Interaction between a magnetic island and turbulence in fusion plasmas

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Magnetic islands are a ubiquitous structures generated in a process of magnetic field reconnection in magnetized plasmas. In magnetically confined fusion plasmas, magnetic islands are known to play a dual role for the plasma confinement. On one hand, they can degrade the plasma confinement. The fast parallel transport along the reconnected filed lines short-circuits either side of an island O-point (the center of an island) and the stochastic region around an island separatrix becomes a fast radial transport channel through the X-point (the reconnection site). They can also lead to disruptive events when they grow explosively. The hot core plasmas are released to the edge region across the magnetic island following its reconnecting field lines. On the other hand, stationary magnetic islands can behave like a transport barrier by generating strong flow shear near their separatrix. The latter role of an island was suggested to explain the reduced power threshold for the internal transport barrier formation with an island and the proximity of the transport barrier location to the rational surface where an island of low toroidal mode number can grow.

The evolution of magnetic islands has been mostly studied within the physical framework of the resistive magnetohydrodynamics and it has been successful to understand important properties of the island evolution in fusion plasmas. However, recent studies have shown that the interaction between a magnetic island and ambient turbulence can be important for the evolution of magnetic islands. In this talk, we will introduce key results of recent studies on their interaction. Firstly, how magnetic islands can change the distribution of ambient turbulence (broadband drift wave like instabilities driven by pressure gradients) will be discussed [1]. Observations from various experimental devices and gyrokinetic simulations indicate that the combined effect of the modified pressure and flow profiles by magnetic islands results in a strongly inhomogeneous turbulence around an island. The inhomogeneous turbulent transport would complicate the island evolution. For example, the reduced heat influx from the hot core region by the turbulence suppression should result in a flatter temperature profile and the more loss of the bootstrap current inside an island, facilitating the positive feedback loop of the neoclassical tearing mode. Secondly, complex turbulence phenomena which can affect the island evolution will be introduced with some experimental evidence being accumulated [2]. They include turbulence spreading, nonlinear mode coupling, and turbulent magnetic reconnection. For example, turbulence spreading which can carry the heat or particle flux is considered to be responsible for the spontaneous transport of heat and fluctuation into a magnetic island in which drift wave like instabilities are linearly stable due to a low pressure gradient. The finite pressure gradient inside the island by turbulence spreading would be beneficial for the recovery of the bootstrap current or the island saturation by the classical stability index change. An opposite harmful contribution of turbulence was also implied during the magnetic island driven plasma disruption whose fast magnetic reconnection could be facilitated by the correlated increase of turbulence at the reconnection site. These studies would extend our understanding of the complicated magnetic island evolution in magnetic fusion plasmas as well as provide general insights into the magnetic reconnection process.

References

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