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Effect of exhaust confinement and fuel type upon the blowoff limits and fuel switching ability of swirl combustors

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The use of swirl burners with premixed hydrogen–methane fuel blends is a promising technology for low-emission power generation. Utilisation of hydrogen containing fuel mixtures can result in low-emission levels, but it is well known that there are many difficulties, primarily because of the very high laminar and turbulent flame speeds of hydrogen. Problems such as blowoff and flashback limits are extremely important where fuel flexibility is required. In this study, a generic swirl combustor at Cardiff University's GTRC is utilised to investigate blowoff and the ability of the premixed combustor to switch fuels whilst still maintain the same thermal load, for a range of alternative hydrogen based fuel mixtures in configurations where the confinement is representative of gas turbine practice. This complements previous work on the same generic combustor, where the focus was entirely on flashback limits.

Ideally to achieve fuel switching or dual fuelling for nominally similar combustor geometries, the operating points for pure hydrogen and natural gas should lie in an operational regime between the blowoff and flashback limits of both fuels. Normal concepts of equivalence ratio matching need modification to allow for the varying stoichiometric requirements of different fuel mixtures and the associated differences in their heating values. Here heating input from the various fuels as a function of mass flow is used to compare their ability to operate in the same operational, fuel lean regime of the premixed combustor. In practice this is extremely difficult; however, fuel switching/dual fuelling is possible in the swirl burner with certain fuel blends (where the hydrogen content is limited).

The results demonstrate and quantify improvements in blowoff limits for hydrogen-enriched methane flames. Moreover, for all geometrical configurations considerably improved blowoff characteristics were observed for the confined cases in contrast to the unconfined cases. This data offers a significant insight to burner manufacturers aiming to use swirl combustors with hydrogen-containing alternative fuels.

1. Introduction

Lean premixed combustion along with alternative and gasified biomass fuels offer a potential reduction in net CO_2 along with NO_x in the context of gas turbine combustion and power production.

Lean premixed (LP) combustion is a commonly used approach to minimize harmful emissions from gas turbines. By definition within LP combustion systems, lean mixtures of fuel and air are mixed prior to the combustion chamber in order to lower the average combustor temperature and reduce NO_x. To facilitate LP combustion new premixed swirl combustor systems are being developed by manufacturers. Such systems have an increased propensity for flashback and blowoff to occur as operation at lean equivalence ratios is necessary in order to reduce the flame temperature and hence minimize NO_x formation. Flashback and combustion induced instabilities are a particular problem with hydrogen fuel blends [1,2].

Hydrogen/methane fuel blends are thought to offer a promising technology, with recent studies aimed at achieving power generation with limited environmental impact. Hydrogen rich fuels may offer potentially lower, desirable, emission levels, but as is well documented [3–6], there are many difficulties when operating existing combustion technologies on pure hydrogen, primarily because of the relatively high flame speed. Methane blended hydrogen can provide a suitable fuel mixture which can give many advantages in terms of emissions [7,8].

Swirl combustors are almost universally used within gas turbines along with many other combustion processes due to the benefit of

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