§2. Effect of Active Control on Plasma Performance in Magnetically Confined Toroidal Plasmas

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1. Objectives

In high-beta toroidal plasmas such as Spheromak (SP), Field Reversed Configuration (FRC), Spherical Tokamak (ST), and Reversed Field Pinch (RFP), various methods for active control have been applied to realize improvement of plasma performance or to control plasma dynamics during MHD relaxation. This collaboration program started three years ago. The machines involved are HIST (SP) at Univ. of Hyogo, NUCTE (FRC) at Nihon U., TS-3 and 4 (SP, FRC, ST) and UTST (ST) at Univ. of Tokyo, RELAX (RFP) at KIT, and LHD at NIFS, with research topics related to active control. Theoretical works related to this collaboration program include particle simulation at Gunma Univ., 3-D MHD simulation at NIFS, two-fluid MHD equilibrium and stability analysis at JCGA. In the first year 2011, we made several review trips to understand the details of research programs at each institution and to discuss possible collaboration programs. In the second year 2012, we started some experimental and theoretical collaborative programs, with emphasis on encouraging students to participate in the activities. In 2013, corresponding to the third year, in addition to continuation of the collaboration, we made a brief summary for the three-year programs, with discussion about the prospects of expanding themes and participants for this type of collaboration.

2. Results

2.1 Soft-X ray measurement in UTST merging experiment (U. Tokyo, KIT)

Soft-X ray emission is measured in merging phase of two STs to study if there is any correlation with the visible light emission from C III. A burst of SXR is observed slightly after the C III emission, and the SXR intensity increases in proportion to toroidal magnetic field. The results suggest electron acceleration at magnetic reconnection with strong guide field.

2.2 Measurements of dynamo and associated plasma flow in ST produced by magnetized coaxial plasma gun (U. Hyogo, JCGA, KIT)

In HIST device, experiments are carried out on current drive by multi-helicity injection. Fluctuations of plasma flow and magnetic fields are measured with dynamo probe, and correlation analyses provide dynamo electromotive force, Reynolds stress, Maxwell stress, and Hall dynamo effect. The experimental results are compared with those from two-fluid MHD simulation. The mechanism of current drive was discussed at the US-Japan CT Workshop (Kobe, 2013). Design study on the dynamo probe has started for use in RELAX. RFP.

2.3 Construction of diagnostic system for spontaneous rotaion measurement in FRC (U. Tokyo, Nihon U.)

In NUCT device, FRC plasmas are produced using reversed-bias theta-pinch scheme. The most dangerous mode in FRC is the n=2 rotational instability which leads to destruction of magnetic configuration. In NUCTE, two magnetized coaxial plasma guns are installed at both ends of the theta-pinchi produced FRC for injection of two spheromac plasmas with opposite helicity to avoid net hekicity injection. They succeeded in suppressing the n=2 instability to realize longer life time of the FRC. Using the framework of this collaboration, an eight-channel Doppler spectroscopic system has been transferred from the University of Tokyo to NUCTE device for the measurement of time evolution of spontaneous plasma flow associated with stabilization of the n=2 rotational instability. The initial results and possible interpretation was presented at the US-Japan CT Workshop (Kobe, 2013).

2.4 3-D MHD simulation studies on the formation process of helical RFP state in low-aspect-ratio configuration (KIT, NIFS)

This work started from the first year of this collaboration program. The 3-D non-linear MHD simulation results agree well with the experimental results in RELAX. In the simulation, two possible route to self-organized helical state was identified, and comparison with experiments is in progress. The results were presented at US-Japan JIFT Workshop (2013, Madison) and IEA Stellarator/Heliotron and RFP Workshop (2013, Padova). Comparison of the experiments and simulation results for validation of the MHD model is also in progress between MST (U. Wisconsin-Madison) and RELAX as a US-Japan Fusion Collaboration program. Discussion is also going on about possible inclusion of the MIPS simulation to the validation collaboration.

2.5 Evaluation of a diagnostic method to measure current profile in RFP (KIT, Gunma U.)

A proposed method for measurement of internal magnetic field profiles in RFP is evaluated by means of particle simulations. Using realistic experimental arrangement of RELAX and realistic helium beam parameters (energy, density, beam divergence), the expected Doppler-shifted He line profiles are calculated to evaluate sensitivity, spatial resolution, and effect of pitch-angle scattering on when the proposed method is applied to RELAX. The calculations show the desirable beam energy of ~1 keV for beam penetration, and radial variation of the accuracy of the method.

2.6 Presentations at the 25th IAEA FEC

The above results from UTST, HIST, NUCTE, and RELAX are going to be presented at the upcoming 25th IAEA Fusion Energy Conference in October 2014.

3. Acknowledgment

This collaboration has brought about benefits to both the faculty members and students. It also works for students as a preparatory step to long-term studies in foreign institutions.