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Effect of Resistive Metal Conductor on Translation of a Field-Reversed Configuration Plasma

磁場反転配位プラズマ移送における金属導体の効果

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The effect of a SUS 304 metal vacuum chamber on a reflection process of a translating field-reversed configuration has been investigated, using a filament ring current model, experimentally and by a numerical technique. The chamber of NUCTE-T is a truncated cone and the skin time is about 6 ms, which becomes a flux conserver at the time scale of the reflection process of ~10 μs. The estimated induced current is about ~10 kA in experiment and numerical calculation, which is a several percentages of the total current of the confinement coil, which is the product of the total number and the current of coils.

1. Introduction

On translation experiments of *field-reversed configuration* (FRC) plasmas, metal vacuum chambers are used to avoid wall-plasma interaction at a reflection region. Confinement properties are degraded by the contamination of the impurity and FRC plasmas sometimes terminate at the first reflection. Figure 1 shows the schematic diagram of the confinement chamber on translation experiment version of NUCTE-III [1]. Vacuum chambers at upstream and downstream regions, which mirror coils are installed, are made of 304-stainless steel. The truncated cone chamber has the smallest radius of r_{t1}=0.128 m, the largest one of r_{t2}=0.20 m and the height of l_t=0.35 m. The skin time is 0.6 to 0.9 ms in cone-shaped flanges and 5 to 8 ms at the connected flanges assuming that the shape is a thin cylinder. An Effect of the metal conductor is investigated experimentally and in a numerical simulation.

2. Numerical simulation results

The following numerical simulation is conducted for the effect of a metal chamber. For simplicity, the FRC plasma is a filament circular current with the plasma current of I_p=500kA. Each confinement coil is the superposition of one-turn coil with the total number of turns. The FRC plasma starts with the translation velocity of V_0=100 km/s from the mid-plane to the downstream chamber. The coil current of confinement coil (I_C) is 490A. The following magnetic diffusion equation for magnetic flux function ψ is solved using *alternating direction implicit iterative* (ADI) method,

$$\frac{\partial}{\partial t}\psi = \frac{1}{\mu_0 \sigma}\left(r\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial \psi}{\partial r}\right) + \frac{\partial^2 \psi}{\partial z^2}\right)$$

where μ_0 and σ are magnetic permeability and conductivity, respectively. Magnetic flux density (B_r(r,z,t) and B_z(r,z,t)) and induced current density (J_i(r,z,t)) calculated from the solved flux function, using, $\begin{cases} B_z = \partial\psi / r\partial r \\ B_r = -\partial\psi / r\partial z \end{cases}$ and $\nabla \times B = \mu_0 J$.

The relation of kinetic energy versus position of translating plasma and the dependence of translation velocity are shown in Fig.2. It is found that the kinetic energy of translation is conserved and the metal chamber works as a flux conserver. The permeability and the conductivity are the value of the free space and SUS 304, respectively. With

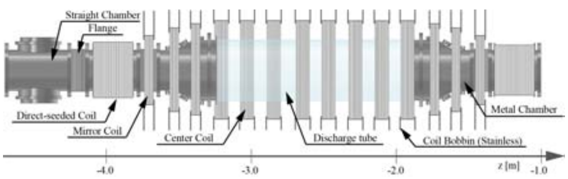

Fig.1 Translation Confinement Chamber on NUCTE-T. The center of chamber is z=-2.6m

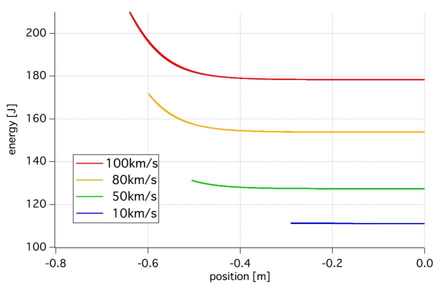

Fig. 2 The relation between kinetic energy and position of the translation plasma, and its dependence of translation velocity.

