Reduction of Magnetic Chaos and Transport in Fusion Plasmas

The magnetic field in some toroidal plasma configurations is observed spontaneously to fluctuate in time, even if the magnets produce a time-independent magnetic field. The fluctuations are small, about 1%. However, they have a very large effect on the plasma behavior. They cause magnetic field lines to wander chaotically throughout the plasma. Since charged particles follow the field lines, the chaotic magnetic field yields transport and loss of energy from the plasma. The transport is sufficiently large that if the plasma were unheated it would cool down in 1 millisecond. Such magnetic chaos and transport have long been considered an unavoidable attribute of plasma configurations in which the confining magnetic field is relatively weak. However, it has recently been discovered that control of the driven current density profile (the energy source for the fluctuations) can dramatically reduce both the chaos and loss of energy.

In the past year, researchers have succeeding in reducing the magnetic fluctuations by about a factor of two – from about 1% to 0.5%. This seemingly small change has a huge effect on the macroscopic behavior of the plasma. The temperature doubles, from 4 million K to 8 million K. The energy needed to maintain the plasma decreases several-fold. The net result is that the energy confinement (or cooling) time is increased ten-fold, demonstrating the strong connection between magnetic fluctuations, magnetic chaos, and transport. The reduction in magnetic chaos is also reflected in the appearance of energetic electrons (up to 100 keV), which are otherwise absent. The reduction is effected by control of the applied electric field that drives the plasma current (the energy source for the fluctuations). These results were accomplished in the MST reversed field pinch experiment at the University of Wisconsin – Madison.

Magnetic fluctuations dominate transport in a class of toroidal magnetic configurations that are referred to as magnetically self-organized. The reversed field pinch is one such configuration. The externally applied magnetic field (by magnets) is relatively weak. Whereas the weak field is a potential engineering advantage for a fusion energy system, magnetic fluctuations are stronger when the confining magnetic field is self-organized. This class of configurations was previously considered to be of physics interest for basic studies of magnetic turbulence, but of little interest as a fusion system. The recent results suggest that there may be a path to overcome the influence of magnetic chaos in these systems.

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Presentations of Topic at DPP Meeting

B. Chapman, “High Confinement Plasmas in the MST Reversed Field Pinch,” Invited paper K11.003.

S.C. Prager, “MST Progress and Plans,” Poster FP1.002