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Asymmetric Shock Wave Generation in Microwave Rocket Using Magnetic Field

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A beamed-energy propulsion is a novel launching system to reduce the launch cost of small satellites. The flight demonstrations of a beamed-energy vehicle were performed, which indicated that the beam-riding flight became unstable and deviated from the incident beam line, because the enough feedback forces for bringing the vehicle position closer to center of the beam line cannot be maintained during the repetitive-pulses flight. The flight simulations revealed that decoupling between the angular moment and the centering-feedback force is important on maintaining the beam-riding flight; however, such decoupling method was not proposed in past studies. It is necessary to induce the asymmetric shock wave inside the microwave-rocket nozzle for obtaining the lateral- and angular-feedback forces. The asymmetric shock wave can be generated inside the nozzle if spatial distribution of the gas heating by beam irradiations is not uniform. Hence, an external magnetic field is applied to the rocket nozzle in order to obtain non-uniformity of the gas heating. The gas heating is locally enhanced by the electron cyclotron resonance (ECR) heating under the magnetic field. The energy-absorption rate is evaluated under the magnetic field using a fully kinetic model of the plasma transports coupled with an electromagnetic wave propagation. The shock wave propagation inside the nozzle is reproduced using the computational fluid dynamics code based on databases of the energy-absorption rate obtained by the particle simulation. The asymmetric shock wave is obtained by controlling the ECR region inside the nozzle, and the lateral- and angular-feedback forces are induced because of interactions between the shock wave and the nozzle wall. A spatial distribution of the external magnetic field is designed to decouple the lateral-feedback force from the angular moment for keeping the beam-riding flight.

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