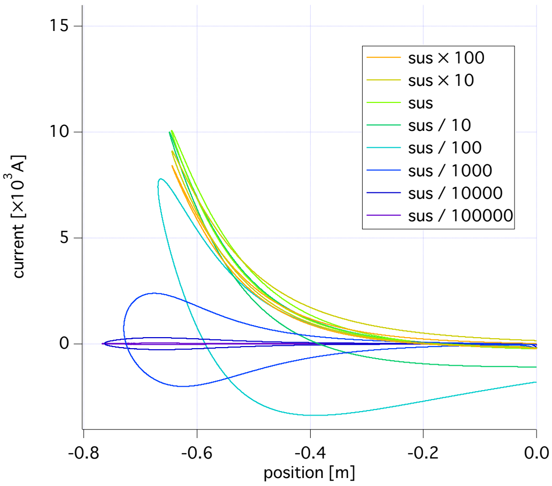

Fig. 3 The relation of inductive current versus position and its dependence of the metal chamber conductivities in the case of the initial translating velocity of 100km.

the increase of kinetic energy, the FRC plasma reflects in the deeper region of the chamber.

Figure 3 shows the relation between the inductive current in the chamber and the position of plasma and its dependence of the conductivity of the metal. With the decrease of the conductivity of the metal chamber, the induced current decreases. The metal chamber does not work as a flux conserver. The estimated induced current is about 10kA with the metal conductivity of SUS 304 and the initial translation velocity (t=0) of 100km.

3. Experiment results.

From the measurement of magnetic flux and magnetic flux density on the surface of the confinement chamber, the plasma current of translating FRC plasma, the inductive current on the metal boundary and the structure of separatrix are reconstructed using the following model. The

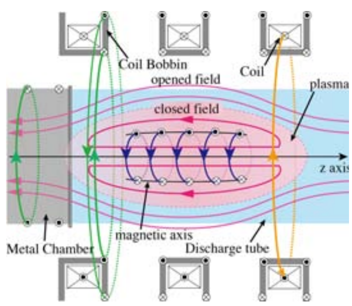

Fig.4 Filament Circular Current Model for system of Translating FRC plasma.

FRC plasma and the confinement coils are modeled as a group of filament circular currents, which is shown in Fig.4. Conductor boundaries of a vacuum chamber and a coil bobbin are also modeled as the

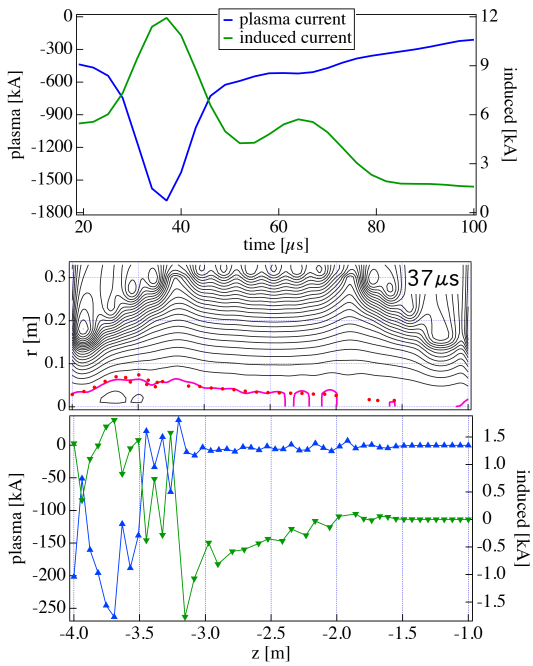

Fig. 5 Time evolution of Plasma current and Inductive Current on metal boundary (up) and sepratrix (red line), inductive current (green line) and plasma current (blue line) profiles at the first reflection process (37μs)

same one. The modeled filament currents are estimated by the least-square method or minimum norm solution.

Fig.5 shows the example of the reconstructed plasma current, the inductive current and the separatrix, the inductive current and the plasma current profiles at the first reflection. The effective skin time of the downstream chamber is about 6ms in from the experimental result. The inductive current increases at the first (t=37μs) and the second (t=65μs) reflection and the plasma current increases at the first reflection. The obtained separatrix profile closely resembles that of exclude flux radius, which is shown as the red closed circles in Fig. 5. The inductive current, which is induced with the injection of FRC plasma into the metal chamber, compresses the injection plasma to reduce the plasma-wall interaction.

Acknowledgments

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References

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