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Asymmetric fine structure formation of guide field reconnection in merging spherical tokamak formation experiments

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Here we report asymmetric fine structure formation process of guide field reconnection in toroidal plasma merging experiments in TS-6 and ST40. We have found two types of asymmetry both during and after the end of merging. The former forms poloidally tilted asymmetric heating profile under the influence of guide field at the positive potential region via parallel electric field acceleration, while the latter forms inboard/outboard asymmetry during the confinement phase of spherical tokamak after the end of merging plasma startup.

Magnetic reconnection is a fundamental process which rearranges the topology of field lines and converts magnetic energy to kinetic/thermal energy of plasmas. This process is used for an effective way of high temperature spherical tokamak formation method such as in TS-3~TS-6, START, MAST and ST40 [1-4]. The heating performance depends on the magnetic energy of reconnection field $\Delta T_i \propto B_{rec}^2$ and the amplitude of B_{rec} is proportional to plasma current I_p and driving PF coil current I_{PF}: $B_{rec} \propto B_p \propto I_p \propto I_{PF}$. When plasma current I_p is same, smaller machine has higher B_{rec} because current density is high. Figure 1 shows an example of merging plasma startup scenario in the TS-6 spherical tokamak. The initial two plasma rings at the top and the bottom of the device as shown in the fast camera image are formed by the induction of the merging driving PF coils. The initial plasma current I_p after the end of merging linearly increases as a function of the driving coil current I_{PF}, and reconnecting field B_{rec} proportionally increases as a function of plasma current I_p. The formation efficiency of reconnecting field is higher in a smaller machine because current density is higher (r_0 ~ 0.2m in TS-6 and r_0 ~ 0.4m in TS-4).

Figure 2 shows time evolution of 2D ion temperature profile with poloidal flux, the evolution of peak temperature in the high field side (r ~ 0.1m) and the low field side (r ~ 0.2m) from t = 60μs to 130μs, and reconnection electric field E_{rec} and plasma current I_p from t = 50μs to 90μs. From t = 60μs to 80μs, reconnection electric field becomes active, plasma current increase and ion heating starts. At t = 70μs, ion temperature profile forms poloidally tilted structure as reported in [5] and finally ion temperature profile becomes hollow after the end of merging. In comparison with the time scale of reconnection heating and heat transport, tens of microseconds are much longer than the equilibration time but it has been observed that inboard/outboard asymmetry exists after the end of merging as well as reconnection phase for the first time. Under the influence of toroidal effect in the small machine, the amplitude of toroidal field is 2 times higher at the high field side (r ~ 0.1m) with B_t = 0.30T and is smaller at the low field side (r ~ 0.2m) with B_t = 0.15T, suggesting the variation of ion temperature via adiabatic compression (μ conservation) on field lines by toroidal effect during confinement phase after merging [6]. Comparison of the heating characteristics in ST40 which drives higher field merging/reconnection experiment will also be presented at the conference.

References

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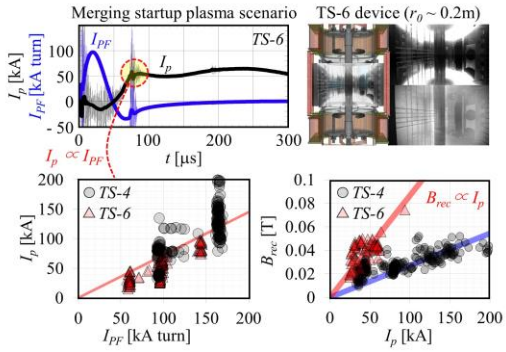

Figure 1 Merging plasma startup scenario in the TS-6 and scaling plots of I_p - I_{PF} and B_{rec} - I_p.

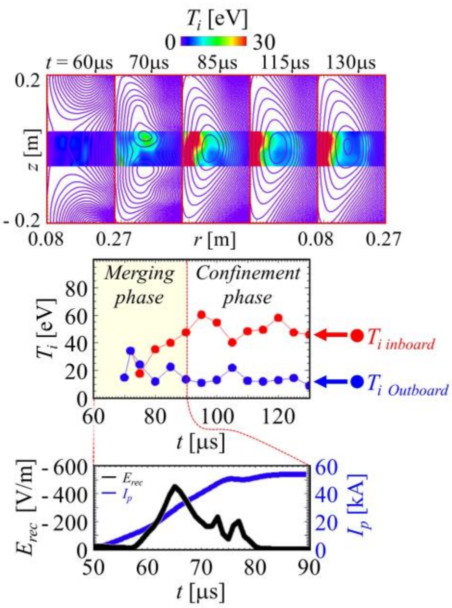

Figure 2 Time evolution of 2D T_i profile, time history of peak ion temperature at high field side and low field side, and the reconnection timing reference with E_{rec} and I_p.