Tokamak rotation sources, transport and sinks

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Abstract

Toroidal rotation has become a topic of wide interest experimentally and theoretically because of the recognition that it is important for confinement, stability, and even access to the H-mode confinement regime. The inception of ITER has generated a focus upon developing a prediction for rotation in burning plasmas where auxiliary injected torque will be relatively small. We will describe experimental results and cite theory, organized by sources of toroidal momentum, transport of this momentum, and sinks for momentum, including the effects of some loss of toroidal axisymmetry (AS). We will also describe so-called "intrinsic rotation" where rotation under AS conditions is observed in the absence of any auxiliary momentum source, presumably due to effects such as off-diagonal transport elements, or turbulent stresses, and others. We describe how rotation is measured, and specific areas where the importance of rotation has been established. The predominant source of rotation generation in present devices is the toroidal torque from neutral beam injection. Experiments verify the accuracy of neoclassical (NC) models to describe the torque deposition process in AS conditions. Applied electromagnetic wave power is also found to generate rotation. The radial transport of momentum is found to be much larger than predicted by standard NC theory, having transport rates similar to that of ion thermal energy. Experiments have also verified the existence of a pinch term in the momentum transport, which could generate the interior rotation gradient often observed with intrinsic rotation. The ambient or purposely imposed non-axisymmetric magnetic fields can provide an interior sink for momentum, and that may also drag the rotation to a nonzero offset value. The rotation itself tends to shield out resonant perturbations. Nonresonant perturbations from toroidal field ripple have long been considered, and the area of nonresonant perturbations has taken on new import for the fields generated by perturbation coils for mitigation of edge localized modes. We consider some of these effects in relation to what might be extrapolated to ITER, but continued experimental and theoretical efforts are required.

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