§7. Turbulence Driven Magnetic Reconnection Causing Long-wavelength Magnetic Islands

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Magnetic reconnection caused by turbulence in a current sheet is studied by means of numerical simulations of fluid equations. It is found that turbulence produces long-wavelength magnetic islands, even if the current sheet is so thick that spontaneous magnetic reconnection does not occur. Thus, turbulence modifies the threshold of magnetic island formation predicted by the conventional theory of spontaneous magnetic reconnection in a current sheet. In spite of the fact that the turbulence is driven by a short-wavelength instability due to a pressure gradient, the length of the magnetic island is the same order as the system size. The width of the island is several times the ion Larmor radius, and stronger turbulence causes wider magnetic islands. This suggests that the turbulence can trigger neoclassical tearing modes which are the main nonlinear instability that limits the plasma pressure in magnetically confined plasmas. The long-wavelength magnetic island is formed by merging of small-scale magnetic islands[1].

We have found that turbulence driven by short-wavelength instability causes magnetic reconnection and produces long-wavelength magnetic islands in a current sheet, even when the sheet is so thick that there is no spontaneous magnetic reconnection, i.e. Delta' is negative. The long-wavelength magnetic islands are caused by the energy transfer from small-scale turbulence. Two-fluid simulations showed that turbulence driven by ion temperature gradient instability produces long-wavelength magnetic islands (Fig. 1). The length of the island is the same order as the system size, and the island width is several times the ion Larmor radius (Fig. 2), and stronger turbulence causes wider magnetic islands. The long-wavelength magnetic islands are formed by the merging of small-scale magnetic islands produced by magnetic reconnection driven by turbulent fluctuations. MHD simulations showed that turbulence driven by pressure-gradient instability causes long-wavelength magnetic islands too, and thus the formation of large magnetic islands does not depend on types of instability which drives turbulence. Notice that the effect of zonal magnetic field is not responsible for the formation of the long-wavelength island in our simulations.

Our results suggest a mechanism of long-wavelength magnetic islands formation in a current sheet in addition to spontaneous and driven magnetic reconnections. Long-wavelength magnetic islands or plasmoids are directly produced by the energy transfer from small-scale turbulence, even if there are no spontaneous reconnection due to a macro-scale current density gradient and no reconnection driven by macro-scale external flow.

The results obtained by two-fluid simulations are critically important for experimental devices, such as tokamaks. One of primary MHD activities that limit the plasma pressure is neoclassical tearing mode (NTM). NTMs are nonlinear instabilities and they require finite size magnetic islands, called seed islands, for overcoming a threshold of destabilization. The typical width of seed island is evaluated to be several times as large as the ion Larmor radius by using experimental data. Thus, such turbulence-driven magnetic island can be the seed island for NTM. We have also found that the magnetic islands propagate in the electron diamagnetic direction. The propagation of the island is also important for NTM destabilization because of polarization current effects.

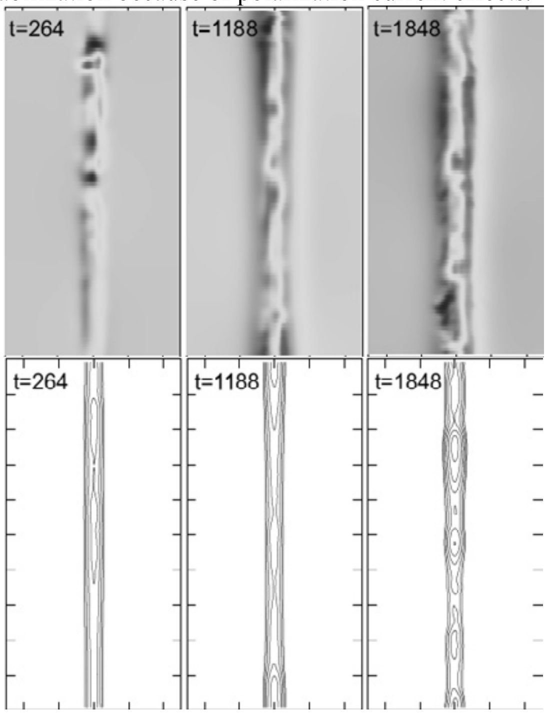

Fig. 1. Color map of electrostatic potential and equi-contours of magnetic flux that indicates long-wavelength magnetic islands, even if there is no spontaneous magnetic reconnection, Delta' = -0.76.

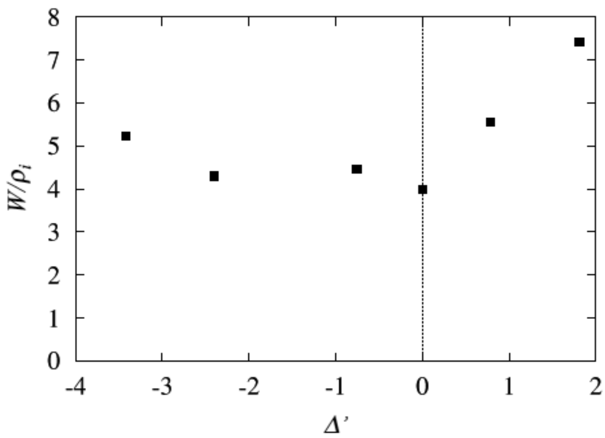

Fig. 2. Magnetic island width W as a function ofthe stability parameter of tearing instability Delta' for the case eta_i=3.5.

1) Ishizawa, A., Nakajima, N., Physics of Plasmas **49** (2010) to appear in July issue.