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Measurements and modeling of viscosity in a stochastic magnetic field

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Controlled perturbation of the momentum in MST RFP plasmas has allowed the first comprehensive test of a theoretical model [Finn et al., Phys. Fluids B (1992)], originally derived for the tokamak, for rotation damping in a stochastic plasma. Both a resonant magnetic perturbation (RMP) and an inserted biased probe were applied, separately, to a wide variety of spontaneously rotating Ohmic plasmas with a 10-fold span in normalized magnetic fluctuation amplitude, b/B. These control techniques provide measurements of the perpendicular kinematic viscosity, which is found to increase as (b/B)ˆ2 and which agrees well with predictions from the model. The dominant magnetic fluctuations in MST are linearly unstable m=1 tearing modes resonant at multiple locations in the core. The islands associated with these modes commonly overlap, producing stochasticity. The applied RMP also has m=1, causing deceleration of the co-rotating core plasma and m=1 modes. The biased probe initially spins up the core, but when bias is turned off, the core decelerates. The viscosity is derived from the deceleration curves in both cases and reaches 50 mˆ2/s, roughly 100 times the classical prediction in the absence of stochasticity. Applying both techniques to the same plasma conditions provides a valuable cross check. The theoretical model, targeting the tokamak edge with an applied magnetic perturbation, is based on stochastic field line diffusion, which increases as (b/B)ˆ2 [Rosenbluth et al., Nucl. Fusion (1966)]. Rotation damping in the Finn model occurs as the local radial electric field is shorted out, and this damping can be characterized by an effective perpendicular viscosity. The results described here are relevant to any magnetically confined plasma, such as the tokamak and RFP, where rotation is important, and magnetic stochasticity is either intrinsic or externally imposed. Work supported by USDoE.