Turbulent Current Drive Mechanisms

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Non-inductive current drive mechanisms are essential to the realization of steady state tokamak operation and also play an important role in determining the plasma's MHD stability. In this work we discuss the efficiency of various mechanisms through which turbulence can modify the plasma current. The first mechanism treated results from the establishment of an equilibrium between trapped and passing electrons due to resonant scattering by drift wave microturbulence [1]. This mechanism is closely analogous to the familiar neoclassical bootstrap current except that it relies on wave-particle interactions to detrap electrons rather than Coulomb collisions. In addition to the above turbulent mechanism, it has also been suggested [2,3] that mean plasma current can be driven by either a turbulent acceleration or a "residual stress" term in the electron momentum flux [4]. The former mechanism relies on turbulence mediated exchange of momentum between ions and electrons. Such an exchange of momentum can lead to the acceleration of electrons, and hence appears as an effective source term in Ohm's law. The residual stress, in contrast, corresponds to a term in the momentum flux that is independent of the parallel electron flow (current) and its gradient, and hence can also act to drive an electron current.

In order to determine the relative importance of these mechanisms, a mean field formulation is developed that incorporates the above turbulent mechanisms as well as a Coulomb collision operator. Such a formulation allows for turbulent current drive mechanisms to be treated on an equal footing with neoclassical effects, such that no assumption of "additivity" of turbulent and neoclassical mechanisms is made. The solution of the above system indicates that modifications to the plasma current from turbulence are most robust near low-q rational surfaces, providing significant modifications to the mean plasma current profile in these regions for fusion reactor relevant regimes. In addition, contributions due to the individual mechanisms discussed above can be easily isolated, allowing for the determination of the relative efficiency of each mechanism in various parameter regimes. This work was supported by DOE OFES.

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