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Response of Tokamaks to Non-axisymmetric Magnetic Perturbations

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Tokamaks are sensitive to non-axisymmetic perturbations. Non-axisymmetry as small as $\delta B/B \approx 10^{-4}$ can deform or destroy flux surfaces causing significant non-ambipolar transport and possibly plasma disruption. Important progress in understanding tokamak plasma responses has been made through the applications of Ideal Perturbed Equilibrium Code (IPEC), which solves self-consistent ideal equilibria in the presence of non-axisymmetry in tokamaks. Non-axisymmetric perturbations can be amplified or shielded with strong poloidal harmonic coupling, and such plasma responses are shown to be essential to explain error field correction. Consistency over different machines, parameters, and fields including DIII-D mock-ups of ITER Test Blanket Modules (TBMs) has been demonstrated. A salient feature of the theory and modeling is the dominant distribution of non-axisymmetric field to which tokamaks respond most strongly by an order of magnitude relative to other orthogonal distributions. The design of correction coils in tokamaks including ITER can be greatly improved based on the new findings. Ideal plasma responses are already strong as shown by IPEC applications, but non-ideal plasma responses can be also important in high-performance tokamaks, as demonstrated in recent Resonant Field Amplification (RFA) experiments. One of the most important non-ideal plasma responses is the non-ambipolar transport along with the non-axisymmetric variation in the field strength, which can induce large friction forces and change the perturbed equilibrium itself. The progress in understanding non-ambipolar transport and eventually more general perturbed equilibria will be discussed. This work was supported by the US DOE Contract #DE-AC02-09CH11466.