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Plasma Current Start-up and Ramp-up Experiments on the TST-2 Spherical Tokamak

Plasma current (Ip) start-up and ramp-up are being studied on the TST-2 spherical tokamak (R = 0.36 m, a = 0.23 m, Bt = 0.3 T, Ip = 0.1 MA). Both inductive and non-inductive methods are used. Up to 400 kW of RF power at 200 MHz, in the lower hybrid (LH) frequency range, is available. An innovative antenna called the capacitively-coupled combline (CCC) antenna was developed to excite a traveling LH wave with a sharp, highly directional wavenumber spectrum with the electric field polarized in the toroidal direction. Two CCC antennas are installed in TST-2, a 13-element outboard-launch antenna and a 6-element top-launch antenna. The latter was installed to improve LHW accessibility to the core and to achieve strong single-pass damping, thus avoiding the suspected wave power loss in the scrape-off layer plasma. The outboard-launch LH wave was found to be more reliable in creating the initial ST plasma, but the top-launch LH wave was found to be more efficient in subsequent Ip ramp-up. Bottom launch can be simulated using the top-launch antenna by reversing the direction of the toroidal magnetic field Bt. It was found that the bottom-launch LH wave was as efficient as the top-launch LH wave, contrary to naïve expectation, but this result can be explained by more elaborate numerical simulation.

Low voltage Ohmic Ip start-up with electron cyclotron (EC) wave assistance was also investigated. Application of EC power in the conventional Ip start-up scenario with poloidal field null extended the low pressure limit for breakdown as well as the high pressure limit for burn-through. Application of vertical field during breakdown was beneficial at low pre-fill pressure and high EC power.

AC Ohmic coil operation is a pre-ionization method in which an inductive electric field down to 0.5 V/m with a typical frequency of 1 kHz is applied. Due to the AC nature, the flux swing amplitude is about 2 orders of magnitude smaller compared to a typical Ohmic discharge. It is demonstrated that this method can be used to generate a target plasma for Ip ramp-up using either outboard-launch or top-launch LH wave.

Primary author: TAKASE, Yuichi (The University of Tokyo)

Co-authors: Dr EJIRI, Akira (Graduate School of Frontier Sciences, The University of Tokyo); Mr KO, Yongtae (The University of Tokyo); Dr MOELLER, Charles (General Atomics); Prof. TSUJII, Naoto (The University of Tokyo); Dr WATANABE, Osamu (The University of Tokyo); Mr YAMAZAKI, Hibiki (The University of Tokyo); Mr AOI, Yuki (The University of Tokyo); Mr IWASAKI, Kotaro (The University of Tokyo); Mr MATSUZAKI, Kyohei (The University of Tokyo); Mr OSAWA, Yuki (The University of Tokyo); Mr PENG, Yi (The University of Tokyo); Mr RICE, James (The University of Tokyo)

Presenter: TAKASE, Yuichi (The University of Tokyo)