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Experimental Study of Magnetic helicity Injection Mechanism of the UTST Spherical Tokamak Plasmas

UTST球状トカマクにおける磁気ヘリシティー入射機構の検証

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A spherical tokamak (ST) plasma is produced by double-null merging (DNM) method by using two pairs of external poloidal field coils in the University of Tokyo Spherical Tokamak (UTST) device. In the late phase of the DNM formation, a single ST is connected to the external poloidal coil flux, which permits magnetic helicity injection from the helicity source (the coil flux) into the helicity sink(the ST plasma). Our 2-D magnetic field measurement indicates that the magnetic helicity injection is related with magnetic reconnection.

1. Introduction

Magnetic helicity is a useful plasma parameter for of initiating or ramping up plasma current drive for various magnetized plasmas. It is now widely used in ST, spheromak and reversed field pinch (RFP) experiments such as the coaxial helicity source in NSTX [1] and the point-source dc helicity gun in PEGASUS [2]. The helicity injection is also observed around the connection region between poloidal coils and ST plasma during double-null merging (DNM) formation in the University of Tokyo Spherical Tokamak (UTST) plasmas[3].

2. Experimental equipment

A ST plasma is produced by the DNM method by using two pairs of external poloidal field coils. In this scheme, the magnetic reconnection generally produces a current sheet and plasmoids, which may directly influence its helicity injection processes [4-6]. The magnetic helicity is considered to be injected from a helicity source with a high eigenvalue into a helicity sink with a low eigenvalue. However, the helicity injection requires the helicity source, i.e. the coil flux, to be connected with the helicity sink through magnetic field lines. The eigen value profiles of ST plasma and that during helicity injection have not been measured yet. We measured for the first time 2-D eigenvalue profile of the connecting region between the coil flux and the core plasma flux. Figure 1 shows the experimental setup of the UTST device (a) and color contours of the measured 2-D poloidal magnetic flux with toroidal current density *jt (b),* toroidal eigen-vlues λt (c) and poloidal eigenvalues λp (d) at 760μs after PF coil discharge began.

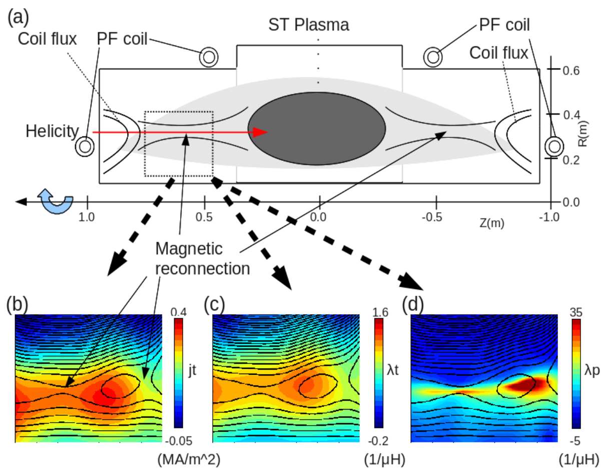

Fig1. (a) Experimental setup of UTST device with two pairs of PF coils on each side. Color contours of the measured 2-D poloidal magnetic flux with (b) toroidal current density *jt* (c) toroidal eigen-vlues λt and (d) poloidal eigen-values λp

3. Results

We observed for the first time in plasma experiments that a long thin high λ region produced by the current sheet bridges the helicity source (the coil flux) and the helicity sink (the ST plasma). Both the ST plasma and the coil flux are surrounded by a common flux during helicity injection. Magnetic reconnection transforms the common flux into a private flux, forming a long thin current sheet having high λ. Also, we observed a plasmoid having high λt that formed in the current sheet carries magnetic helicity intermittently from the coil flux to the ST plasma. The plasmoid tends to have a peaked λt profile at the center of the closed flux. It has a maximum value of $\lambda t \sim 1.4\ \mu H^{-1}$ at around z = 0.53m until 840 μs and moves toward the ST plasma. Then, the flux decreases, but the high λt area spreads. The λt value at the entrance region of the ST plasma increases from 0.6 to 1.15 μH^{-1} between 680 and 880 μs because of this helicity injection and plasmoid motion. The plasma current increases from 90 to 125 kA under the constant vacuum toroidal field because of helicity injection into the ST plasma.

4. Summary

In this experiment, the relationship between magnetic helicity injection and magnetic reconnection was observed for the first time in reconnection experiments [7]. Our 2-D eigen-value measurement indicates that helicity injection is caused by the dynamics of a high-λt current sheet arising from magnetic reconnection that bridges the helicity source and the ST plasma. Plasmoids with high λt are observed to grow intermittently and move toward the central ST plasma, carrying magnetic helicity.

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