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Super H-mode: Optimizing the pedestal to greatly raise performance in future fusion reactors[1]

MATTHIAS KNOLKER, Oak Ridge Associated Universities

The Super H-mode (SH) [1,2], a regime with high pedestal pressure and stored energy, has been developed into a reliably reproducible scenario on DIII-D using 3D fields to limit core mode growth. Unlike prior studies that employed counter-current beam injection with a quiescent H-mode edge, recent experiments have employed co-current beam injection at full magnetic field ($B_T = 2.1 - 2.2T$) and high current ($I_P = 1.4 - 2.0MA$), where discharges experience edge localized modes (ELMs). The discharges evolve from a high-performance transient phase that stores up to threefold higher energy density than conventional standard H-mode plasmas, into a stationary phase with $\beta_N \approx 2.5 - 2.9$, $W_{MHD} \approx 1.8 - 2.2MJ$, $\tau_e \approx 0.15 - 0.22s$, $H_{98} \approx 1.3 - 1.6$, labelled the near Super H (NSH) regime. The transition from the very high confinement, high T_i/T_e SH state at early times, to the reduced, but still high confinement NSH phase at lower T_i/T_e has been studied with focus on limiting ion temperature gradient (ITG) turbulent transport and MHD instabilities. The transition correlates with a decrease in rotation shear and inductance (reducing beta limit and critical ITG) and either occurs through larger ELMs or abruptly by the destabilization of an internal mode. This global MHD event can cause energy losses of up to 20 % of the stored energy. Typical H-mode instabilities do not show increased severity: overall moderate ELM sizes dominate with values below 5 % relative to the total stored energy and present neoclassical tearing modes (NTMs) do not lead to disruptions. Progress towards divertor compatibility was achieved by decreasing ELM energy densities by 30% through neon injection with constant or improved pedestal performance. The Super H-mode regime eases the operation margins for ITER to obtain Q=10 and is attractive for compact fusion reactor devices and possibly JET D-T. [1] Solomon PRL 2014 [2] Snyder NF 2015

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