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核融合ロケットにおけるエネルギースケーリング則の数値シミュレーションによる検討

The research of energy scaling by numerical simulation for Laser Fusion Rocket

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1. Introduction

Recently, various space explorations were conducted. Manned interplanetary flight is planned as a next step. Laser Fusion Rocket (LFR)[1)] is expected to solve many challenges such as mission term and to be one of critical solutions of traveling to Mars. It is a rocket using fusion produced plasma, and it obtains the thrust by emitting this plasma by magnetic field. The thrust system of the LFR is called magnetic thrust chamber. It emits the plasma due to the interactions between plasma and the magnetic field generated by the superconducting coil. It is important to know the plasma structure in the magnetic field, so many simulations[2)] and experiments[3)] were conducted as previous research.

However, the simulation as the concept design[4)] has never been conducted. It is necessary to simulate of this design and confirm if the parameters are optimal such as the size of the coil and mass of the fuel, and so on. In addition, the simulation in the small energy scale is also important to compare the simulation with the experiment, so the simulations in various energy scale from J to MJ were conducted in this study. Then, the momentum efficiency (η) and impulse bit were compared in various parameters.

2. 3D hybrid simulation

The 3D hybrid simulation[2)] was conducted in this study. The interaction between plasma and magnetic field was calculated in this simulation. Ions were treated as particles and electrons were treated as fluid without inertia. Density, velocity, and current were calculated by Particle-In-Cell method and electromagnetic field was calculated by equations of motion.

Firstly, the case of designed parameters[4)] were simulated in the plasma energy (E_p) of 62 MJ. Then, the ratio of the distance from the propellant to the coil (z_c) to the coil radius (r_c) was changed and confirmed which ratio is optimal. Other energy scale of simulation was also conducted. The parameters of the coil were optimized in each case based on the momentum efficiency.

3. Result

The momentum efficiency in the E_p =62 MJ case is shown in Fig. 1.

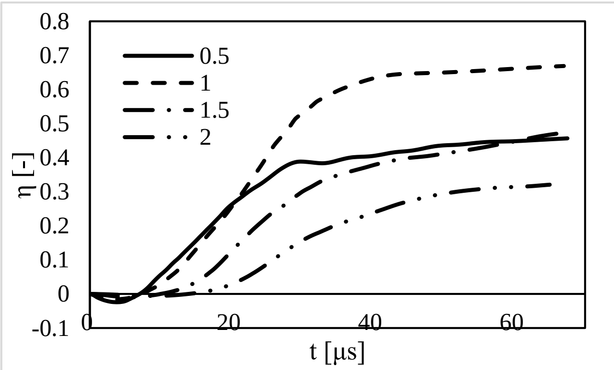

Fig. 1 The time evolution of momentum efficiency (η). The black, blue, light blue, silver line show z_c/r_c= 0.5, 1.0, 1.5, 2.0, respectively.

The value of η is in the case of z_c/r_c=1.0, which is the highest. On the other hand, the value of η at the E_p=496 J is about 30% in each coil parameter case. Other parameters, such as propellant mass, may contribute to differences in efficiency across energy scales.

4. Reference

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