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Title

Investigation of Heat Transfer and Nucleate Boiling of Ethanol in Additively Manufactured Cooling Channels

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Abstract

One of the key design challenges for liquid rocket engine thrust chambers is to accurately predict the pressure drop and heat flux in the cooling channels. This is especially true for small thrust chambers using liquid propellants, as two-phase phenomena should be avoided in order not to destabilize the injection and combustion process. Typical engineering correlations as well as CFD models to predict the heat transfer and the pressure drop are calibrated to configurations manufactured by turning and milling. In contrast, additively manufactured structures feature a far higher surface roughness beyond the validation area of these prediction models. This is known to result in increased pressure drop and heat transfer rates, if no post-processing of the surfaces is applied. As of today, no satisfactory update of the models to account for the effect of the macroscopic roughness has been reported for liquid propulsion applications.

Led by ArianeGroup as design authority for Ariane6's propulsion systems and developer of the storable propellant engine (SPE), a consortium of Belgian and German research institutes and industrialists has initiated a basic research project to investigate in detail the effects of wall roughness on pressure drop and phase change phenomena in liquid rocket engine cooling channels, focusing especially on the onset of nucleate boiling of liquid propellants.

The experiments, which are currently being performed at the Von-Karman-Institute of Fluid Dynamics, use ethanol in an optical accessible cooling channel setup. Different from other research groups (ref [1]), the heating of the channel floor, manufactured by 3D Systems, is realized by applying an electrical current. Conventional measurements by thermocouples and dynamic and static pressure transducers are complemented by optical high-speed imaging and laser induced fluorescence (LIF) temperature measurements of the ethanol. TUM and Cadence provide expertise to enhance CFD codes to more accurately predict the performance of additively manufactured cooling channels. The paper will present in detail the experimental setup and the test data obtained so far.

References

[1] Omar S. Al-Yahia, Daesong Jo: ONB, OSV and OFI for subcooled flow boiling through a narrow rectangular channel heated on one side, International Journal of Heat and Mass Transfer 116 (2018) 136-151, DOI: 10.1016/j.ijheatmasstransfer.2017.09.011