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Title:
"Design and Fabrication of Oxygen/RP-2 Multi-Element Oxidizer-Rich Staged-Combustion Thrust Chamber Injectors"

Authors:
C.P. Garcia, C.R. Medina, C.S. Protz, R.J. Kenny, G.W. Kelly, and M.J. Casiano (NASA MSFC)
J.R. Hulka, B.R. Richardson (Jacobs/ESSSA Group)

Abstract:
As part of the Combustion Stability Tool Development project funded by the Air Force Space and Missile Systems Center, the NASA Marshall Space Flight Center was contracted to assemble and hot-fire test a multi-element integrated test article demonstrating combustion characteristics of an oxygen/hydrocarbon propellant oxidizer-rich staged-combustion engine thrust chamber. Such a test article simulates flow through the main injectors of oxygen/kerosene oxidizer-rich staged combustion engines such as the Russian RD-180 or NK-33 engines, or future U.S.-built engine systems such as the Aerojet-Rocketdyne AR-1 engine or the Hydrocarbon Boost program demonstration engine. On the current project, several configurations of new main injectors were considered for the thrust chamber assembly of the integrated test article. All the injector elements were of the gas-centered swirl coaxial type, similar to those used on the Russian oxidizer-rich staged-combustion rocket engines. In such elements, oxidizer-rich combustion products from the preburner/turbine exhaust flow through a straight tube, and fuel exiting from the combustion chamber and nozzle regenerative cooling circuits is injected near the exit of the oxidizer tube through tangentially oriented orifices that impart a swirl motion such that the fuel flows along the wall of the oxidizer tube in a thin film. In some elements there is an orifice at the inlet to the oxidizer tube, and in some elements there is a sleeve or "shield" inside the oxidizer tube where the fuel enters. In the current project, several variations of element geometries were created, including element size (i.e., number of elements or pattern density), the distance from the exit of the sleeve to the injector face, the width of the gap between the oxidizer tube inner wall and the outer wall of the sleeve, and excluding the sleeve entirely. This paper discusses the design rationale for each of these element variations, including hydraulic, structural, thermal, combustion performance, and combustion stability considerations. This paper also discusses the fabrication and assembly of the injector components, including the injector body/interpropellant plate, the additive manufactured GRCop-84 faceplate, and the pieces that make up the injector elements including the oxidizer tube, an inlet to the oxidizer tube, and a facenut that includes the fuel tangential inlets and forms the initial recessed volume where oxidizer and fuel first interact. Hot-fire test results of these main injector designs in an integrated test article that includes an oxidizer-rich preburner are described in companion papers at this JANNAF meeting.