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Recent progresses of EAST towards long plasma operation

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Long pulse operation is essential for future reactors to sustain fusion energy output for sufficiently long time. EAST fully superconducting tokamaks with no resistance in coils have been made lots of efforts on exploring long pulse operation in support of fusion reactors. Recently, new achievement of a plasma operation in thousands second time scale have made, associating with good solutions for a few key issues and challenges for long pulse operations.

EAST have developed lots key technologies related to long plasma operation. Impurities, particle recycling and hydrogen content in deuterium plasma could be well controlled by ICRF cleaning, lithium coating and lithium real-time injection. Good density control and particle exhaust could be achieved by SMBI feedback fueling and high speed pumping system. Reliable heating and current drive systems, including LHCD, ICRF, ECRF and NBI, have been developed for long operation. ITER-like W/Cu divertor have been installed as top divertor for eight years.

Specially, to explore high performance steady state operation, more upgrades on various systems have been successfully carried out in EAST in 2020-2021. Plasma H&CD system have re-arranged with new techniques application, i.e. new PAM antenna for 2.45G LHCD, minimize $k_{||}$ antenna for ICRF. A new low divertor using welded W/Cu structure, with good heat removal capacity up to 10MW/m^2 and dedicated configuration, have been installed to replace the old bolted C/Cu divertor. Diagnostics with high spatial/temporal resolutions and robust plasma control system have also been improved. Stable plasma equilibrium magnetic control was also upgraded, including using fiber optic current sensors with no signal drift for plasma and PF coils current measurement, low zero drift integrator and GPU parallel equilibrium reconstruction.

Those key technology development leads plasma parameters and pulse length increased step by step. Based on previous long plasma operation experience, in the last year, long pulse plasmas with high electronic temperature, i.e. 101s with a Te(0) >10 keV, 1056s with Te(0) ~6.5 keV, have been successfully achieved on EAST with the full metal walls, with help of well controlled plasma configuration, heat flux, impurities and recycling, using high performance divertors, robust plasma control, good particle exhaust, SMBI feedback fueling, continues H&CD, diagnostics in long duration.

For the fully non-inductive high Te(0) >10 keV plasmas operation with pulse length up to 101s, plasma density is about 1.8×10^{19}m^{-3} and total power injection for electronic dominant heating is about 3.8MW using LHCD and ECRH, as shown in figure 1. The temperature on the tungsten divertor is well control to be less than 300 °C, which is useful for the reduction of impurities production.

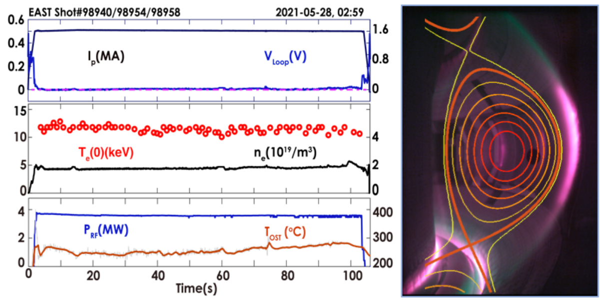

Figure 1, 101s fully non-inductive plasma with Te(0) >10 keV achieved on EAST

For the 1056s fully non-inductive long-pulse plasma, it is also an electronic dominant heating with a power of 1.65MW, as shown in figure 2. Fully non-inductive current drive was achieved with f_{RF}~70% and f_{BS}~30%. It was also defined as Super I-mode with core e-ITB with βp ~1.5 and H_{89}~1.3 under double null configuration.

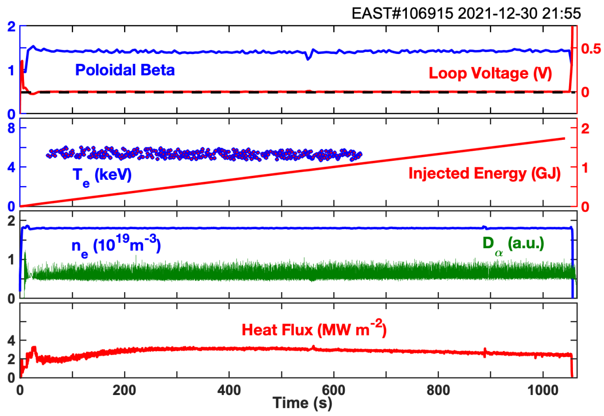

Figure 2, 1056s fully non-inductive plasma with Te(0) >6 keV achieved on EAST

Those long plasma discharge was achieved in a impurities content lower than 6 ×10^5 and recycling rate about 0.9 using good wall conditioning, high efficiency pumping, and well configuration control, associated the development of high performance W/Cu divertor, precise plasma equilibrium and configuration control system, an so on. And Intrinsic turbulent current with e-ITB was found. The turbulent current in counter-current direction is beneficial for the formation of a self-regulation system of turbulence, turbulent current. Those integrated solutions will accelerate EAST to explore steady-state plasmas towards high ne, high Te & Ti, in support of ITER,CFETR and future reactors.