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Title
Experimental Investigation of a LOX/Methane Liquid Centered Swirl Coaxial Injector During Ignition, Startup and Subcritical Operation

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Abstract
In the context of the ever-growing interest in liquid oxygen and methane as a propellant combination for liquid rocket engines, swirl coaxial injectors have been found to present an interesting alternative to the shear coaxial injectors classically used in European launcher engines. By not only relying on shear, but also on centrifugal forces as well as propellant impingement, swirl coaxial injectors can offer improved propellant atomization compared to shear injectors. This could lead to improved flame anchoring characteristics for liquid oxygen/methane flames, especially under varying operating conditions like deep-throttling. By retaining geometric and operational similarities, they also allow for simple interchangeability with the latter, especially when compared to other injector types.

However, publicly available experimental data, especially from hot-fire tests of such elements is very limited. For this purpose, a single liquid centered swirl coaxial injector operating with liquid oxygen and gaseous methane is designed and hot-fire tested at the M3.1 testbench at the German Aerospace Center (DLR) Institute of Space Propulsion in Lampoldshausen, Germany. The injector is designed to be representative of elements of main stage combustion chambers previously found in industrial and literature applications. The liquid oxygen is swirled by the use of tangential inlet holes. Compared to the liquid centered swirl injectors commonly found in literature, the element presented in this study features a special fuel annulus in which, through the use of specifically designed guiding vanes, tangential momentum is also applied on the methane flow. Additive manufacturing is used to create the sophisticated methane annulus geometries.

Cold-flow studies as well as hot-fire tests are conducted in an optically accessible subscale combustor with a 60-millimeter diameter. The experiments are accompanied by high-speed Schlieren diagnostics as well as high speed OH* visualization techniques. Focus of the hot-fire testing is the investigation of the injector's behavior during ignition, the startup transient phase as well as during short quasi steady-state operation at subcritical pressures. Ignition is achieved via a pulsed laser ignition system. Important injector characteristics such as spray shape, flame anchoring and -topology as well as combustion stability are being investigated in this study. The performances of different injector geometries (co- and counter swirling methane flow) with regard to these characteristics are being compared and evaluated accordingly.