Predictive Numerical Simulations of ECH Assisted H-mode scenarios at KSTAR

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1. Introduction

One of the early research topics in the KSTAR (Korea Superconducting Tokamak Advanced Research) project is to achieve a H-mode plasma in the absence of NBI to address its physics issues such as plasma confinement and momentum transport. The transition from low confinement mode (L-mode) to high confinement mode (H-mode), so-called L-H transition is believed to occur when plasma heating is applied above certain threshold value. In this work, a reliability of ECH (Electron Cyclotron Heating) assisted H-mode operation in the KSTAR tokamak is investigated by applying L-H power threshold scaling laws derived from the international H-mode power threshold database, which provides a possible operational domain of H-modes. In addition, predictive numerical simulations on KSTAR ECH-assisted H-mode are carried out using an integrated transport simulation code.

2. Methods and Results

In this section the process to obtain the operation scenario of ECH assisted H-mode at KSTAR are described.

2.1 System of integrated fusion plasma transport simulations with the ECH heating

ASTRA (Automatic System of TRansport Analysis in a tokamak) code for the simulation of the fusion plasma transport is integrated with a TORAY-GA code and an ESC (Equilibrium and Stability Code) code organically. The TORAY-GA is to simulate the ECH/CD (Electron Cyclotron Heating/Current Drive) and the ESC is to simulate the plasma equilibrium. The version of ASTRA transport code and TORAY-GA code is 6.0 and 1.6 respectively. However, the 1.6 version of TORAY-GA cannot simulate an ITER (International Thermonuclear Experimental Reactor) - liked big sized tokamak properly. Therefore, the 1.6 version of TORAY-GA code is replaced by the 1.8 version of that and the interface is modified between ASTRA and TORAY-GA. Figure 1 represents that the 1.8 version of TORAY-GA coupled with ASTRA has a bigger current density than the 1.6 version of that in ITER prediction.

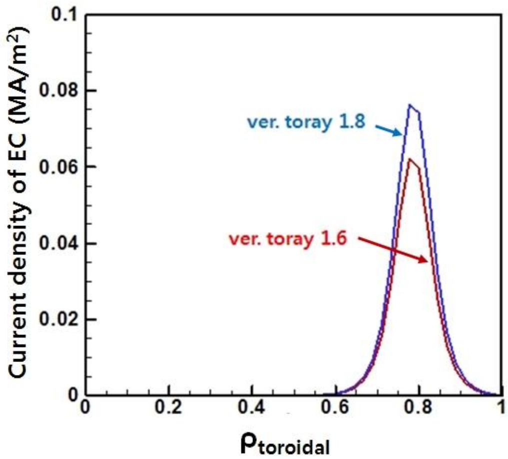

Fig. 1. Current density profile of EC for the 1.8 version of TORAY-GA against the 1.6 version of TORAY-GA

2.2 H-mode Operation domain at KSTAR

Operation domains to access H-mode with ECH heating in KSTAR tokamak are found. Scaling laws of the L-H transition power threshold [1-2], plasma stability limits (current limit, density limit, and beta limit) and ECH resonance requirements were considered as physics constraints. The engineering constraints such as achievable ECH power, plasma current and plasma configurations are referred from the instruction of the 3rd KSTAR experimental campaign in 2010[3]. Table 1 represents major operational parameters of KSTAR experimental in 2010. Here, an ideal wall condition is assumed. Figure 2 represents an analysis result of the H-mode operation domain. The gray colored area indicates an achievable H-mode operation regime in the D-shaped plasmas assisted with 0.5 MW, 110 GHz ECH. Even though an Ohmic H-mode without ECH is not reachable within the current KSTAR capabilities, it is found that 0.5MW ECH heating is sufficient enough to overcome the L-H transition power in the wide ranges of the plasma current.

2.3 Predictive simulations of ECH assisted H-modes at KSTAR

Based on the operation domains, predictive numerical simulations of an ECH assisted H-mode discharge are carried out using the 1.5-D ASTRA code in order to estimate the performance (β_N) and global energy confinement time (τ_E) of the H-mode in KSTAR. The GLF23 model is employed for calculation of anomalous contribution on the plasma heat transport. The PEDESTAL module is adopted to estimate the pedestal density and temperature in a self-consistent way. A flow shear stabilization model and a thermal conduction model selected from PEDESTAL module are used. And as mentioned earlier the TORAY-GA code is embedded in ASTRA to calculate ECH heating deposition profiles.

