Merging Formation of FRCs and STs in TS-3, TS-4 and TS-U

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In 1986, we started the first merging formation of the field-reversed configuration (FRC) in the TS-3 merging experiment, leading us to a new scenario of FRC slow-formation, heating and current-amplification. Two force-free spheromaks with opposing toroidal field were merged together in the axial direction to form a high-ß FRC with much higher efficiency than the conventional theta pinch method. A center ohmic heating (OH) coil is used to amplify the FRC by factor 2-3. This unique relaxation from the force-free (ß≈0.05-0.1) spheromaks to the high-ß (ß≈0.7-1) FRC is attributed to conversion of the toroidal magnetic energy to the ion thermal energy through the reconnection outflow. Its energy conversion efficiency is as high as 90% due to the X-point structures fully surrounded by the thick reconnected flux. Our merging experiments made clear the promising scaling and characteristics of reconnection heating: (i) its significant ion heating energy that scales with square of the reconnecting magnetic field B_{rec}, (ii) its ion heating energy (in the downstream) 10 time larger than its electron heating energy (at around X-point), (iii) formation of electrostatic potential well in the downstream for the ion acceleration/ heating. Based on this scaling, we realized significant ion heating up to 250eV in TS-3 FRC experiment [1] and to 1.2keV MAST ST merging experiment [2,3]. This promising scaling leads us to new high B_{rec} reconnection heating experiments for future direct access to burning plasma: TS-U (tokamak, FRC) in Univ. Tokyo (2017-) and ST-40 (tokamak) in Tokamak Energy Inc. (2017-).

[1] Y. Ono *et al*., Physical Review Letters (1996).

[2] Y. Ono et al., Plasma Phys. Control. Fusion **54**, (2012) 124039.

[3] H. Tanabe *et al*., Nucl. Fusion **57**, (2017) 056037.