E.J. Strait Press Release

A Little Rotation Provides a Lot of Stability

The minimum speed of rotation needed to improve the stability of a high-pressure plasma is smaller than expected, a result which may help future fusion reactors.

In the quest to develop high temperature, high-pressure plasmas for fusion power, at least one problem may turn out to be less challenging than expected. Under certain conditions, rapidly spinning the plasma dramatically improves its stability. However, recent research at the DIII-D National Fusion Facility (General Atomics, San Diego) now indicates that the rotation speed needed for this additional stability is lower than previously thought. This research has important implications, since it makes the technique more applicable to the International Thermonuclear Experimental Reactor (ITER) and future power plants.

This favorable result was made possible by recent upgrades to the DIII-D facility, including the capability to control the plasma rotation. DIII-D has four “neutral beam” injectors that send streams of high-energy atoms into the plasma, heating it to thermonuclear temperatures and also causing it to spin. This year, one of the injectors was repositioned to oppose the rotation driven by the others. By using these injectors in different combinations (Fig. 1), the effects of plasma rotation can be studied in a controlled way.

Nuclear fusion, a process in which two light atomic nuclei combine to form a heavier one, has the potential to produce large amounts of energy from a small quantity of fuel. At the temperatures of more than one hundred million degrees required for the fusion reaction, the fuel becomes an ionized gas known as a plasma. Tokamak devices such as DIII-D use strong magnetic fields to confine the hot plasma, preventing it from coming into contact with other materials. However, as the pressure of the plasma increases, it gains enough energy to push aside the magnetic field and escape from the “magnetic bottle”. Finding ways to avoid such instabilities is one of the major challenges of fusion science research.

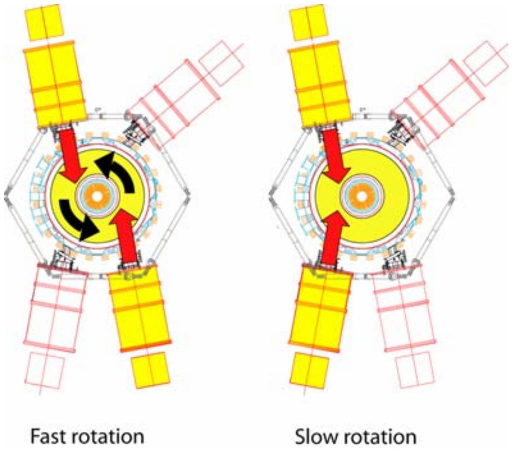

Fig. 1. The donut-shaped DIII-D plasma is heated by 4 neutral beam injectors, which also exert a rotational force on the plasma. Injectors that push in the same direction lead to rapid rotation of the plasma (left), while injectors that push in opposite directions lead to little or no rotation (right). Combined use of all of the injectors at different power levels allows control of the plasma rotation.

Previous work at DIII-D and other laboratories has shown that rapid rotation of the plasma, in combination with a nearby metal wall, improves the stability of the plasma and allows it to be heated to higher pressure. In some cases, this technique has made it possible to increase the plasma pressure by 50%-100%. Since the fusion power increases roughly as the plasma pressure squared, there is a large potential payoff in raising the pressure.

In DIII-D, the “neutral beams” of high-energy atoms that heat the plasma also exert a force on the plasma, causing it to rotate in much the same way that a stream of water makes a water wheel rotate (Fig. 1). Earlier experiments varied the rotation by using magnetic fields to exert a drag on the rapidly rotating plasma. With the gentler reduction of rotation now possible with bidirectional beams – which also more nearly resembles the conditions expected in a fusion reactor – the plasma is found to remain stable at slower speeds.

The earlier experiments suggested that the stabilizing effect required rotation speeds of 50-100 km/s (kilometers per second), but recent experiments show that the same stabilizing effect is achieved with rotation speeds as low as 10-20 km/s. This may still sound like an extremely high speed (for comparison, the orbiting space shuttle has a speed just under 8 km/s). However, the lower speed is within the range expected in ITER, and opens the possibility that future fusion reactors can take advantage of this stabilizing effect.

Research at any modern fusion laboratory requires the efforts of a large number of scientists and engineers. These experiments on plasma rotation were carried out by a team of scientists from Columbia University, General Atomics, and Princeton Plasma Physics Laboratory. The results will be reported in an invited talk (paper ZI1.06) by E.J. Strait of General Atomics, at the American Physical Society's Division of Plasma Physics conference in Philadelphia, October 30 through November 3, 2006.

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Contacts: E.J. Strait, General Atomics, San Diego, (858) 455-3889, strait@fusion.gat.com
M.R. Wade, General Atomics (858) 455-4156, Mickey.Wade@gat.com