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Experimental investigations of coaxial injectors in a laboratory-scale rocket combustor

Dai Jian, Cai GuoBiao, Zhang Yang, Yu NanJia*

Beijing University of Aeronautics and Astronautics, 100191 Beijing, PR China

Abstract

An investigation is performed through experiments of a laboratory-scale optically accessible combustor equipped with a single-element shear coaxial injector. Various optical diagnostics approaches, such as hydroxyl (OH) planar laser-induced fluorescence (OH-PLIF), high-speed imaging and infrared imaging, are simultaneously used to determine the OH radical spatial distribution, flame instantaneous fluctuations, and temperature fields outside the combustor nozzle. This study emphasizes the combustion characteristics and flame stabilizations of two propellant combinations under the same thrust level, including gaseous hydrogen/gaseous oxygen (GH2/GO2) and gaseous methane/gaseous oxygen (GCH4/GO2). Moreover, to validate a pressure-scaling criterion, different pressure conditions are also considered. Based on the results of the high-speed and OH-PLIF images, combustion similarities are evident under different chamber pressures for each propellant couple. The two kinds of flame are seen to be stabilized in the vicinity of the oxidizer injector lip but the anchor region in the GCH4/GH2 cases is found to change dynamically near the lip. The lift-off GCH4/GO2 flame exhibits evident unsteady combustion phenomenon in the combustor. Experimental data indicates that GCH4/GO2 flame stabilization is hard to achieve compared to the GH2/GO2 flame. Furthermore, the GCH4/GO2 flame has a greater heat releasing intensity and gentler reaction zone distribution. This indicates that relative to the GH2/GO2 flame, the GCH4/GO2 flame causes major issues with regard to heat protection of the inner wall in the combustor. Meanwhile, according to the infrared images, the GCH4/GO2 plume has a lower outlet core temperature and larger temperature gradient, which is an advantage for employment in future space engines. This study, identifying preliminary behavior differences between the GH2/GO2 and GCH4/GO2 flames, will be applicable for future engine design.

Keywords: Liquid rocket engine; Shear coaxial injector; Turbulent combustion; Non-intrusive optical diagnostics

1 Introduction

Considerable efforts have been made to model combustion in liquid rocket engine chambers [1]. Gas-gas injector, which is an important component of a full-flow stage combustion rocket engine, has a significant impact on engine performance, combustion efficiency, and stability. In hydrogen and oxygen rocket engines, shear coaxial element has already been widely used as a common injector configuration [2-4]. Though operated engines use multi-injector systems, consisting of hundreds of coaxial injectors, the flame of a single-element injector is still a serious problem and requires in-depth study [5]. Previous designs have been developed with very expensive experimental test procedures [6, 7]. Therefore, it is desirable to use the analytical and predictive capabilities of laboratory-scale engines to limit the amount of experiments required during the development phase of a new engine.

Injector element behavior is crucial as it controls the combustion dynamics in various aircraft power systems. Huang et al. [8, 9] have studied the influence of several different injector geometric configurations in order to obtain the best performance of the transverse injection flow field in the scramjet combustor. Especially, the shear coaxial injector, employed in the principal

* Corresponding author

E-mail address:ynjtougao@126.com