Numerical and Experimental Investigation of the Methane Film Cooling in Subscale Combustion Chamber

Y. Daimon[1], H. Negishi[1], M. Koshi[2], D. Suslov[3],

[1]JAXA's Engineering Digital Innovation Center, Japan Aerospace Exploration Agency

[2] The University of Tokyo

[3] Institute of Space Propulsion, Germany Aerospace Center (DLR)

Abstract

The rocket engine techniques currently used for orbital transfer and space exploration are based on using mostly well established storable propellants. Due to simple operation these propellants have been preferred up to now. However their significant disadvantages, such as toxicity and average performance compared to cryogenic propellants, drive us to investigate the application of other propellant combinations.

Oxygen/methane is a very attractive propellant combination for this application as it provides an improvement of 50 s specific impulse compared to storable propellants. LOX/LCH4 combination may be said to be “space storable” (liquid temperature ca 90 K-130 K depending on the tank pressure). With passive thermal protection the methane boiling rates are significantly smaller than for hydrogen. Another significant advantage is no risk to human health. For this reason they are often considered as “green propellants”.

One of the key aspects of the advance research is improving knowledge of heat transfer processes and cooling methods in the combustion chamber which is mandatory for engine design. The intended thermal design concepts include film cooling as one of the favourable cooling methods. Film cooling has significant advantages: high efficiency, simple thrust chamber construction, and relatively low pressure drop. These effects make the use of film cooling attractive, even if a certain decrease in propulsive performance has to be expected.

This paper presents the numerical analysis of the film cooling performance in an O_2/CH_4 subscale combustion chamber as well as the results of the experimental investigation used for the validation of the numerical tools. The presented investigation provides detailed information about the cooling film and thermal load distribution on the hot inner surfaces of the combustion chamber at real rocket engine conditions and pressures up to 1.2 MPa. The investigation focuses on the interaction of the reacting flow with film cooling in the cylindrical part of the combustion chamber near of the injector head (up to 250 mm). Due to the extremely complicated flow phenomena in this area (extreme variation of flow properties, steep temperature gradients ...) in combination with intensive chemical reactions, the problem is partially simplified injecting gaseous oxygen and methane. These investigations aim to provide a significant contribution to the understanding of the thermal transfer processes and to validation of the design tools.