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Title

Simulation of plume impingement on flat plates via the hybrid Fokker-Planck – DSMC approach

Authors

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Abstract

During their operation in orbit spacecraft make use of rocket thrusters to perform various tasks. A thruster plume due to its spread in high vacuum can reach and impinge neighboring surfaces. This can produce undesired forces or heat loads on especially large areas like solar arrays and negatively impacting sensitive surfaces like optical diagnostics [1]. Degradation of critical surfaces as well as correction burns which use up valuable propellant can greatly reduce the spacecraft's life time. Reliable and accurate modeling of plume impingement effects is therefore an important factor in the design process of spacecraft [2, 3].
Leading to impingement the flow exiting a nozzle goes through a wide range of Knudsen numbers as it expands into vacuum and compresses again due to interactions with the surface [1]. These effects can be described by the well-known Boltzmann equation. A common approach to numerically solve it is the Direct Simulation Monte-Carlo (DSMC) method pioneered by Bird [4]. The method is very efficient for high Knudsen numbers but becomes increasingly computationally intensive when approaching the continuum limit. In this regime the Boltzmann equation can be numerically solved using the recently proposed kinetic Fokker-Planck (FP) method [5] which, like DSMC, relies on simulated particles to transport mass, momentum and energy through the flow domain, but does not resolve individual collisions. Due to the similarity in their formulation a hybrid method based on DSMC and FP can be derived which allows a computationally efficient simulation of flows with a broad range of Knudsen numbers [6].
In the proposed work we apply the hybrid approach to simulate plume impingement of N2 and He on flat plates and compare the simulation results to experimental data.

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