Torch Igniter for Liquid Fuel Rocket Engine

Research Project

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Abstract

Torch igniters are widely used to initiate combustion in non-hypergolic engines, but scaling them down to laboratory dimensions introduces unique challenges related to flow momentum, mixing, and thermal management. This work documents the steps of the development of a scaled hydrogen–oxygen torch igniter for a bi-propellant liquid fuel rocket engine. The original NASA Repas torch igniter operated with gaseous oxygen and hydrogen at flow rates of approximately 11.3 g/s and 2.3 g/s respectively, producing a stable torch flame temperature of about 3100 K and a pre-chamber O/F ratio of nearly 40, later reduced to around 5 at the exit, using an annular channel. These reference conditions served as the baseline for all scaling and similarity analyses in this work.

First, a review of foundational literature was summarized, emphasizing mixing, ignition, and flashback risks in small engine geometries. The NASA Repas igniter demonstrated reliable ignition over more than 500 cycles, operating at a chamber pressure of about 1.7 MPa with an ignition energy of only a few mJ supplied by a surface-gap spark plug. Later work reported comparable torch configurations with total mass flows between $0.37 - 1.1$ g/s, confirming that performance strongly depends on injector geometry and spark location. These studies also highlight typical hydrogen-to-oxygen momentum ratios ranging from 0.05 to 0.15, which ensure adequate flame anchoring while avoiding flashback. Such data provided key reference points for evaluating the scaled igniter's expected behavior.

Next, a scale-down of the NASA Repas igniter is presented, which theoretically preserves Reynolds number, jet-momentum ratio, and mixture ratios at the torch chamber and exit. After reconsider the scale-down of the igniter, in terms of manufacturability and flow characteristics, it has been decided to minimize the changes of the original design of NASA's Repas torch igniter and to change it's integration manner to the engine in order to adapt it to the current engine structure. The integration is made with a pilot flange, which replaces part of the torch tube original structure and, also, used to cool the igniter using water flow through a channel.

At last, due to not sufficient time, the manufacturing of the igniter hasn't been done yet. However, the planned experimental setup, test stand (P&ID), diagnostics, and safety logic that will be used to validate the design were prepared for future work.