Computer Simulation of "Current Hole" Phenomena in Plasmas Could Lead to Better Fusion Reactor

Newly observed phenomena in high-temperature plasmas — hot, ionized gases — may lead to more efficient fusion power reactors. A computational physics team at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) employed supercomputers to simulate recently observed phenomena in high-temperature laboratory plasmas. Dubbed "current hole," the phenomena have been observed in large tokamaks, which are toroidal shaped experimental fusion reactors. Scientists observed current holes in the Joint European Torus (JET) and JT-60U tokamaks in England and Japan, respectively. These machines normally conduct 1-2 million amperes of electrical current during an experimental discharge, where the current is typically peaked in the plasma center where the temperature is the highest.

In published accounts of current hole experiments, researchers applied time varying and static electric fields to the device in order to decrease the current in the plasma center. According to the standard theory, this sequence of events could lead to reversal of the central plasma current. Instead, researchers observed that the current density did not reverse, but became clamped in the center at near zero. Thus, the plasma current became concentrated in a toroidal annular ring surrounding the region with zero current density — a current hole. There is growing interest in this current hole configuration since both the stability of the plasma and its confinement properties are observed to be much better than expected. This makes the configuration a promising candidate for a fusion power producing device.

A PPPL computational physics team used supercomputers to simulate the current hole phenomena. The team implemented a computer model with external conditions sufficient to drive negative current on axis in their model plasma. They found that the central region of current would initially decrease and start to reverse direction as predicted by the standard theory. But, just as the reversal was to occur, and the central current density was passing through zero, phenomena called "magnetic reconnection" occurred in the simulation. The magnetic reconnection generated a large plasma motion as soon as the central region of the current became even slightly negative. This outward transfer of small negative current has the effect of keeping the net current density positive or zero everywhere. This motion continually repeated itself in the simulation, keeping the central value of the current density effectively clamped at zero. The calculations were performed on a 3000 processor IBM SP3 computer at the National Energy Research Supercomputer Center.

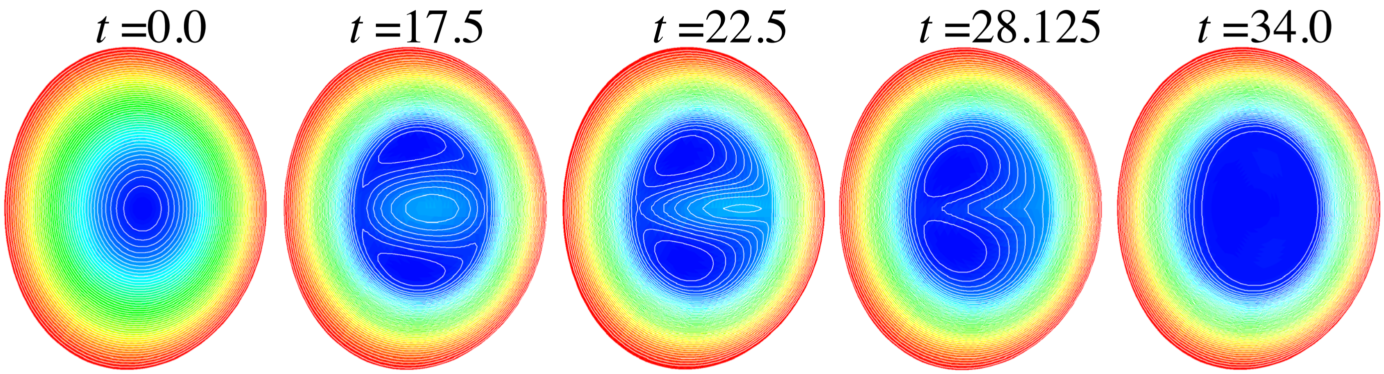
This magnetic reconnection process is closely related to similar processes that occur in solar flares, and in specially designed laboratory experiments. This new investigation of the role of magnetic reconnection in the current hole phenomena may be useful in designing a next generation of fusion power demonstration experiments.

For more information, contact Joshua Breslau at (609) 243-2677, jbreslau@pppl.gov.

J. Breslau, "Simulation Studies of the Role of Reconnection in the 'Current Hole' experiments in JET," invited talk at 2002 APS-DPP. (invited oral, Tuesday Morning FI1.005)

Hawkes, N.C., et al., Phys. Rev. Lett. 87 (2001) 115001-1.

Fujita, T., et al., Phys. Rev. Lett. 87 (2001) 245001-1.



Caption: Computer simulation of the sequence of events in the reconnection process. Shown are contours of constant pressure at different times. As the current starts to become negative, the reconnection process begins and moves the center rapidly to the edge, effectively clamping the current in the center at zero.