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Fast Wave Current Drive in Neutral Beam Heated Plasmas on DIII–D*

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The physics of non-inductive current drive and current profile control using the fast magnetosonic wave has been demonstrated on the DIII–D tokamak. In non-sawtoothing discharges formed by neutral beam injection (NBI) preheating of the plasma, the radial profile of the fast wave current drive (FWCD) was determined by the response of the loop voltage profile (measured using the motional Stark effect) to co, counter, and symmetric antenna phasings. A record 275 kA of non-inductive current has been driven by the fast waves for co and counter antenna phasings with a current drive efficiency of 0.46×10^{19} A/m^2 W; no FWCD was measured for a symmetric antenna phasing. The magnitude and radial profile of the measured FWCD was in good agreement with theoretical models. The FWCD efficiency was found to increase linearly with central electron temperature over a factor-of-4 range. The current density driven by the fast waves was comparable to the total current density near the plasma axis, which resulted in substantial current profile modification. The application of counter FWCD increased the magnetic shear reversal of the plasma and delayed the onset of sawteeth, compared to co FWCD. The different current profiles produced by co and counter FWCD also exhibited different thresholds for resistive tearing mode activity. Although L-mode plasmas were utilized for most of these FWCD experiments on DIII–D, VH–mode and ELMing H–mode plasmas have also been studied with up to 3 MW of coupled FWCD power. Under most conditions the FWCD efficiency for H–mode plasmas was in good agreement with the L–mode results, although the radial profile was broader for H–mode plasmas. In parallel with the current drive experiments, the interaction of fast waves with energetic beam ions at high harmonics of the ion cyclotron frequency was also studied. The partial absorption of fast waves by beam ions is evident from a build up of fast particle pressure near the magnetic axis and a correlated increase in the neutron rate; the fast particle pressure profile was determined from a magnetic equilibrium reconstruction after allotting for the thermal pressure profile. The anomalous fast particle pressure and neutron rate peaked when a harmonic of the deuterium cyclotron frequency passed through the center of the plasma. The anomalous fast particle pressure also increased with increasing NBI power, giving further evidence that the fast waves were interacting with the beam ions. The experimental FWCD efficiency was highest at 2 T where the interaction between the fast waves and the beam ions was weak; as the magnetic field strength was lowered, the FWCD efficiency decreased to approximately half of the theoretical value. The observed absorption of fast waves by beam ions was of the correct magnitude to explain the decrease in the FWCD efficiency; however, the magnetic field dependence of the FWCD efficiency was not as sensitive to the presence of a central ion cyclotron harmonic as was the anomalous fast particle pressure.

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