Fast Pressure Crash Associated with Double Tearing Modes in Tokamaks.

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In present Tokamaks (such as DIII-D, TFTR, NSTX, ASDEX-U, JET and TPX), it is found that the negative magnetic shear in the core region can help to suppress the drift instabilities, stabilize ballooning mode instabilities, suppress Electron Temperature Gradient Turbulence, and then significantly improve plasma confinement. Due to its advantage in the superior energy confinement, the reversed magnetic shear configuration has been adopted as one of the advanced scenarios in future fusion reactors such as ITER and CFETR. However, there exists a destructive non-ideal instability, double tearing mode (DTM), in such configurations. In the linear phase, DTM grows much faster than a single tearing mode if the two tearing modes on the resonant surfaces couple with each other. If not, the two tearing modes develop independently. The nonlinear evolution of DTM can result in an off-axis sawtooth crash or a core-crash sawtooth, which can significantly degrade energy confinement in Tokamak. During an off-axis sawtooth, the temperature crash only takes place in the annular region, while the temperature around the magnetic axis remains almost unchanged. However, during a core-crash sawtooth, the temperature becomes flattened in a broad region (including the magnetic axis). Our presentation is divided into three parts:

(1) The mode-mode coupling effect dominates the nonlinear evolution of the DTMs. When we numerically filter out the n=0 component, the system can not saturate, and the instabilities continue to grow up until the code crashes. While, if we filter out the high n (n>=2) components, the fast reconnection process will not occur throughout the simulation.

(2) Weak shear flows can suppress the DTM's linear growth. However, at the nonlinear stage, the suppression effect of weak shear flows will be eliminated by the 'mode locking' between the two tearing modes. Moreover, the strong shear flows can cause the 'Kelvin–Helmholtz' instability, which is even more dangerous than the DTM.

(3) The two different kinds of pressure crashes observed in TFTR, i.e. the off-axis sawtooth and the core pressure crash, are both related to the nonlinear evolution of the DTMs. The behaviors of the pressure crashes are dominated by the radial location of the inner resonant surface, the distance between the two resonant surfaces, and the local magnetic shear.

(4) The on-axis plasma pressure can oscillate during the nonlinear evolution of the m/n=2/1 DTMs, which is similar to the sawtooth-like oscillations observed in many Tokamaks (such as the TFTR, JET, and ASDEX-U). The properties of the oscillations are associated with several parameters, such as the heat source, the thermal conductivity, and the viscosity.

References:

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