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Control of Spontaneous Rotation in a Field-Reversed Configuration by Double-Sided Magnetized Plasmoid Injection

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The mechanism and control of spontaneous toroidal spin-up of a field-reversed configuration (FRC) have been investigated on the Nihon University Compact Torus Experiment (NUCTE). The FRC has highly favorable technological features especially as a D-3He fusion reactor core, i.e., extremely high beta, linear device geometry, natural divertor and axial mobility, allowing separation of start-up and confinement functions. One of the critical issues of FRC study is to understand the toroidal spin-up which triggers the most dangerous global instability (the rotational instability) a centrifugally-driven interchange-like mode with toroidal mode number n = 2.

The radial profile of this self-generated toroidal flow has commonly been described as relaxing toward rigid rotation, i.e., toward uniform angular rotation frequency v_theta/r, with the driving torque acting from outside in. Surprisingly, detailed observation of toroidal flow revealed that, rather than tending toward rigid rotation, the profile showed slower rotation in the edge region, thus indicating the transmission of toroidal torque directly into the interior rather than by a diffusive "viscous" process. This suggests the action of the flux-loss spin-up mechanism.

Toroidal rotation eventually causes a destructive instability reflected by a deformation of the toroidal cross-section. In the experiments, plasmoid injection from each end by "magnetized coaxial plasma guns" (MCPG) has been conducted aiming to mitigate the spin-up. Each MCPG generates a spheromak-like plasmoid which travels axially to merge with the pre-existing FRC. The particle inventory of the plasmoids is less than 1/50 of the target FRC in these experiments. The toroidal fluxes of the two plasmoids are opposed so that the MCPGs add no net toroidal flux. Since the MCPG discharges form isolated plasmoids, the open field lines do not electrically connect the FRC core to the gun electrodes. Nevertheless, the injection has a dramatic effect to limit toroidal spin-up: it halts the rise of angular velocity and delays the onset of the n = 2 deformation from 25 to 35 micro seconds. This instability may also be suppressed through non-magnetized plasma injection by end-on plasma guns. However, the possible refluxing effect by the magnetized plasmoid injection indicates an advantage of MCPG for both current drive and stabilization.

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