*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-5.118 (2007)*

Preliminary results on the EAST plasma initiation and ramp-up

L.Q. Hu, B. Shen, S.Y. Lin, Y.W. Sun, X. Gao, B.N. Wan, and EAST Physics Team

Institute of Plasma Physics, Chinese Academy of Sciences, Hefei230031, P. R. China

Plasma initiation--breakdown, burn-through and initial current ramp-up is one of the key issues for the constructing new generation tokamak ITER, in which both coils of poloidal field and toroidal field (PF and TF) are superconducting magnets [1]. Differing from existing superconducting tokamak, finite in-vessel electric field coming from terminal voltage limitation of the multi-turn superconducting PF coil system and poloidal error field for reliable plasma breakdown, impurity burn-through, D-shaped plasma formation during the initiation, magnetic flux consumption etc., have an important influence on the ITER plasma operation scenario and need to be considered carefully. Being a similar configuration tokamak to ITER with full superconducting coils, EAST device has executed studies of the plasma initiation during its initial two experimental campaigns. Preliminary statistic results on the EAST plasma initiation and ramp-up have been presented in this paper.

1. Introduction

The main parameters of EAST are Bt=3.5T, R_0=1.75 m, Ip=1MA, a=0.4m, (b/a)=1~2 with the flexibility of double and single null divertor configuration, and the maximum pulse will be up to 1000 second [2]. The plasma discharge was controlled by a plasma control system (PCS) built under the collaboration between GA and ASIPP, which is of EAST features based on DIII-D PCS. In the first two campaigns, the EAST machine was equipped only with full stainless steel in-vessel components, with 5 new built diagnostics and other 10 diagnostics moved from HT-7, and using hydrogen as operation gas. Two movable molybdenum limiters with R=2.235m allow maximum plasma minor radius a=0.45m with a major radius of about 1.8m in circular cross-section. A well developed RF boronization and RF wall conditioning technique, routinely used in HT-7 tokamak, was employed to control recycling and reduce impurity level. To accumulate dada base of different wall conditioning techniques with full metal wall on EAST and to determine future effective wall conditioning way for the EAST, GDC (glow discharge cleaning) boronization and cleaning techniques were also tried and compared with RF boronization. The 1st campaign in 2006 is limiter plasma discharge, and the

2nd campaign in 2007 is divertor discharge. 0.5MA with a flattop of 0.5s and long pulse 0.2MA/8.5s divertor plasmas were obtained.

2. Plasma breakdown and null field configuration

Good pre-operation conditioning to keep very low impurity level is a very important step and a guarantee not only for reliable plasma initiation but also for D-Shape plasma formation with good performance. Essential condition for initial Townsend avalanche breakdown and following toroidal plasma current formation is clean vacuum environment (<10^{-5}Pa), good null field configuration (large poloidal region), toroidal magnetic field, the pressure (~10^{-3}Pa) of the filling operation gas, and sufficient toroidal electric field Et. Available breakdown voltage in EAST is 5-8 Volt, limited by available maximum current variation of the PF coil and output voltage of the PF power supply (PS). The large in-vessel structure (components and blankets) with low resistance will shield the plasma from outside magnetically and retards the penetration of the applied poloidal flux for plasma breakdown and formation. Fast variation of the PF coil damping speed to induce enough toroidal electric field Et for plasma breakdown is realized by inserting different resisters to the PF coil circuit, while null field geometry is adjusted by applying a feed-forward voltage through PCS on the PS to fit plasma breakdown. Upon the plasma breakdown, the resistors are shorted. Initial plasma current ramp-up and plasma formation are done by adjustment of total 14 PF coil currents to control the plasma current, shape and displacement. The influence of the eddy current in the vacuum wall on the null field configuration must be considered since the eddy current is near 0.1MA in case of 4V loop voltage. Due to the imperfect positioning of the TF, CS, and PF coils, the need to correct imperfections in the magnetic field symmetry requires future use of 'correction coils', which is able to provide a helical field of a few 10^{-5} times the TF field strength to avoid the MHD instabilities caused by the error fields.

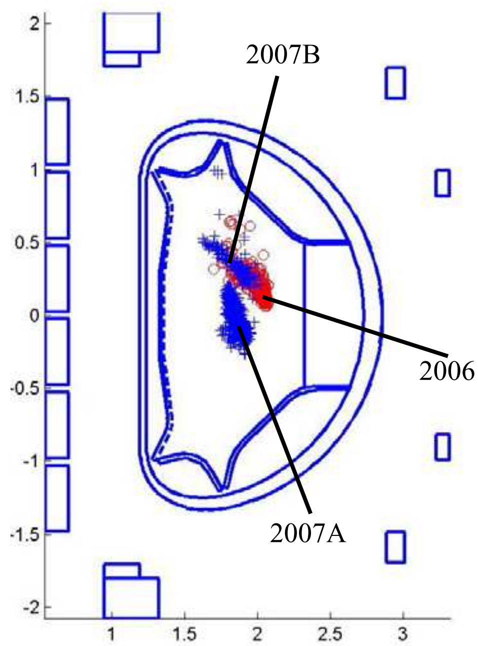

Fig.1 Center of the 10 Gauss null field just before plasma breakdown

Based on the equations $L_{eff}=0.25a_{eff}B_T/B_\perp$ and $Et_{min}(V/m)=3.4\times10^4p(Torr)/\ln[300p(Torr)L(m)]$ [1], the effective connection length L_{eff} for avalanche breakdown growth is about 250m, and the minimum Et depending on the filled gas pressure p(Torr) can be got, however, reliable breakdown Et will be higher because more issues like impurity concentration will affect the breakdown as well. A 180 kW LHW is used to assists not only for pre-ionization of the discharge to lower breakdown voltage but also for plasma ramp-up rate.

