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NUMERICAL AND EXPERIMENTAL INVESTIGATION OF RESONANCE IGNITER AND ITS OPTIMIZATION BY GENETIC ALGORITHM

Abstract

Resonance Igniter are ignition device based on Hartmann-Sprenger tube, comprising of nozzle and tube. The resonance igniters' tube traps high pressure gas, which gets heated by series of shock waves and friction and results in ignition. The shock waves are generated by the bow shock oscillation present at the open end of the tube. The resonance Igniter finds applications in rocket engine test stands and in cryogenic and semi-cryogenic engines. These Igniters can potentially replace pyro-igniters in engine by enhancing their capabilities such as multiple start-ups and shutdowns, reduced electronic systems etc.

The goal of the study is to arrive at an optimum resonance igniter through genetic algorithm, with fitness based on end wall temperature computed by computational fluid dynamics simulations. Furthermore, experiments were conducted to validate the findings. Another major focus of the study is to understand the relationship between the bow shock oscillation frequency and the harmonic frequencies of resonance tube in jet-screech condition. The heating is maximized when bow shock oscillation matches the harmonic frequencies of the tube. The oscillation's amplitude is also correlated with temperature rise in the tube.

The genetic algorithm optimization was done at different nozzle diameter (ND) since diameter differs with application. Igniter was initially optimized for 5 mm nozzle diameter with hydrogen as operating gas, with initial population of 10, and with 4 input parameters nozzle pressure ratio (NPR), gap (TG), tube diameter (TD), and tube length (TL). The resulted igniter was experimented on and it achieved maximum temperature of 1060K at 6.25 NPR. In simulation, the resonance tube followed the jet-Regurgitant mode till NPR value of 4, the heating screech mode for NPR values from 4 to 8, and the second screech mode above NPR value of 8. At NPR 6.25, the bow shock oscillation amplitude is found to be 25% of ND (1.3mm) and the bow shock oscillation's frequency is found to be 11,700 Hz by FFT analysis, which matches the tube's fundamental frequency. The resonance tube while experiment readily catches fire with ambient air; therefore, a hole of diameter of 0.5 mm was added at tube end. The resultant igniter can now be used for burning unburned hydrogen fuel at rocket test stands. Finally, all genetic algorithm optimization results will be combined to produce deployable resonance igniters for engine and other applications. The final design will be fabricated with regenerative cooled and mixture ratio controlled chamber