A new spin on understanding plasma confinement

November 10 2011

To achieve nuclear fusion for practical energy production, scientists often use magnetic fields to confine plasma. This creates a magnetic (or more precisely "magneto-hydrodynamic") fluid in which plasma is tied to magnetic field lines, and where regions of plasma can be isolated and heated to very high temperatures—typically 10 times hotter than the core of the sun! At these temperatures the plasma is nearly superconducting, and the magnetic field becomes tightly linked to the plasma, able to provide the strong force needed to hold in the hot fusion core. The overall plasma and magnetic field structure becomes akin to that of an onion, where magnetic field lines describe surfaces like the layers in the onion. While heat can be transported readily within the layers, conduction between layers is far more limited, making the core much hotter than the edge.

Yet, even at these extreme temperatures, plasmas still have some electrical resistance and the magnetic field structure can slowly tear apart under certain conditions. Typically this happens within fractions of a second, and can lead to the formation of "magnetic islands", structures which connect the hot plasma core to cooler layers further out (Figure 1). Plasma follows field lines about these magnetic islands, bleeding energy from the core, lowering its temperature, and reducing fusion power production.

Recent experiments in the DIII-D tokamak—a toroidally shaped magnetic confinement device located in San Diego—have shown scientists how spinning the plasma can impede the formation of these magnetic islands.

"Plasma rotation creates a variation in the flow of plasma between magnetic surfaces, very similar to the wind shear that pilots experience," said Dr. Richard Buttery, who led these experiments.

This work shows that naturally occurring rapid rotation in the core of the tokamak plasma creates a stress across surfaces further out that prevents the formation of magnetic islands. The effect was confirmed by applying additional magnetic fields to brake the plasma motion. As the braking increases and plasma rotation slows, the stabilizing effect of the sheared flow is reduced and a magnetic island spontaneously appears. The magnetic island is born rotating, confirming that it is a natural instability of the plasma, rather than being directly driven by the static braking field.

These effects highlight an interesting and curious physics effect: creating flow shear (which might be seen as a source of energy causing islands to appear), strengthens a magnetic fluid's resilience to tearing, enabling it to support higher pressures, and so a hotter and higher performing fusion core. Thus, by applying torque on the plasma to spin it faster while minimizing stray magnetic fields that brake plasma rotation, tokamak fusion performance can be raised.

Provided by American Physical Society