Paper ID: 68246
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations - IAF SPACE PROPULSION SYMPOSIUM (IPB)

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COMPUTATIONAL STUDY OF PLASMA DETACHMENT FROM MAGNETIC NOZZLES IN APPLIED FIELD MPD THRUSTERS USING LATTICE BOLTZMANN METHOD

Abstract

Applied Field MagnetoPlasmaDynamic (AF-MPD) thrusters are high power electric propulsion (EP) thrusters that utilises converging-diverging magnetic nozzles (MN) to accelerate ionised plasma to supersonic speeds in which thrust is generated when the plasma detaches from the magnetic field lines. This type of EP has high specific impulse but low thrust levels. Despite this, they have a high thrust theoretical limit which has not been achieved in practice yet. Therefore, this study aims to examine various ways to increase the thrust efficiency of AF-MPD thrusters through inducing plasma detachment. This is achieved through proposing and assessing three different nozzle topologies to study the coupled effect of varying the applied magnetic field and the flow velocity at the throat of the nozzle on inducing detachment, hence the amount of thrust generated. This has been achieved through developing an in-house C++ code within the framework of lattice Boltzmann method (LBM) to simulate plasma flow through the three MN configurations. The numerical values of various quantities were recorded such as the plasma detachment parameter, Alfven Mach, and divergence angle to allow for the direct comparison between the three MN configurations and to assess whether detachment has taken place. The LB algorithm was validated by simulating the Orszag Tang vortex problem and comparing the numerical LB data to reference data.

The main findings of the present study include that the MN configuration with the intermediate values of throat velocity and applied magnetic field had the best overall performance with good trade-off between the values of applied magnetic field strength and throat velocities as it detaches at the earliest point along the domain with high nozzle efficiency and low divergence losses. It also causes considerable amount of plasma to detach from the MN thus increasing thrust. It was found that increasing the throat velocity has more dominant effect on the divergence losses than the magnetic field strength. To further progress from the findings of the present study, the main recommendations for future work are to conduct experimental studies on inducing plasma detachment in propulsive MN through varying two parameters simultaneously which can be used to validate the numerical data. Additionally, examining the thrust vectoring capabilities of MN along with developing an empirical equation to compute the divergence angle are important areas for future research. The LB C++ numerical code shall be modified so that it can be used to simulate compressible flows with adequate accuracy.