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Toroidally asymmetric density profiles and turbulence induced by applied 3D fields in DIII-D[1]

ROBERT WILCOX, Oak Ridge National Laboratory

Small non-axisymmetric magnetic field perturbations that are applied to tokamaks (dB/B˜10ˆ-4) are shown to produce 3D plasma equilibrium changes that alter the stability of microturbulence modes in the pedestal region. Measurements from the DIII-D tokamak show that the density gradient scale length in the pedestal at the outboard midplane changes with the toroidal phase of the applied 3D fields, and this change is qualitatively reproduced using two-fluid M3D-C1 modeling. This modeling shows that the density may be non-constant within flux surfaces in the pedestal region when 3D fields are applied. The pressure gradient and resulting diamagnetic rotation are large in the pedestal, so that the ion and electron fluid velocities differ significantly, necessitating the use of a two-fluid model to resolve this effect. Calculated changes to surface topology using single fluid modeling are shown to be too small to affect turbulence stability directly, through modification of the curvature and local magnetic shear, without the additional changes to the 3D density profiles that arise from two-fluid modeling. In DIII-D experiments and simulations, field-aligned helical flux tubes in the pedestal region with an increase in normalized density gradients correspond to locations with increased broadband density fluctuation amplitudes, measured using beam emission spectroscopy and Doppler backscattering. These pedestal effects may help explain the longstanding mystery of density pumpout, by which 3D fields used for control of ELMs and other properties in tokamaks lead to a rapid decrease in plasma density, and improve understanding of the heat and particle fluxes into the scrape-off layer and to the divertor.

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