Force-free plasma motion in a tokamak during current decay

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Tokamak disruption events typically impair plasma position control, which allows the plasma column to move and hit the wall. These detrimental events enhance thermal and mechanical loads due to halo currents and runaway electron losses. Their fundamental understanding and prevention is one of the high-priority items for ITER.

The characteristic timescale of disruption is longer than Alfvenic time. It is therefore appropriate to ignore inertia and view the plasma motion as a sequence of force-free states that evolve in step with magnetic field diffusion. The corresponding flow velocity profile is then governed by the condition that magnetic diffusion meets the force-free constraint. This work describes such time-dependent flows in cylindrical and toroidal geometries for purely ohmic dissipation of the plasma current as well as in the presence of significant runaway electron population.

In addition to two-dimensional calculations, we examine the force-free motion within a 0-D model that treats the plasma-wall system as a set of conducting wires with wall conductors being fixed in space. The current in the plasma wire decays due to ohmic losses and/or slowing down of the runaway electrons. This simple model gives a functional relation between the plasma vertical position and the decaying current when the decay time is shorter than the wall resistive time.

The results of this work highlight the underlying mechanism of the vertical displacement events during plasma disruption and suggest an improved physics-based algorithm for plasma disruption simulations.

This work was supported by the U.S. Department of Energy Contracts DEFG02-04ER54742 and DE-SC0016283.