Table I: Operational parameters of KSTAR experiment in 2010

Operation TF Field	1.5 T, 2.0 T, 3.0 T
Plasma Current	< 1 MA
Plasma Shape	Double Null
Gas	Hydrogen, Deuterium
ECH Heating System	0.5 MW (84 GHz) 0.5 MW (110 GHz)

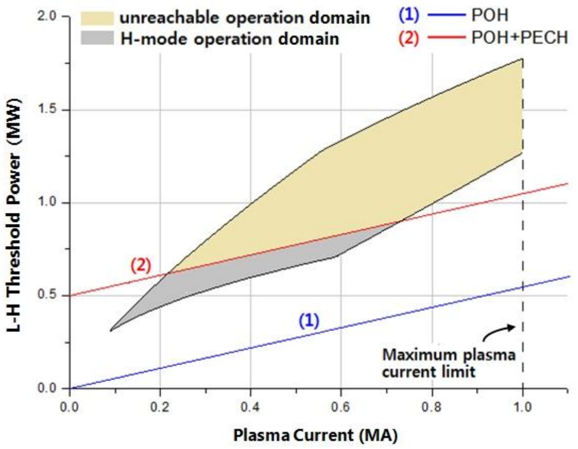

Fig. 2. Operation regime of 0.5 MW, 110 GHz ECH assisted and D-shaped H-mode at KSTAR

2.4 Optimization of the operation scenario for H-mode at KSTAR

The correlations between the ECH power resonance and H-mode performance are discussed. The ECH power delivered to plasmas plays a role as an input power to overcome the L-H transition power and it also affects the electron temperature distribution which mainly changes a plasma resistivity related with the Ohmic heating power. Therefore, an optimization of the operation scenario is required, which could be obtained by controlling the resonance position of ECH.

3. Conclusions

From the simulation results, the optimal plasma parameters to achieve an H-mode in KSTAR are discussed under the present experimental constraints. Furthermore, the predictive numerical simulation for ITER can be carried out with the integrated fusion plasma transport code by including the simulation code of ECH/CD.

REFERENCES

[1] E.J. Doyle (Chair Transport Physics), W.A. Houlberg,a (Chair Confinement Database and Modelling), Y. Kamada (Chair Pedestal and Edge), V. Mukhovatov (co-Chair Transport Physics), T.H. Osborne (co-Chair Pedestal and Edge), A. Polevoi (co-Chair Confinement Database and Modelling), G. Bateman, J.W. Connor, J.G. Cordey (retired), T. Fujita, X. Garbet, T.S. Hahm, L.D. Horton, A.E. Hubbard, F. Imbeaux, F. Jenko, J.E. Kinsey, Y. Kishimoto, J. Li, T.C. Luce, Y. Martin, M. Ossipenko, V. Parai, A. Peeters, T.L. Rhodes, J.E. Rice, C.M. Roach, V. Rozhansky, F. Ryter, G. Saibene, R. Sartori, A.C.C. Sips, J.A. Snipes, M. Sugihara, E.J. Synakowski, H. Takenaga, T. Takizuka, K. Thomsen, M.R. Wade, H.R. Wilson, ITPA Transport Physics Topical Group, ITPA Confinement Database and Modelling Topical Group and ITPA Pedestal and Edge Topical Group, Chapter 2: Plasma Confinement and Transport - Section 4.3. L-H transitions, Nuclear Fusion, 39, 2175, 1999

[2] Y. Martin, T. Takizuka and ITPA CDBM H-mode Threshold Database Working Group, Power Requirement for Accessing the H-mode in ITER, J. Phys.: Conf. Series 123, 012033, 2008

[3] M. Kwon and the KSTAR Team, KSTAR Operation Status and Plan for 2009-2010, EPICS Technical Meeting, NFRI, July 27-29, 2009