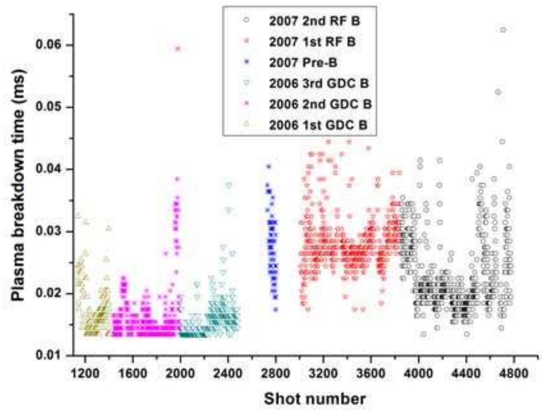

Fig.2 Time history of the plasma breakdown time

Fig.1 shows the center R_{NF0} of the null field region, enclosed by the contour of 10Gauss, which is obtained by the least-square calculation of the poloidal field coil currents and the votex current profile in the wall from the magnetic measurements. In 2006 campaign, R_{NF0} is above the equatorial plane with a scattering of the horizontal position R between 1.7m and 2.2m. In 2007 campaign, R_{NF0} is separated to two groups, main group “2007A" is close to rated major radius 1.8m with a scattering of the vertical position Z around the equatorial plane. The data in group “2007B” is from last three days' shots, in which a different group resistors in the PF coil circuit was adopted mainly for plasma breakdown study, however so large scattering is difficult to be explained by unsuitable resistors and needs further analysis to find th cause. Effects of different boronization and wall conditioning techniques on plasma breakdown delay and voltage were investigated and shown in Fig.2 and Fig.3, in which the time of inserting resistor is defined as time “0”. More scattering in each later phase after boronization suggests the effect of impurity production increase, and more scattering in each early phase after RF boronization suggests that wall

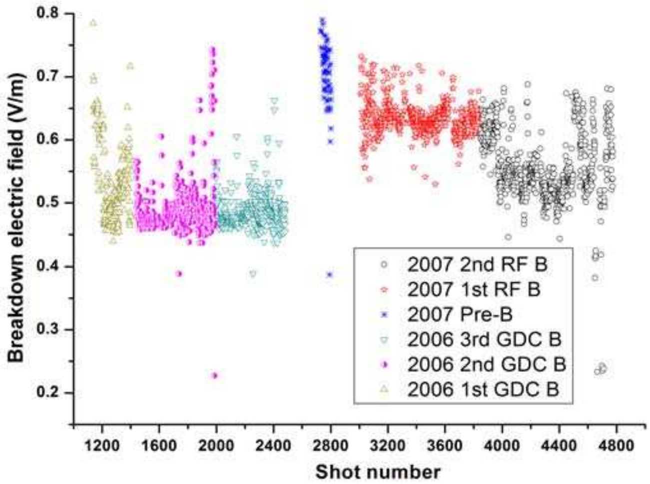

Fig.3 Time history of the plasma breakdown E

conditioning may be not enough and wall recycling play a important role. Different from in HT-7, the boronization process on EAST in 2007 was controlled by Boron thickness measurement, large scattering on the breakdown electric field and breakdown time delay indicate that EAST boronization technique need more study to optimize boronization process even considering the fact of full metal wall. It is clearly seen that breakdown in 2006 was generally early and with lower breakdown electric field than those in 2007. Plasma breakdown has not optimized by adjustment relative issues due to machine time limitation.

3. Plasma current ramp-up

Key issues for plasma ramp-up is plasma position control, impurity production and MHD instability. It is no doubt that more reliable breakdown with high Et, large tolerance of the null field and clean vacuum environment would be great helpful to the plasma formation and ramp-up following the breakdown. Establishing a gradually increasing suitable vertical field to control plasma horizontal displacement is an important step to give initial weak plasma free space to grow up. From Fig.4, high plasma ramp-up speed up to 0.6MA/s is found in 2006 limiter plasma, while more impurity production during the plasma formation, however, divertor plasma in 2007 is of low ramp-up speed less than 0.3MA/s, and much lower speed about 0.12-0.2MA/s for the plasma with a flattop current over 0.2MA. Impurity radiation reduction and plasma detached with the Mo limiter could be observed clearly in CCD and optical signals when D-shaped plasma formed during its ramp-up way.

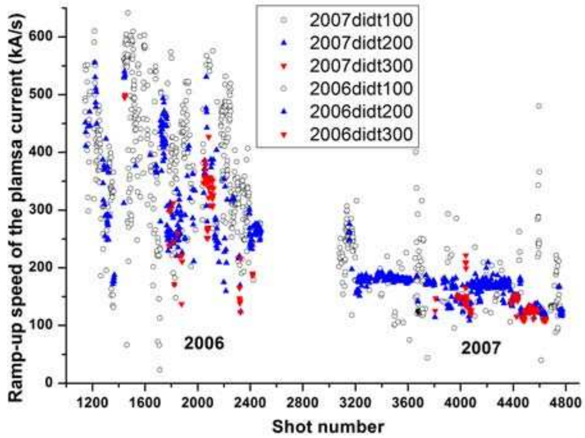

Fig.4 Time history of the plasma current ramp-up speed (positive and negative triangular symbols in blue and red color are plasma shots with the current flattop of 200-300kA and over 300kA, respectively)

[1] ITER Physics Expert Group, Nucl. Fusion 39 (12), 2577 (1999).

[2] Yuanxi Wan, et al., 2006 Proc. of 21st IAEA Fusion Energy Conference, OV 1-1.

This work has been supported partially by the National Nature Science Foundation of China, No. 10675124, and by the Core-University Program of Japan Society of Promote Society.