The effect of magnetic islands on the bootstrap current in Wendelstein 7-X

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The bootstrap current in W7-X is small and largely controllable by the magnetic configuration. The minimization of bootstrap currents, moreover, is an optimization criterion for helical axis advanced stellarators with beneficial consequences for the plasma stability and the magnetic equilibrium. Remnant bootstrap currents, however, need to be controlled to avoid extensive loads on plasma facing components and require careful consideration for the plasma control in long-pulse operation. While experiments on W7-X demonstrated that the bootstrap current agrees well with predictions from neoclassical theory, this agreement is in some cases not perfect. This paper reports on the characterization of the observed differences. Experimental findings suggest that magnetic islands within the confined plasma volume are the reason for the observed deviances between measured currents and neoclassical predictions.

Systematic changes of the magnetic configuration were performed at roughly fixed heating power and density. The scan is made by a shot-by-shot variation of the planar/non-planar coil-current-ratios. In consequence, the 5/5-rational-value of the rotational transform is shifted from the plasma edge to the very core of the plasma [1,2]. Two effects are observed: First, the thermodynamic forces – mainly the electron pressure profile - are changed since magnetic islands appear to affect the radial transport locally flattening the profiles in the vicinity of low order resonances. Second, a more subtle result of systematic modelling with the NTSS code is that the expected stationary bootstrap current and L/R time from drift kinetic theory resembles larger currents than the measured plasma current response. The largest deviation is about 50% when the island is in the profile gradient region. The configuration scans of the rotational transform are concluded to provide first measurements of significant braking of the parallel transport due to magnetic islands in low-shear stellarators.

[1] T. Andreeva et al., Nucl. Fusion 62 (2022) 026032

[2] J. Geiger and Y. Suzuki, this conference