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Development of high performance scenario toward high beta steady-state plasmas at KSTAR

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For the realization of the fusion reactor, solving issues for high beta steady-state operation is one of the essential research topics for the present superconducting tokamaks and in this regard, KSTAR[1] has been focusing on maximizing performance and increasing pulse length addressing scientific and technical issues. Typically, previous study on high beta operation has been focusing on advanced scenario in relatively short pulse discharge at KSTAR and partial success has been reported. However, it must be stressed that it is also essential to verify compatibility of developed high beta scenario to long-pulse and stable long-pulse operation is possible only with reduced level of performance compared with that of the short-pulse. In this work, the results of recent experimental approaches in long-pulse operation are presented focusing respectively on high β_N, high beta poloidal, Hybrid scenario and internal transport barrier discharge.

For high β_N experiments[2], conditions of the maximum β_N is investigated mainly by parametric scans of toroidal magnetic field (B_T=1.4-2.0 T) and neutral beam injection power (3-5MW). The achieved β_N is above 3 with Ip=0.6 MA, BT=1.2 T and Pext ~ 5 MW and it is found to be limited by m/n=2/1 tearing mode and is sensitive on the internal inductance and safety factor.

For high β_p experiments, conditions of the maximum β_p is investigated mainly by parametric scans of plasma current (Ip=0.4-0.7 MA) and also neutral beam injection power (3-5MW). The achieved β_p is also above 3 with Ip=0.4 MA, B_T=2.9 T and P_{ext} ~ 6 MW and it is found to be limited by heating power and there is no indication of MHD activities. In addition, high β_p discharge is due to high bootstrap fraction, closed to the state of fully non-inductive current drive. However, pulse length is limited to 12 second by excessive heat-load on the protection limiters which is turned out mainly due to NBI prompt loss. To minimize fast ion loss, by the securing mid-plane gap among various techniques, the discharge sustained more than 20 sec successfully.

For the access of the internal transport barrier (ITB) formation [3], by an early injection of the full NBI power (~ 4.5 MW) during the current ramp-up. It is experimentally confirmed an ITB at rho_pol~0.6 form with L-mode edge in limiter configuration. To avoid the H-mode transition, we have produced inboard limited plasmas with detaching from the both upper and lower divertors. An ITB formation during L-mode has been observed and ion and electron temperature profiles show the barrier clearly in the temperature profile, and it was sustained for maximum 7 s in the dedicated experiment providing feasibility for steady-state operation.

Finally, the development of stable low q95 operation and hybrid scenario with sawteeth tailoring will be presented in detail addressing applicability to high beta steady-state discharges.

References

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