§32. 2-D MHD Simulation of Translation Processes of FRC Plasma

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High beta field-reversed configurations (FRCs) are attractive to be the core plasma of D-^{3}He fueled fusion. The simply-connected FRC core plasma can be translated from the formation region which is surrounded by a quartz tube. The translated plasma is confined in a metal chamber, and it is built up by such as NBI. Here, we simulate translation of FRC plasma by using the 2-D resistive MHD code to study an acceleration process.

The temporal change of the pressure profile in the axial direction is shown in Fig. 1, where the profile is drawn on the fixed surface r=0.069 [m] that is field-null at initial time. By weakening the external field in the right outside of the separatrix, the axial force imbalance occurs and then the plasma starts to move rightward. The pressure near the field-null decreases from the right side as the plasma elongates, and the axial force due to the pressure gradient acts on the plasma subsequently. After the elongating process, the FRC plasma gradually moves rightward, and the translation motion can be seen from 29 μs. In the translation phase, the pressure of the upstream side (left side of Fig. 1) is clearly higher than the downstream side. The time evolution of the axial velocity volume-averaged over the region inside the separatrix is presented in Fig. 2, where the velocity is normalized by v_{A0}. The velocity reaches the peak value of $0.58v_{A0}$ at about 24 μs for the normalized viscosity coefficient of 1.0×10^{-2}. Before reaching the peak, the acceleration is simply due to the elongating motion of FRC plasma. After the peak, the axial velocity is found to decrease gradually. This slowdown is partially because of the axial Lorentz force and partially because of the viscosity. In Fig. 2, the translation speed for $\bar{\mu}=0.5\times10^{-2}$ is also presented. Because of smaller viscosity, the deceleration is found to be also smaller than the case of $\bar{\mu}=1.0\times10^{-2}$. Although the pressure gradient force and the Lorentz force balance in an equilibrium state, the balanced state breaks for an accelerating/decelerating FRC. The axial component of forces acting on the FRC plasma inside the separatrix is shown in Fig. 3. Here, the viscosity $\bar{\mu}$ is 1.0×10^{-2}. The viscous stress arises on the separatrix surface due to the axial velocity gradient when the core of FRC starts to move axially. It is found from Fig. 6 that the axial Lorentz force also decelerates the FRC plasma because it has negative sign. Since deceleration by the Lorentz force begins at the initial time, it accompanies the translation motion. The time evolution of the powers are presented in Fig. 4. Although the magnitude of viscous force in Fig. 3 is larger than the Lorentz force, the power it produces is smaller because of mismatched spatial profiles between the viscous force and the axial flow. Since deceleration by the Lorentz force is caused by the curved magnetic field around the separatrix, it is found that the open field should spread out radially along the translation direction in order to accelerate an FRC plasma effectively.

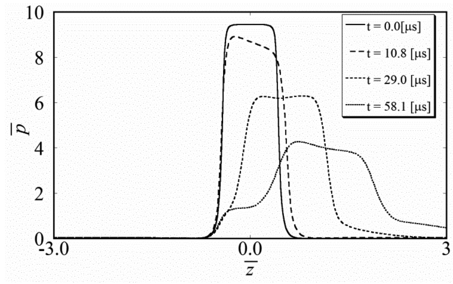

Fig. 1. Axial pressure profile on r=0.069 [m] where the field-null circle is located initially

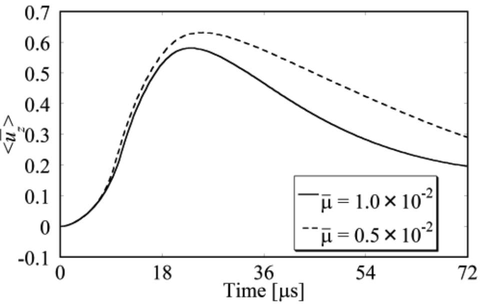

Fig. 2. Time evolution of the axial velocity volume-averaged over the region inside the separatrix

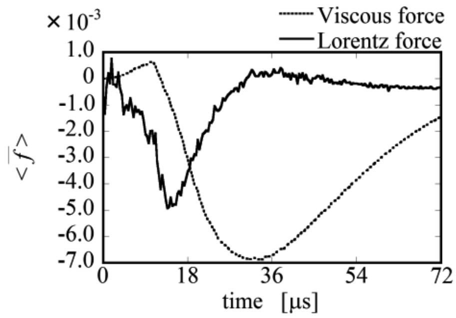

Fig. 3. Time evolution of the viscous and Lorentz forces acting on the FRC inside the separatrix

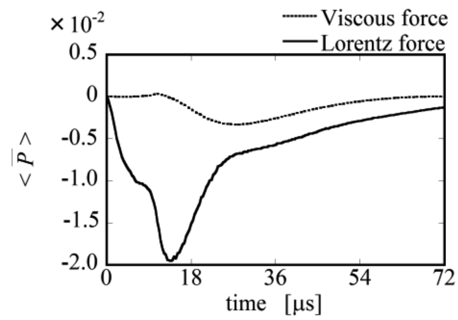

Fig. 4. Time evolution of the power due to the viscous and Lorentz forces acting on the FRC inside the separatrix