§9. Experimental and Theoretical Studies of Startup Methods for Spherical Tokamak Plasmas

Ono, Y., Nagayama, Y., Takase, Y., Mekawa, T., Nishio, S., Nagata, M. (Univ. Tokyo, NIFS, Kyoto Univ., JAERI, Hyogo State Univ.)

A key issue for the spherical tokamak (ST) research is how effectively we can startup high-beta ST without using the center solenoid coil whose space is limited in the center of ST. The University of Tokyo has three key ST devices for ST startup but a few plasma diagnostics while NIFS has a variety of plasma diagnostics, especially high special resolution measurements of plasma temperature and density useful for the ST startup measurements but not ST device. We have been collaborating with the ST group in NIFS using ST committees in JSFS and IEEJ. In this program, we made the all-Japan joint study of ST startup based on collaboration not only with NFS but also with all ST groups in Japan: Kyoto Univ., Hyogo State Univ., Kyusyu Univ. and Kyusyu-Tokai University.

Our goal is to optimize the ST startup methods theoretically and experimentally. In 2005, the joint group made the high beta ST startup in TS-3 and 4, by combining PF coil induction and complete merging/ reconnection of two STs and also solenoid coil-less ST startup in TST-2, using RF and PF coil induction. We also made the corresponding Magnetohydrodynamic (MHD) simulation to verify these experimental results and started the first merging / reconnection experiment of NSTX.

At university of Tokyo, the merging techniques of TS-3 and 4 and also the RF heating/ current drive techniques of TST-2 were up-scaled to UTST device (R~0.4m) as shown in Figs. 1(a) and (b). In this device, all PF coils are located outside of the vacuum vessel to demonstrate (1) double-null startup of STs without CS coil, (2) their reactor-relevant reconnection heating for high-beta ST formation and (3) their sustainment by advanced RF and NBI techniques. The mega-watt heating power of reconnection is expected to transform the initial low-beta merging STs (~5%) to the high-beta ST (~30-50%) within short reconnection time. A new finding at Univ. Tokyo is that ejection of current sheet (or plasmoid) causes high-speed merging as well as high-power heating. respectively. In Fig. 2(b), the ion temperature T_i after the reconnection as well as the reconnection speed γ, increased inversely with the toroidal field B_{t0} normalized by the constant poloidal field $B_{//}$. It is because resistivity of the sheet as well as γ and T_i increase with ion gyroradius ρ_i ($\propto B_{t0}^{-1}$) normalized by its thickness δ[1]. In the high compression case, T_i increased right after the current sheet ejection[2], in sharp contrast with the low compression cases without sheet ejection. The increase in outflow was found to cause the ion heating. Based on this fact, the transient effects such as the flux pileup and ejection, enable us to have the high reconnection speed as well as the high-power reconnection heating, even if the merging high-q tokamaks have low current-sheet resistivity.

References

[1] E, Kawamori Y. Ono et al., Phys. Rev. Lett. **95**, 085003, (2005).
[2] Y. Ono et al., to be published in Fusion Energy 2006.

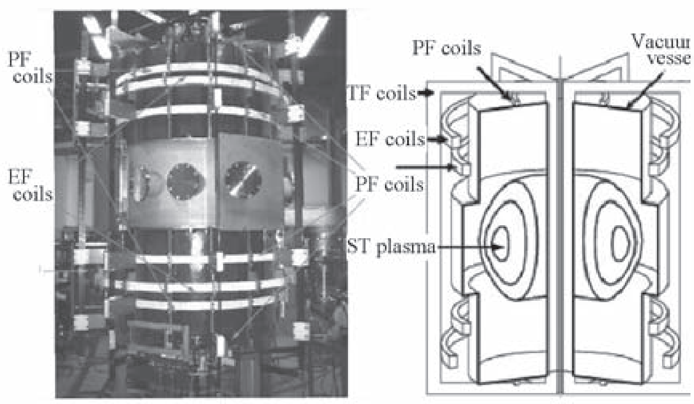

Fig. 1 Completed UTST Merging ST Device

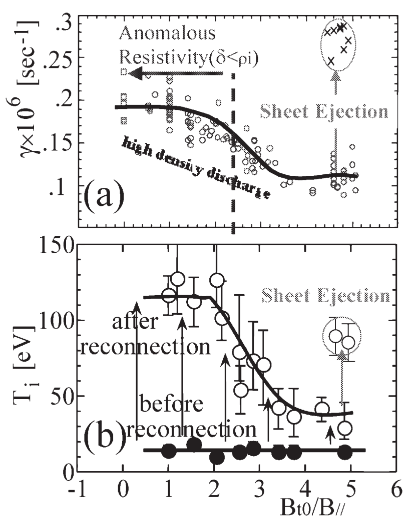

Fig. 2 The reconnection speeds γ (a) and ion temperatures T_i (b) as a function of toroidal field $B_{t,0}$ normalized by reconnecting poloidal field $B_{//}$ (constant). The transient γ and T_i right after ejection are also plotted.