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Some implications of recent technology advances on divertor physics performance requirements of DT fusion tokamaks

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The continuing rapid evolution of a number of advanced technologies being strongly pursued for major non-fusion applications, is potentially transformative for the divertor physics performance requirements of reactors:
Advanced Manufacture, e.g. 3D printing, holds promise to increase the power handling capability of solid divertor targets significantly above the present limit for total power deposited on the target, ˜ 10 MW/m2, by increasing the contact area between coolant and solid surfaces, and by reducing the risk for failure from fatigue.
Robotics. When the toroidal field coils are not openable, as in ITER, then all internal components including the divertor must be modular for construction, maintenance and repair since the components have to be moved in and out of the vessel through ports. Advances in robotics can be expected to enable improved installation, maintenance and repair procedures for modular devices, making it possible to use smaller gaps between modules/tiles and to reduce radial misalignments. This will be highly beneficial: in order to shadow-protect leading edges, the relatively large gaps and misalignments in ITER necessitate that the angle between B and the target surface, θ_⊥, be restricted to very large values, ˜ 4.5o, compared to typical values that can be safely used in present tokamaks, ˜ 1-2o. This then causes much higher loads on the primary power-handling surfaces of the targets than would occur if smaller θ_⊥could be safely used.
HTSC magnets. High temperature superconductor toroidal field magnets have the potential of being openable which makes it possible to use monolithic rather than modular internal structure of the vessel. ARC, for example, calls for HTSC toroidal field coils and θ_⊥ ˜ 1o; FNSF-AT, although using copper magnets, also calls for openable coils and θ_⊥ ˜ 1o. For both devices the entire, highly-aligned and structurally-strong, monolithic divertor would be pre-assembled and lowered in and out of place, thus making possible the safe use of small θ_⊥.

These technological advances have potentially major implications for a number of critical divertor physics performance requirements regarding survival of the targets in reactors:
optimal plasma temperature and density at the divertor target, Tt¬, nt,
minimum level of volumetric power dissipation in the SOL/divertor, P_(diss-edge),
values of upstream plasma density (at the outside midplane separatrix).
R&D in these high technology areas is being pursued for major and rapidly growing non-fusion applications. The robotics industry, for example, is doubling in size every ˜3 years. If these advances are proven at the time that a fusion power device is being designed, it will be essential that they be fully exploited. While the ITER design is now largely fixed, it will be possible to take advantage of advances in robotics and additive manufacture to upgrade the ITER divertor, which is designed to be replaced.

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