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Experimental Test of the Neoclassical Theory of Poloidal Rotation in Tokamaks[1]

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Plasma rotation plays many critical roles in fusion plasmas such as the suppression of turbulence, the formation of transport barriers and the stabilization of both resistive wall modes and neoclassical tearing modes. Despite the importance of rotation, our present understanding of momentum transport is clearly inadequate. Our lack of understanding is in part related to the difficulty of performing accurate poloidal rotation measurements. Recently, detailed measurements of poloidal rotation have been obtained in the core of a wide range of DIII-D discharges using charge exchange recombination spectroscopy, and these measurements have been compared with predictions based on the neoclassical theory of poloidal rotation from the code NCLASS. The analysis shows that the neoclassically predicted poloidal rotation is in many cases too low by an order of magnitude compared to the actual measurements. The inferred poloidal rotation is based on careful consideration of the effective energy-dependent cross-section (which is modified by the presence of excited beam neutrals) and of the gyro motion of the ions. These effects can generate apparent poloidal velocities that are many times greater than the neoclassical predictions. For consistency, the radial electric field is independently computed from different impurity species and also compared against motional Stark effect spectroscopic measurements. The large discrepancy between the measured and predicted poloidal rotation suggests that (i) the neoclassical theory of poloidal rotation may need substantial revision and (ii) knowledge of poloidal rotation is essential for quantitative determination of the radial electric field from charge exchange measurements.

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