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COMBUSTION DYNAMICS IN CRYOGENIC ROCKET ENGINES: RESEARCH PROGRAMME AT DLR LAMPOLDSHAUSEN

Abstract

The Combustion Dynamics group in the Rocket Propulsion Department at DLR Lampoldshausen strives to advance the understanding of dynamic processes in cryogenic rocket engines. Leveraging the test facilities and experimental expertise at DLR Lampoldshausen, the group has taken a primarily experimental approach to investigating engine transients, ignition, and thermoacoustic instabilities for over one and a half decades.

Understanding the behaviour of fluids under transient conditions and upon injection into the combustion chamber is the basis for successful ignition and start up of a rocket engine. The opening and closing of valves in propellant supply lines of rocket engines causes non-steady fluid- and thermodynamic conditions. The resulting dynamic flow processes and phase changes are investigated experimentally on specialised test benches, and predictive models are developed to describe these phenomena.

Work on ignition in the group focusses primarily on examining laser ignition processes in close cooperation with industry. The applicability, reliability and robustness of laser ignition have been proven under both ambient and in-space (vacuum) conditions with flashing propellants and various ignition sequences. Ignition testing is performed with gaseous or liquid oxygen and hydrogen or methane fuel in a windowed,

contoured thruster, or in a sub-scale combustor. High-speed optical diagnostics allow precise characterisation of the injection, ignition, flame development, and stabilisation processes, and provide valuable data sets for the validation of CFD simulations. Low-order models are also developed to predict the conditions necessary for successful ignition.

Thermoacoustic instabilities have always played an unwanted role in the development of liquid rocket engines Work on this problem focusses on the interaction of acoustic disturbances and combustion processes. This interaction is captured quantitatively in specially developed research combustors using high-speed optical diagnostics. The details of energy transfer from combustion into the acoustic field are then studied using in-house developed data analysis routines. Both low-order and CFD numerical modelling supports the interpretation of the experimentally observed processes.

On the whole, the Combustion Dynamics group aims to develop comprehensive understanding of all dynamic processes in cryogenic engines. The group's strategy is to use real fluids and representative conditions, and to complement experimental work with low-order through to advanced CFD modelling. Experimental test cases are also provided to the wider community for code validation. This article provides a summary of past achievements of the group, and an overview of current and planned future research activities.