these coherent structures. Numerical simulations using FLUENT confirmed the existence of these structures with high level of reliability, allowing the expansion of the study to pressurized conditions.

Results

Different configurations showed considerable differences to flashback resistance depending on the type of geometry and constriction utilized. The use of injectors demonstrated major resistance compared to those cases where no injector was used. Regions of re-attachment were observed at conditions just over the flashback limit. These are detrimental to the equipment due to soot growth and overheating of the system. Figure 1 shows the case with a Wide Injector.

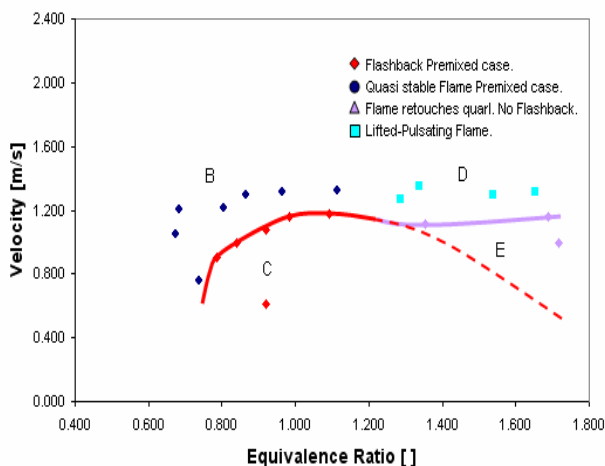


Fig. 1. Flashback using a Wide Injector.

In order to reduce the attachment problem and axial flashback to the injection system, the use of constrictions demonstrated that the flame can be pushed up, changing the shape of the Recirculation Zone. Different shapes showed varied efficiencies that were qualitatively defined by the color of the flame and quantitatively by the flow speed using Phase Locked PIV.

Conclusions

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Several varied CRZ developed in the field as a consequence of the exhaust nozzle configuration, showing high dependence not on the Swirl Number (S), but on the type of flow expansion. The use of different injection systems showed diverse behaviours, increasing or decreasing the resistance to complete flashback depending on their geometry. Small quantities of diffusive injection were required for the correct development and avoidance of total flashback. However, this also increased the likelihood of flashback into the injection system, augmenting the soot growth nucleation which degraded the tip of the latter. It was confirmed that the flame can be manipulated to avoid physical contact with the solid surfaces, S being a particularly important parameter. The size and shape of the CRZ can be readily manipulated to satisfy particular requirements.

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