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Magnetic bumps + Super-bananas = Mountain of Torque

New experiments at low rotation find enhanced torque from magnetic bumps that can be exploited to improve plasma performance

An important issue in fusion energy research based on the tokamak approach is avoidance of instabilities that are encountered as the energy content of the plasma increases. Toroidal rotation of the plasma plays an important role. Faster rotation allows higher plasma pressure before instabilities cause large energy losses. However, rapid rotation could be impractical in a self-heated burning plasma, where toroidal momentum injection from neutral particle beams presents technical, and economical problems. Therefore, demonstration of instability avoidance at low rotation without significant external momentum input from neutral beams is advantageous.

Recent developments in the theory of how magnetic bumps (local variations in field strength) affect plasmas have led to predictions that such bumps produce torques on the plasma which strongly peak at low rotation. Physicists at the University of Wisconsin calculate that the naturally occurring radial electric field in the plasma can vanish at low rotation, leading to creation of ‘super-banana’ particles. These particles escape more easily from the plasma and in doing so, exert additional toroidal torque on the plasma. In recent experiments at the DIII-D National Fusion Facility, scientists carried out detailed measurements of the dependence of this torque on the plasma velocity by applying magnetic bumps with special coils inside the DIII-D vacuum vessel, while varying the momentum input from neutral beam injection. These measurements have shown that a peak in the torque exists at very low plasma rotation, as predicted by theory. The results are encouraging for future large-scale fusion experiments such as ITER, where the newly observed torque peak could essentially act as an insurmountable mountain for the plasma if the rotation tries to slow to zero, thereby forming a barrier so as to maintain a given level of rotation and plasma performance.

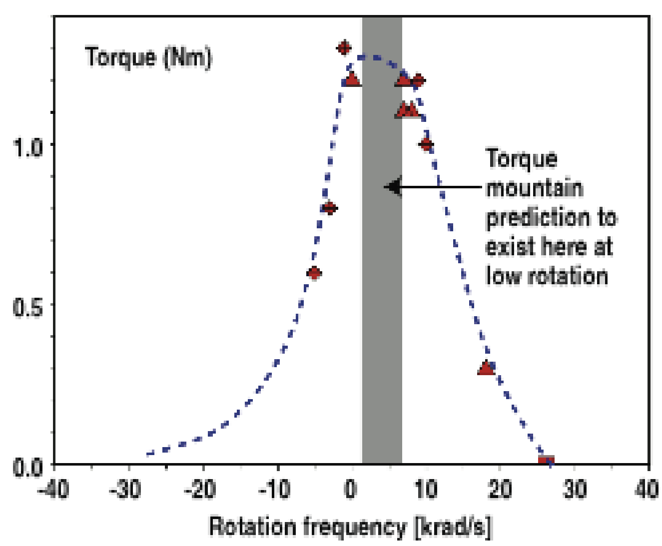

Figure 1: Measurements of the torque from magnetic bumps, as a function of plasma toroidal flow rate. The location of theoretically-predicted torque peak is in good agreement witht the measurements.

In related experiments, the DIII-D scientists utilized these magnetically driven torques to control the plasma rotation in the edge and maintain the suppression of edge instabilities known as ELMs. (A.M. Garofalo et al., "Quiescent H-Mode Plasmas with Rotation Driven By Static Nonaxisymmetric Fields" to be published in Bull. Am. Phys. Soc., 2009). Previous studies have shown ELMs can be suppressed only if sufficient radial shear in the plasma rotation is produced near the plasma edge. In past experiments, this rotation shear was produced using neutral particle beams to provide toroidal torque. In the present experiments, this torque was nearly completely replaced by the torque from applied magnetic bumps, successfully producing plasma rotation in the edge leading to ELM-free operation. Furthermore, results show that the beneficial effects of the applied fields are amplified as the energy content of the plasma increases, which projects favorably toward the realization of an ELM-free self-heated burning plasma without neutral beam injected torque.

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