Numerical Simulation of An Expanding Magnetic Field Plasma Thruster

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Electric propulsion technology emerged over last few decades for deep space mission, satellite orbit correction and satellite orbit keeping. Once the spacecraft lifts out of Earth's gravity, one can switch from chemical propulsion to electric propulsion due to the low thrust requirement. This increases the cost effectiveness of the mission by reducing the fuel mass.

In recent times, it has been realized that flying space debris poses serious challenges for smooth operations of man made satellites and space missions. The amount of man made space debris near the lower Earth orbit, is rapidly increasing with time and remedial steps needs to be taken for safe operation of space missions and orbiting satellites.

The expanding magnetic field plasma thruster or Helicon plasma thruster (HPT) is emerging out to be a suitable candidate for driving the spacecraft and to remove flying space debris , simultaneously. In an expanding magnetic field plasma thruster, plasma expands into a diverging magnetic field and due to the mass difference of electrons and ions, an electric field is generated in the bulk plasma. This bulk plasma electric field accelerates the ions and results in a directed ion beam. The net ejected momentum can be controlled by magnetic field gradient and fuel gas flow rate.

We have developed a 1D3V PIC-MCC model to capture the some important aspects of the expanding magnetic plasma thruster. A flux conservation model is used to incorporate the 2D spatial effects. This model holds good only for $|B_r|<<|B_z|$. Both unidirectional and bi-directional magnetic field plasma thruster are simulated using our PIC model. In a unidirectional plasma thruster, plasma expands only in one direction of the plasma heating region and in bi-directional plasma thruster, plasma expands into the both sides of the plasma heating region. The unidirectional plasma thruster is purely used to drive the flying spacecraft and live satellites. The bi-directional expanding magnetic field plasma thruster can be used simultaneously, to accelerate-decelerate the spacecraft and to remove the flying space debris. The mode of thruster operation can be controlled by a magnetic field gradient in expansion region and fuel gas flow rate.

For a bi-directional plasma thruster, we introduce different magnetic field gradient in both sides of the plasma heating region to generate net thrust in a particular direction. A net momentum flux can be transferred to the flying space debris in the opposite direction to de-orbit them and make re-entry into Earth's atmosphere where it will be burnt out. Fig.1 below shows net thrust in a particular direction with an asymmetry parameter which is the measure of difference in magnetic field gradient in the both sides of the plasma heating region. More details will be discussed in the presentation.

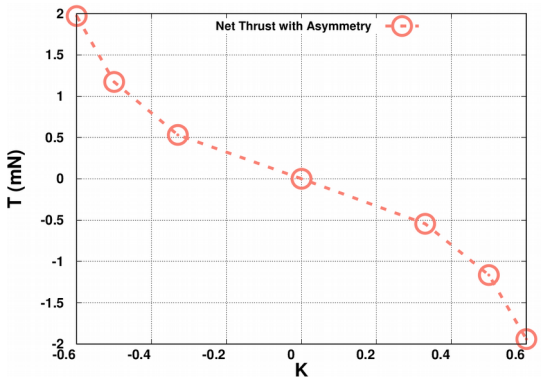

Figure 1. Net ion thrust in a particular direction with an asymmetry parameter K.

References

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