Researchers perform first basic-physics simulation of the impact of recycled atoms on plasma turbulence

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Turbulence, the violently unruly disturbance of plasma, can prevent plasma from growing hot enough to fuel fusion reactions. Long a puzzling concern of researchers has been the impact on turbulence of atoms recycled from the walls of tokamaks that confine the plasma. These atoms are neutral, meaning that they have no charge and are thus unaffected by the tokamak's magnetic field or plasma turbulence, unlike the electrons and ions—or atomic nuclei—in the plasma. Yet, experiments have suggested that the neutral atoms may be significantly enhancing the edge plasma turbulence, hence the theoretical interest in their effects.

In the first basic-physics attempt to study the atoms' impact, physicists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) have modeled how the recycled neutrals, which arise when hot plasma strikes a tokamak's walls, increase turbulence driven by what is called the "ion temperature gradient" (ITG). This gradient is present at the edge of a fusion plasma in tokamaks and represents the transition from the hot core of the plasma to the colder boundary adjacent to the surrounding material surfaces.

Extreme-scale computer code

Researchers used the extreme-scale XGC1 kinetic code to achieve the simulation, which represented the first step in exploring the overall conditions created by recycled neutrals. "Simulating plasma turbulence in the edge region is quite difficult," said physicist Daren Stotler. "Development of the XGC1 code enabled us to incorporate basic neutral particle physics into kinetic computer calculations, in multiscale, with microscopic turbulence and macroscale background dynamics," he said. "This wasn't previously possible."

The results, reported in the journal *Nuclear Fusion* in July, showed that neutral atoms enhance ITG turbulence in two ways:

- First, they cool plasma in the pedestal, or transport barrier, at the edge of the plasma and thereby increase the ITG gradient.
- Next, they reduce the sheared, or differing, rates of plasma rotation. Sheared rotation lessens turbulence and helps stabilize fusion plasmas.

Comparison with experiments

Going forward, researchers plan to compare results of their model with experimental observations, a task that will require more complete simulations that include other turbulence modes. Findings could lead to improved understanding of the transition of plasmas from low confinement to high confinement, or H-mode—the mode in which future tokamaks are expected to operate. Researchers generally consider lower recycling, and hence fewer neutrals, as conducive to H-mode operation. This work may also lead to a better understanding of the plasma performance in ITER, the international fusion facility under construction in France, in which the neutral recycling may differ from that observed in existing tokamaks.

Provided by Princeton Plasma Physics Laboratory

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