Experimental validation of momentum transport theory in the core of the ASDEX Upgrade tokamak

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This work employs the established momentum transport analysis at ASDEX Upgrade to investigate the parametric variations of the momentum transport coefficients [1]. Experimental results are compared to a comprehensive database of gyrokinetic calculations, which includes data points corresponding to experimental observations and isolated parameter scans. Generally, good agreement between predicted and measured diffusive and convective transport coefficients is found. The Prandtl numbers correlate strongly with the magnetically trapped particle fraction. The pinch numbers depend most dominantly on the logarithmic density gradient and magnetic shear, consistent with the theoretical predictions of the Coriolis pinch [2]. The intrinsic torque from residual stress in the inner core is small, scales with the local logarithmic density gradient, and the data suggest a possible sign reversal. In the outer core, the intrinsic torque is always co-current directed and scales with the pressure gradient. Both trends are consistent with prior experimental findings [3–5]. They suggest that different mechanisms contribute to residual stress generation in the inner and outer core, with profile shearing effects dominating the inner core [6, 7]. Towards the edge, most likely, effects from $\mathbf{E} \times \mathbf{B}$-shearing become more influential via the diamagnetic term in the E_r force balance [8]. These results offer the first comprehensive picture of this transport channel in the core plasma and contribute to validating the corresponding theoretical understanding. The derived scaling laws construct a reduced momentum transport model validated against an additional dataset. The successful reproduction of experimental data demonstrates that the reduced model captures the essential contributions to momentum transport in the core plasma. This validation opens avenues for various applications, including integrated modeling approaches and real-time control. Ultimately, the theory validation and scaling laws will provide a foundation for physics-based predictions of rotation profiles in future reactors.

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