Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)
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PEM032-10 Room: Exibition hall 7 subroom 1 Time: May 24 16:21-16:34

Three-Dimensional Localized Magnetic Reconnection Experiments in TS-4 Plasma Merging Device

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Magnetic reconnection has been investigated as important key physics for explaining global restructuring of various magnetized plasmas, such as solar coronas, magnetosphere and various fusion plasmas. Unlike the conventional steady magnetic reconnection models such as Sweet-Parker model, unsteady effects have been studied as fast reconnection mechanisms. We made clear the three-dimensional (3-D) localized magnetic reconnection as a new fast reconnection mechanism using direct measurements of 3-D structures of current sheet.

The TS-4 device was utilized to produce two plasma toroids with various guide (toroidal) fields. After the formation, they merge together axially through magnetic reconnection. During reconnection, external compression force of acceleration coils was used to drive the reconnection inflow. On the midplane, a magnetic probe array was placed at eight toroidal positions for the purpose of checking axial symmetry of current sheet and torus plasmas. We found two unsteady effects: 3-D deformation of current sheet and mass ejection from it caused fast magnetic reconnection. When strong compression force to current sheet was applied to two compact toroids with low guide field, toroidal modes of current sheet were observed to grow only during their reconnection. A new finding is that 3-D deformation of current sheet promotes mass ejection from current sheet, increasing the reconnection (toroidal) electric field and outflow. When weak compression force was applied to two compact toroids with high guide field, their reconnection rate was maintained low. The density pile-up effect in the low guide field case was smaller than the one in the high guide field case. These phenomena indicate that 3-D localized reconnection is one of fast reconnection mechanisms.

A physical issue left unknown is what is responsible for the onset of 3-D localized reconnection. The most probable cause is that local compression of current sheet triggers strong local dissipation, called anomalous resistivity, as is shown by the TS-3 experiment [Y. Ono et al., Earth Planets Space <u>53</u>, 521 (2001); Y. Ono et al., Phys. Plasmas <u>4</u>, 1953 (1997)]. In TS-3, sheet current dissipates anomalously when the current sheet is globally compressed shorter than the ion gyroradius around the X-point. Therefore, we made another experiments to study which physical characteristics of current sheet changed during reconnection. Magnetic probe arrays were set along axial direction to measure axial profiles of reconnecting (radial) fields at four toroidal positions for the purpose of measuring toroidal symmetry of the current sheet thickness. As a result, preferential compression of current sheet was observed when the reconnection speed was fast under the strong compression force and low guide field case. We are measuring the current sheet to conclude whether sheet-current dissipation increases when current sheet thickness locally becomes shorter than ion skin depth or ion gyroradius.

Keywords: three-dimensional localized magnetic reconnection, current sheet, toroidal mode, reconnection rate, anomalous resistivity, plasma merging