§5. Propagation of Resistive Interchange Modes

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The two-fluid effects can cause the rotation of MHD instabilities. From linear analysis, the resistive interchange modes rotate in the direction of the electron diamagnetic drift and the rotation velocity is smaller than the electron fluid velocity[1]. On the other hand, it is observed that resistive interchange modes rotate with the electron fluid velocity in LHD experiments[2]. Thus, the mode rotation observed in the experiments can not be explained by the linear analysis. From three-field model simulation without two-fluid effects, it is found that the resistive interchange modes nonlinearly generate magnetic islands[3]. It implies that the formation of the magnetic islands can affect the mode rotation in the nonlinear phase. In this study, the propagation of the resistive interchange modes has been investigated by nonlinear simulation in order to clarify the mechanism of the mode rotation observed in the LHD experiments.

The simulation code used in this study is based on the four-field model including the diamagnetic drift effects[4] in a slab plasma. In the equilibrium profile, resistive interchange modes are unstable but tearing modes are stable by adding effective gravity and assuming that equilibrium current gradient is zero. From the linear simulation analysis, higher modes are stabilized due to two-fluid effects and dissipation effects. The resistive interchange modes propagate in the direction of the electron diamagnetic drift. The propagation velocity of the mode is about 60% of the electron fluid velocity. Magnetic islands are not formed since the magnetic flux is zero at the magnetic neutral surface.

From the nonlinear simulation, it is found that magnetic islands of low wave number are formed by nonlinear mode coupling as shown in Fig.1. In the nonlinear phase, the electron diamagnetic drift velocity decreases since the pressure profile becomes flattened within the magnetic islands. The ExB flow is generated in the direction of the ion diamagnetic drift at the magnetic neutral surface. The width of the magnetic islands depends on the two-fluid parameter that is ratio of the ion-skin depth to the device length. The relation between width of the magnetic island and the propagation velocity is shown in Fig.2 where the two-fluid parameter is artificially changed. When the saturated island's width is small, the propagation velocity remains smaller than the electron fluid velocity. However, as the saturated island's width increases, the propagation velocity becomes close to the electron fluid velocity. When the propagation velocity is smaller than the electron fluid velocity (small island case), the mode structure of the magnetic flux for the lowest wave number has interchange parity (Fig.1(a)). On the other hand, when the propagation velocity is close to the electron fluid velocity (large island case), the mode structure has tearing parity (Fig.1(b)). Thus, the propagation velocity may depend on the parity of the mode structure as well as the width of the magnetic island.

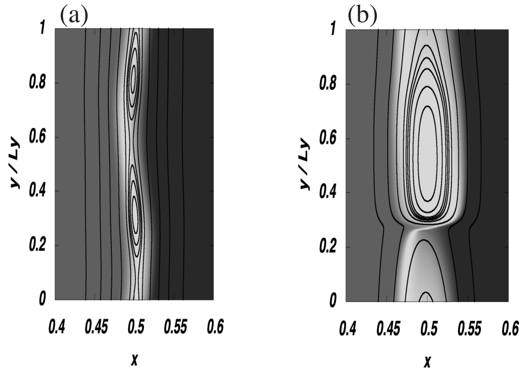

Fig. 1. Magnetic surfaces at the saturated stated are shown by black curves for (a) δ =0.08 and (b) δ =0.02 where δ is the ratio of the ion-skin depth to the device length. The red region (blue region) corresponds to higher (lower) pressure region.

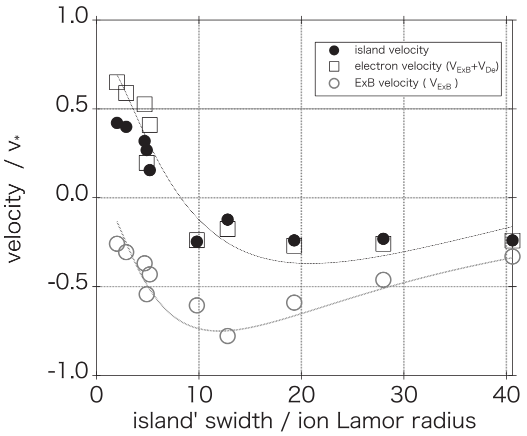

Fig. 2. Dependence of the propagation velocity of the magnetic island on the width of the magnetic island. The electron fluid velocity and ExB flow velocity are also platted. The positive (negative) velocity corresponds to the electron (ion) diamagnetic drift direction. The propagation velocity is normalized by the diamagnetic drift velocity at equilibrium state. As the magnetic island's width increases, the zonal flow is formed in the ion diamagnetic drift direction so that the magnetic islands propagate in the ion diamagnetic drift direction. However, the propagation velocity agrees well with the electron fluid velocity which is the sum of the ExB flow velocity and the electron diamagnetic drift velocity.

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