An Exhaust System for a High Performance Fusion Engine

Electrical power generated from nuclear fusion reactions has been a long-time but elusive goal of thousands of researchers around the world. Recent studies using the DIII-D Tokamak Facility in La Jolla, California, have succeeded in moving the promise of fusion a little bit closer. As in an automobile engine, the performance of magnetic fusion systems is linked tightly to the ability to remove the heat generated by the fusion process without damage occurring to the internal components. Recent studies in the DIII-D tokamak have demonstrated the compatibility between a high performance core plasma (the engine) and a method for removing the created heat efficiently (the exhaust system).

Physically, this compatibility issue arises in the following way. When a deuterium ion “fuses” with a tritium ion, part of the energy liberated by the reaction is in the form of highly energetic helium ions, which transfer most of their energy to a very hot background ionized gas (or “plasma”), helping to maintain the high plasma temperatures needed to sustain an operating regime favorable to fusion production. The power delivered to the plasma eventually leaks out of the plasma onto material surfaces of the tokamak device in a very narrow zone in amounts that can seriously damage the surrounding container walls. While it is known that the severity of this problem can be reduced by dissipating a significant fraction of the power flow toward a specialized surface region called a “divertor” where power loading is likely to be most severe, the cost of doing this is typically a degraded performance.

DIII-D researchers have discovered that such compatibility can be realized by careful control of the amount and location of argon gas injection into the plasma chamber. The argon dissipates the heat by radiating it away as ultraviolet light, particularly near the divertor target. Two-dimensional “images” of the radiated power show the argon presence generates a strong increase in radiated power throughout the edge plasma, most notably near the divertor (Fig. 1). As a result, the maximum heat load at the divertor target was found to be ≈2.5 times lower in the argon injection case, while not affecting tokamak performance. The injected argon did not contaminate the plasma in amounts that could compromise the viability of this approach, because the argon was largely localized to regions where little fusion activity would be expected to take place. If this “radiative divertor” approach can be scaled to future machines such as ITER, it would reduce the risk of damage to the vessel walls by the waste heat.

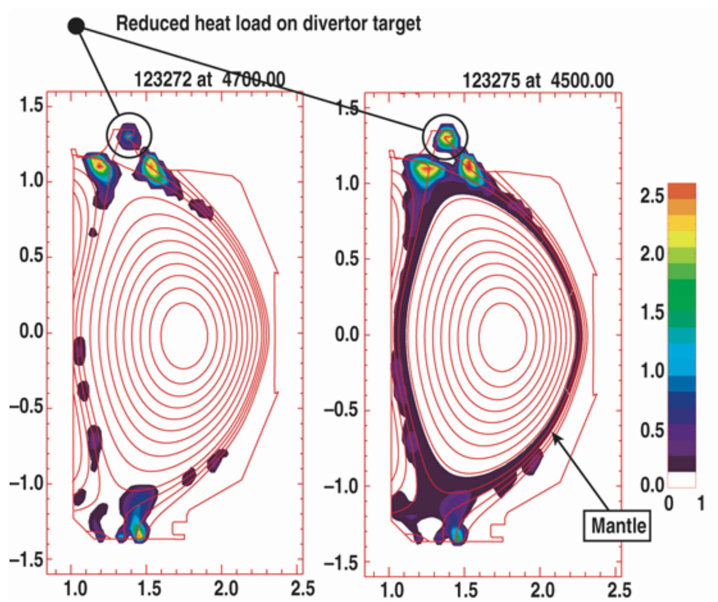

Fig. 1. The radiated power distributions for cases without argon injection (a) and with argon injection (b). The increase in the radiated emissivity was largest at the location of highest power loading at the divertor target (circled). The argon radiates some of the waste heat before it reaches the divertor plate.

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