Up-down asymmetric designs for tokamaks that drive large intrinsic rotation

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Recent work demonstrated that breaking the up-down symmetry of tokamaks removes a constraint limiting intrinsic momentum transport, and hence toroidal rotation, to be small.‡ We show through MHD analysis that low order flux surface shaping (e.g. elongation, triangularity) is most effective at introducing up-down asymmetry throughout the plasma. We then demonstrate a particular tilting symmetry of the flux surface shape in the local nonlinear δf gyrokinetic model. This symmetry establishes an important distinction between the momentum transport in tokamaks with mirror symmetric flux surfaces and tokamaks with flux surfaces that lack mirror symmetry. Using GS2, a local δf gyrokinetic code that self-consistently calculates momentum transport, we first numerically verify this gyrokinetic symmetry. Then we show the momentum flux calculated by GS2 is consistent with both TCV experimental measurements§ and analytically derived scalings in the limit of high order flux surface shaping. Lastly, we investigate the influence of the Shafranov shift on momentum transport and present preliminary numerical scans aimed at optimizing the flux surface shape to maximize toroidal rotation. These results suggest that up-down asymmetry can generate sufficient rotation to stabilize the resistive wall mode in reactor-sized devices.

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