# Recent progress of the KSTAR experiments in exploring the science and technologies relevant to the ITER and DEMO

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Korea Superconducting Tokamak Advanced Research (KSTAR) program is strongly focused on solving the scientific and technological issues in steady-state high performance plasma operation in preparation for ITER operation as well as DEMO design basis [1]. In this regards, KSTAR has made significant advances in developing long pulse and high performance plasma scenarios utilizing the advantage of fully superconducting tokamak. Nine-year of operation showed that KSTAR is the best engineered superconducting tokamak having extremely low intrinsic error field and reliable operation without any serious failure.

According to the effort in plasma control, H-mode plasma discharge in KSTAR has extended up to 1 MA in plasma current and up to 70sec in flat top duration at 0.45 MA with highly non-inductive current drive over 0.9 as shown in figure 1. [2]. The high normalized beta scenario ($\beta_N$ >3) surpassing no-wall limit was sustained up to 3sec without any external field correction. A good candidate for advanced steady-state operation has been developed with high poloidal beta ($\beta_P$ >3). In addition, several advanced scenarios have been explored for the study in transport and MHD instability under extreme conditions; i) Hybrid scenario with large fusion gain (G ~ 0.38) close to ITER baseline (G=0.4), ii) internal transport barrier (ITB) scenario sustaining up to 7sec stably, and iii) extremely low q95 (q95 < 2.3). The dependence of the L-H-mode transition threshold power has been analyzed according to the applied n=1 and 2 error field error field level.

ITER requires robust and fully suppressed edge localized mode (ELM)-crash due to early installation of tungsten divertor. In KSTAR, very robust and reliable ELM-crash suppression at n=1 RMP has been achieved by optimal control of phasing between three rows of RMP coils. Plasma surface interaction and high heat flux effect on tungsten divertor has been investigated very effectively by installing tungsten castellation tiles on divertor with difference shape and elevation.

For the improved plasma performance in steady-state, KSTAR will be upgraded in heating and in-vessel structures. An additional long-pulse capable 6 MW neutral beam (NBI-2, 12 MW in total) and additional 3 MW 105/140 GHz ECH/CD (4 MW in total) will be available from 2019. And pellet injection system with 20 Hz injection, active water cooling in PFC/divertor, liquid helium circulation into the in-vessel cryo-pump will be available from 2017 for the better wall environment. In addition, we plan to upgrade whole in-vessel components around 2021 to support advanced operation in steady-state and technology development in preparing the ITER steady-state and DEMO design.

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