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Playing Atomic Whack-A-Mole: Researchers explore gas puffing to eliminate hot spots in future fusion-energy reactors

It was like an atomic version of the carnival game Whack-a-Mole: Researchers had developed a safe way to create energy-generating burning plasma. However, to create a commercially viable sized fusion power device, they faced the prospect of creating so much energy the supercharged plasma in potentially damaging hot spots.

Researcher Alexis Briesemeister of Oak Ridge National Laboratory found a potential key to the future large-scale fusion energy production in the current fusion device of DIII-D National Fusion Facility, operated by General Atomics in San Diego for the Department of Energy. What she compares to the carnival game, isolating one pesky problem only to have another pop up.

One of the biggest challenges facing fusion for becoming a viable clean-energy source is preventing the plasma from damaging the walls of a fusion machine such as DIII-D. When hot plasma hits the walls around it, not only can it damage the walls, but the material it knocks off the walls ends up contaminating the plasma and resulting in energy losses. To prevent this, a large amount of research has gone into finding the best shape for the magnetic field, which confines the plasma, and the best shape for the walls around the plasma.

Fitting the wall tightly around the plasma so there is even contact with as much surface area as possible is not actually a good solution, the researchers found. Any imperfections in the magnetic field or motion of the plasma itself will cause local hot spots where the plasma knocks material off the vessel wall and contaminates the plasma. The most promising solution has been to create magnetic fields structures, which channels the exhaust plasma to two localized strips, which run around the machine. This exhaust system is known as the divertor, performing for fusion energy what an exhaust pipe does for a car engine by channeling away waste energy.

“It’s a known problem, and it did solve one problem, but it was creating hot spots where you don’t want hot spots,” said Briesemeister.

By creating these channels, researchers can place extra armor on the walls where these strips occur and put baffling around this region to keep more cold gas around the hot exhaust plasma. The process makes it easier to cool the plasma before it hits the walls. This will become even more important in ITER, which will be the largest fusion confinement device when built and will confine larger, hotter plasmas.

Although the divertor does a reasonably good job handing the exhaust plasma most of the time, in high-performance scenarios the plasma periodically ejects sharp intense bursts of plasma, known as Edge Localized Modes (ELMs), which in future reactors may be so large that they damage even the best wall armor.

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"Once we can control it, we can confine it, so we know where to put the extra armor in," said Breisemeister.

It's been found that using electric coils that create wiggles in the normally smooth magnetic field can reduce and even eliminate these bursts. These coils are known as resonant magnetic field perturbation (RMP) coils. One concern about using these field wiggles in future devices is that they split each of the two stripes of hot exhaust plasma into multiple strips, which have a complicated structure. There are concerns that in ITER, this complicated structure will cause some of the hot exhaust plasma to leak into regions where the wall is not well armored and hence cause damage to the walls.

A solution to this problem has been found by scientists working on the DIII-D tokamak, who discovered that if a large amount of gas is puffed into the device, the complex exhaust structure returns to the smooth structure seen without the RMP coils. The measurements, made by measuring the infrared radiation from the divertor, are shown in figure 1. Since ITER was already planning to puff large amounts of gas into this region of the plasma, this work suggests that the complicated structure caused by the RMP coils may be less of a concern than previously though for ITER and future fusion reactors.

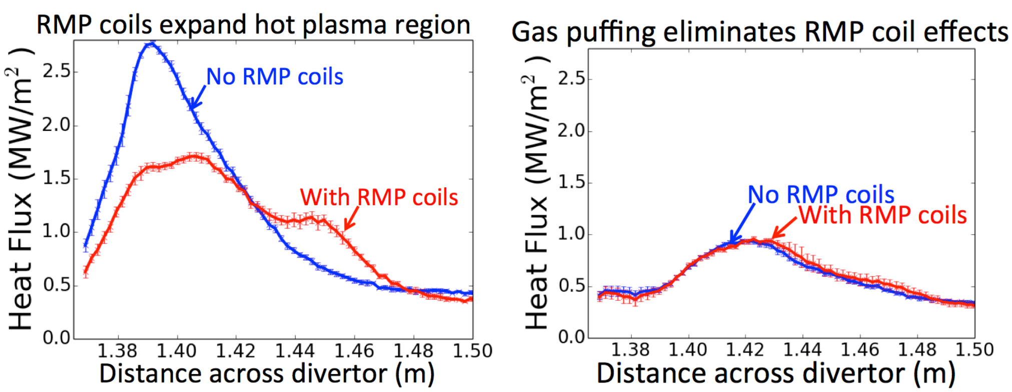

Figure 1. A slice of the heat deposited by the plasma onto the armored divertor tiles is shown for base cases in blue where no RMP coils are used and for cases with RMP coils in red (a) where little gas puffing is used and (b) where a large amount of gas puffing is seen to reduce the heat in both cases, making them nearly identical.

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Abstract:

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