§27. Evolution of Magnetic Island in Hot Ion Plasmas

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Diamagnetic flow plays the central role in determining the relative velocity of magnetic island from balk plasma flow. The relative velocity is responsible for the magnetic island dynamics through polarization current. Previous numerical studies on magnetic island dynamics adopt model equations which include only electron diamagnetic flow and is applicable only for cold ion plasmas. We have developed a simulation code including ion as well as electron diamagnetism [1)], and study effects of finite ion temperature on magnetic island evolution by means of this code [2)].

We find that the polarization current is almost an order of magnitude larger in hot than in cold ion plasmas (Fig. 1). The magnetic island propagates toward the electron diamagnetic direction for all island widths, including in the subsonic regime, and that the propagation velocity of the island in hot ion slows down much faster than that in cold ion plasmas as the width of magnetic island increases (Fig. 2). When the island width is large, the velocity nearly vanishes in hot ion plasma, because the sound wave propagation flattens the density gradient inside the island separatrix, resulting in a very small diamagnetic flow within the island separatrix.

We also find that when the island width is larger than $5\rho_s$, the polarization current $\Delta_{\rm pol}$ becomes destabilizing in hot ion plasmas (Fig. 3). The critical width $W_c \approx 5\rho_s$ is determined by the change in island propagation velocity with the island width. The destabilization is the strongest when the island width is about $10\rho_s$. This destabilizing effect of $\Delta_{\rm pol}$ in finite ion temperature is important because the threshold of NTM excitation is several times of ion Larmor radius. The destabilization is in contrast with the stabilizing effect of the polarization current for thinner islands and in cold ion plasmas. Furthermore, the polarization current in hot ion plasma is about ten times larger than that in cold ion plasmas. Such large polarization current in hot ion plasma is produced by strong flow shear around the separatrix of magnetic island. The flow shear is driven by the Maxwell stress, while it is suppressed by viscosity.

In summary, the polarization current is found to be almost an order of magnitude larger in hot than in cold ion plasmas. As a function of the island width, the propagation speed decreases from the electron drift velocity (for small islands) to the guiding-center velocity (for large islands). When the island width is larger than several times the ion Larmor radius, the polarization current is destabilizing (*i.e.* it drives magnetic island growth). This is in contrast to cold ion plasmas, where the polarization current is generally found to have a healing effect on freely propagating magnetic island.

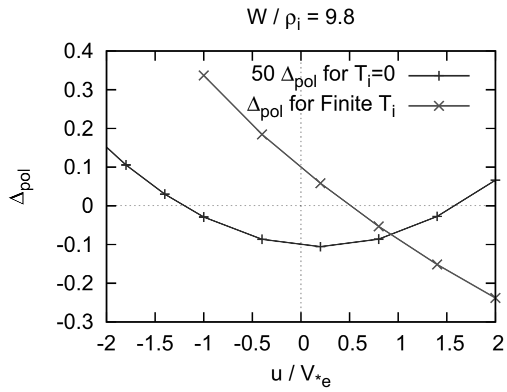

Fig. 1: The polarization current $\Delta_{\rm pol}$ for magnetic islands in helical plasmas as a function of external ExB flow velocity u for hot ion, Finite T_i; for cold ion, $T_i = 0$.

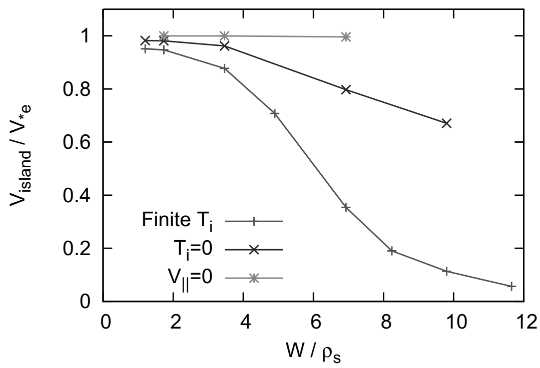

Fig. 2: The propagation velocity of magnetic island V_{island} in hot ion plasma Finite T_i; in cold ion plasma $T_i = 0$; in incompressible plasma, $V_\parallel = 0$.

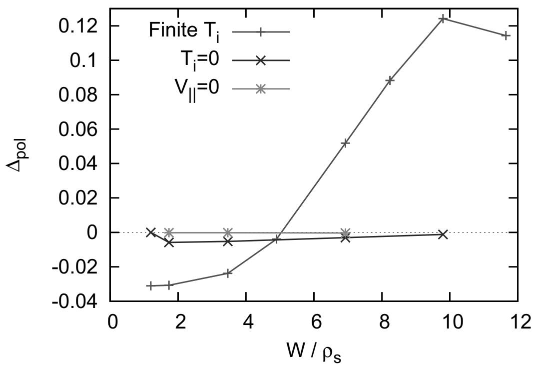

Fig. 3: The polarization current $\Delta_{\rm pol}$ for magnetic island propagating with its natural velocity V_{island} in hot ion plasmas, Finite T_i; in cold ion plasmas, $T_i = 0$; in incompressible plasma, $V_\parallel = 0$.

1) A. Ishizawa and N. Nakajima, *Physics of Plasmas*, 17(7):072308, 2010.

2) A. Ishizawa, F. L. Waelbroeck, R. Fitzpatrick, W. Horton and N. Nakajima, submitted.