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CFD OPTIMIZATION OF FILM COOLING IN GREEN STORABLE BIPROPELLANT ROCKET THRUSTERS

Abstract

Combustion chambers are one of the most thermally loaded parts of a rocket engine. A cooling technique is required so that the chamber walls can withstand high values of pressure and temperature encountered in a combustion chamber. Simultaneously, rocket engine performance parameters directly depend on the quality of the fuel oxidation process. In case of small bipropellant rocket engines and thrusters for spacecraft, film cooling is the key technology present in radiation cooled state-of-the-art solutions. The film cooling method requires a portion of fuel to be injected directly on the combustion chamber walls. Liquid fuel creates a thin layer on the wall surface, which drains in the axial direction downstream. As traveled distance increases, the layer thickness decreases due to vaporization. The structure is protected by the hot gases impact, thus the near-wall gas temperature is reduced and so the heat transfer. However, in case of new developments for small bipropellant propulsion systems, hydrogen peroxide of high concentration and purity (98%) is considered instead of MON or NTO as oxidizer. Yet, the low mass flow of fuel in comparison to toxic systems poses a challenge to efficient film cooling. In case of engines using hydrogen peroxide, potentially the oxidizer could be considered an option for film cooling. However, extensive data on oxidizer thermal decomposition is needed for the development of safe systems using this approach. This is discussed, although this paper focuses on analysis of fuel film cooling. Due to loss of performance in case of directing part of the flow for film cooling, it is desirable to reduce the negative influence of the mentioned method. It was therefore decided to conduct film cooling optimization with focus on green storable bipropellant engines. Possessed knowledge on the cooling method was expanded during carrying out CFD analyses, based on test bench data. This paper presents established film-cooling numerical models and several proposed numerical models of injection were validated using a dedicated research stand. It was verified how impingement splash and propagation of film depend on the size and position of injector orifices. Carried out cold tests, were used to choose the most adequate solver settings for modeling, and recommendations for engine development are provided. The novelty of this paper is due to focus given to the optimization of film cooling of bipropellant thrusters and engines, which use 98% hydrogen peroxide as oxidizer. The work discussed is supported by the European Space Agency.