On the link between turbulent-driven plasma flows and critical confinement device operational limits

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We summarize evidence for the link between turbulent-driven ExB sheared plasma flows at the plasma boundary, the tokamak L-H transition, and the plasma density limit. Basic laboratory device studies provide a detailed view of how turbulent driven sheared zonal flows arise, of the dynamical interaction between turbulence and sheared flow, and how these flows can acquire a net momentum due to their interaction with a neutral gas mantle surrounding the plasma. Furthermore, these studies also reveal how turbulent-driven radially sheared parallel flows also develop; both of these flows are a result of turbulent structures with broken symmetries in the r-θ and r-z planes respectively. These basic physics insights are then used to motivate probe-based and imaging studies in tokamak devices. When operating well below density and beta limits, the tokamak edge plasma show a similar picture in which edge turbulence gives rise to zonal flows at the LCFS which become progressively stronger as additional heating is applied; with sufficient heating the turbulent-driven flows can momentarily quench turbulent transport, giving rise to the L-H transition and the birth of the edge plasma pedestal. As the plasma density is progressively raised in L-mode towards the density limit, the edge zonal flow is observed to weaken, an increase in the intermittent turbulent transport across the LCFS and into the SOL occurs, and the edge profiles flatten prior to the onset of density-limit MHD activity, consistent with a hypothesis that transport changes are responsible for the onset of density-limit MHD activity. Studies of intrinsic rotation in confinement devices provide evidence for turbulent self-organization processes acting both in the edge plasma region and in the core plasma, perhaps acting in concert with orbit loss and other complicating kinetic factors. This talk summarizes the current state of knowledge, and outlines ideas for future experiments that may help elucidate the physics of the density limit, together with the development of a physics-based prediction of intrinsic rotation and its effect on the beta limit in future tokamak devices.

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