Three-dimensional plasmoid-mediated reconnection in tokamaks

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Abstract

Plasmoid-mediated reconnection is examined using global nonlinear three-dimensional resistive MHD NIMROD simulations in a tokamak for two cases: 1) generation of closed flux surfaces during transient Coaxial Helicity Injection (CHI) start-up current-drive and 2) nonlinear edge localized modes. We explore the physics of plasmoids reconnection for flux closure during non-inductive plasma start-up in spherical tokamaks. A rare, classical example of plasmoid formation in a tokamak has been demonstrated during helicity injection, where the injected magnetic field lines are oppositely directed near the injection region and form an elongated Sweet-Parker current sheet. At high Lundquist number a transition to plasmoid instability has been shown in a large-scale toroidal fusion plasma.[1] It is shown that the three-dimensional non-axisymmetric magnetic fluctuations could arise due to edge current-sheet instabilities. The role of these 3-D magnetic fluctuations in i) the plasmoid-mediated flux closure and ii) the onset of axisymmetric current-carrying plasmoids is examined. It is found that i) regardless of non-axisymmetric 3-D edge perturbations, large volume flux closure is formed in transient CHI, ii) 3-D magnetic fluctuations can cause local flux amplification to trigger axisymmetric reconnecting plasmoids formation at the reconnection site.[2] We also show coherent current-carrying filament (ribbon-like) structures wrapped around the torus that are nonlinearly formed due to nonaxisymmetric reconnecting current sheet instabilities, the so called peeling-like edge localized modes.[3] These fast growing modes saturate by breaking axisymmetric current layers isolated near the plasma edge and go through repetitive relaxation cycles by expelling current radially outward and relaxing it back. The physics of the nonlinear dynamics of the field-aligned filaments is explained.

[1] F. Ebrahimi, R. Raman, Physical Review Letters 114, 205003 (2015).

[2] F. Ebrahimi, Phys. Plasmas 23, 120705 (2016).

[3] F. Ebrahimi 2017, http://arxiv.org/abs/1702.02696