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Plasma Rotation Research for Advanced Tokamak Plasma Control in JT-60U

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The fusion research has to establish an efficient control of the self-regulating plasmas for achieving a high integrated performance. Toward this goal, the mechanisms determining the plasma rotation profile and effects of the rotation on transport and stability are the central issues. Reduction of the toroidal field ripple by installing ferritic steel tiles in JT-60U reduced the fast ion losses and resultant counter plasma rotation drive. By combining this newly achieved freedom of rotation with co-, counter- and perpendicular NBs, JT-60U has been promoting an integrated research project focusing on the plasma rotation covering the research areas of transport, stability, pedestal, and steady state operation. With a new perturbed transport analysis, we successfully separated the diffusive and the non-diffusive terms of the momentum transport in L and H-mode plasmas, clarified their dependences, reproduced the toroidal rotation profile utilizing these evaluated transport coefficients and external torque input, and identified the drive for intrinsic rotation which is determined by the pressure gradient locally. In the type-I ELM regime, we found that the shift of the rotation into the co-direction reduces the inter-ELM transport, enhances the pedestal width and height. The grassy ELM frequency increases almost linearly with increasing counter rotation. Even at zero-rotation, a high ELM frequency with sufficiently small ELM energy loss is obtained. This result encourages applicability of the grassy ELM to ITER. As for the high-beta stability, the critical rotation speed for the resistive wall mode stability was found to be 0.3% of the Alfven speed almost up to the ideal-wall limit. Rreversed shear plasmas with bootstrap fraction $\sim$70% was sustained for 8 s, where the beta-collapse was avoided through reduction of the pressure gradient at ITB by the rotation control.