§30. Theoretical Study About MHD Dynamics and Self-organization in a High-beta Toroidal Plasma

Sanpei, A. (Kyoto Inst. Tech.), Takahashi, T. (Gunma Univ.), Mizuguchi, N.

Comparative analyses between the nonlinear three-dimensional MHD simulation results[1)] and the experimental observation at RELAX device[2)] have been carried out for the low-aspect-ratio reversed-field-pinch(RFP) plasma to reveal the physical mechanism of the formation processes of helical structures. The simulation results show a clear formation of n=4 structure as a result of dominant growth of resistive modes, where n represents the toroidal mode number. The resultant relaxed helical state consists of a unique bean-shaped and hollow pressure profile in the poloidal cross section for both cases of resonant and non-resonant triggering instability modes. Moreover, comparison our simulation results with its of NIMROD code in order to validate.

To avoid the degradation of confinement due to the chaotizing of the field lines in the core region of RFP, a unique control method making use of the self-concentrating nature of the plasma perturbations into a small number of modes has been proposed both experimentally and theoretically. Several types of such states have been observed, such as the quasi-single helicity (QSH) and the single helical axis (SHAx) states. However, the physical mechanisms for the formation and deformation of the structures have not been clarified well.

We solve a standard set of the nonlinear, resistive, and compressive MHD equations by the MIPS code in a full-toroidal three-dimensional geometry to investigate the dynamical behavior of RFP plasma on the structural changes within the MHD time scale on the order of sub-millisecond. The initial conditions for the simulation are given by a numerical equilibrium that roughly follows the experimental conditions of RELAX. The equilibria are calculated by the Grad-Shafranov solver with a fitting reconstruction, the RELAXFit code. Two typical cases, where the $q = 1/4$ rational surface does and does not exist, are examined.

Comparing with the experimental observations, we may acknowledge the validity of the simulation. The helical deformation of electron temperature T_e distribution calculated from SXR emissivity[3)] predicted by the simulation described in upper panel of Fig. 1 can explain an experimental result of tilted T_e imaging diagnostic from vertical port shown in lower panel. Both of these deformations are corresponding to $m/n = 1/4$ helical deformation.

The simulation results successfully reproduced the basic nature of the experimentally observed helical structures in RELAX with the n=4-5 components. Such helical structures can be formed from the initial conditions

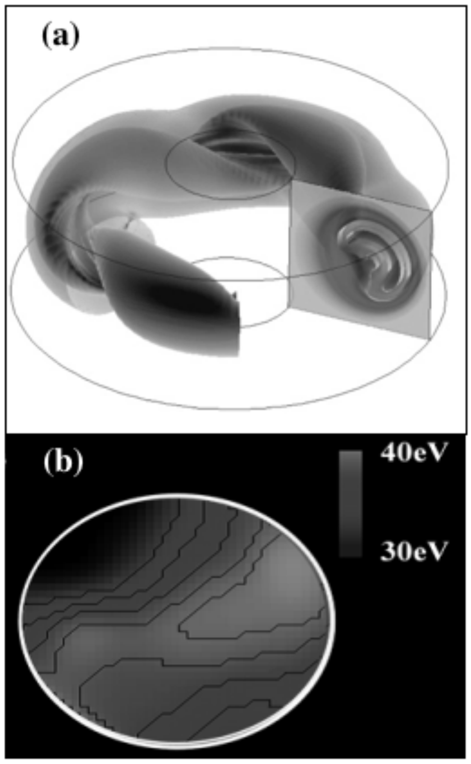

Fig. 1: Simulation and experimental results of the helical structures in RFP plasma. A hellically twisted overall structure (a) and a tilted T_e structure obtained from vertical port (b) are shown.

both with and without a resonant rational surface. In addition, the simulation results imply that there can be a unique helical relaxed state in an RFP with a bean-shaped hollow pressure profile in the poloidal cross section.

Moreover, we make a comparison between our MIPS result and NIMROD result in association with Dr. Karsetn McCollam, University of Wisconsin. From NIMROD code, we observed relatively higher n= 5-8 mode become dominant even starting from same initial distribution as MIPS used. It may be caused by a gradient of current distribution on initial equilibrium.

These comparative analyses would deepen our understanding of the self-organizing phenomena in a low-aspect and high-beta fusion plasma. To find out the basic constraint of the relaxation and its application to the experimental improvement is the next step of our research.

1) N. Mizuguchi, A. Sanpei, et al. : 24th IAEA-FEC, San Diego (2012), TH/P3-26.

2) A. Sanpei, et al. : IEEE Transaction Plasma Science, **39**, 2410 (2011).

3) K. Nishimura, et al. : Rev. Sci. Inst., **85**, 033502 (2014).