§32. Theoretical Modelling of Anomalous Transport Phenomena Observed in FRC Experiments

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Anomalous transport phenomena have been believed as dominant processes observed in high-beta field-reversed configuration (FRC) experiments. Resultantly, conventional FRC plasmas formed by a field-reversed theta pinch method can be maintained for at most a few 100 μs. Estimated from the comparison between the plasma lifetime estimated using a resistive decay model and that measured in FRC experiments, the anomalous factor in the electrical resistivity is approximately 10. Moreover, one of the authors has explained that a spontaneous toroidal flow generation arises from a direct conversion of the resistive flux decay. Therefore, the relationship between global FRC plasma motions and transport phenomena is an important subject to be clarified. Besides, it is necessary to develop theoretical model that can explain transport phenomena measured in recent FRC experiments such as an anomalously fast reconnection in a merging formation of two FRC plasmas and effects of relatively higher magnetic field fluctuations on particle transport processes.

In order to reproduce an axial collision of two FRCs and subsequent merging process by a numerical simulation, we need to give an anomalous resistivity in the reconnection region. In our present study, the electrical resistivity is given by a sigmoid function of the current density as shown in Fig.1. In Fig. 1, our model describes an anomalous increase in the resistivity due to generation of a current sheet between two adjacent FRC plasmas. Introducing this current density model to our 2D resistive magnetohydrodynamic (MHD) simulation, however, we never observe merging of two FRC plasmas. Therefore, particle effects may give an important role of merging processes.

Considering the above reason, we have carried out hybrid simulation in order to reproduce a FRC translation process. When an FRC plasma is supported by the mirror fields in both axial end region, a translation of FRC plasma is triggered by an external field control. We have prepared two cases: the mirror field in the one axial end region is set to decrease gradually (Type 1) and the gradient of the bias magnetic field pressure increases with time (Type 2). Figures 2 and 3 show the density profile in the axial direction on the surface where the field-null point exists for Type 1 and Type 2 respectively. It is found for Type 1 that plasma ions gradually diffuse out from the separatrix and move toward the weak field region. On the other hand, a density increase is never found for Type 2. Furthermore, we also found that the position of the separatrix slightly shifts rightward (toward the weaker mirror field) for Type 2. Unfortunately, we have not as yet been able to reproduce an FRC transport by our hybrid simulation model.

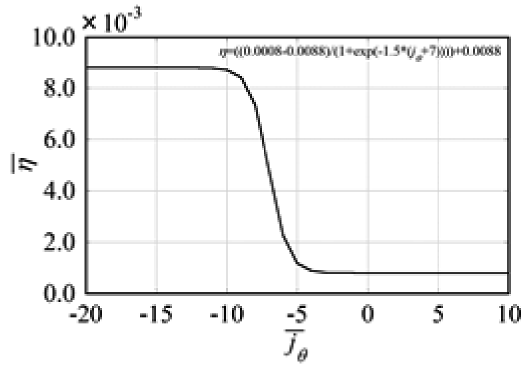

Fig. 1. Relationship between resistivity and current density.

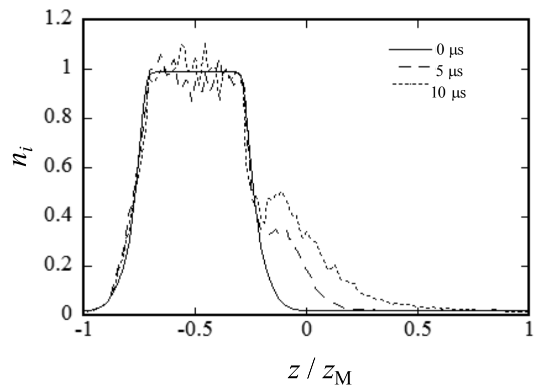

Fig. 2. Axial profile of the ion density for Type 1, where the density is normalized by that of the field-null.

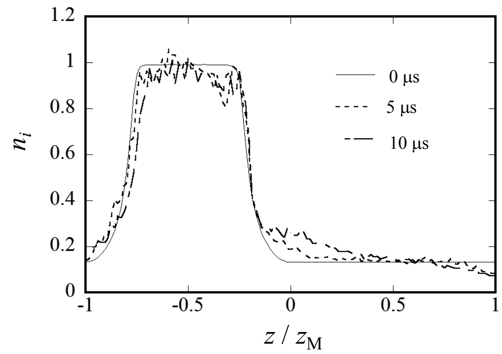

Fig. 3. Axial profile of the ion density for Type 2, where the density is normalized by that of the field-null.