§7. MHD Characteristics in an Extremely High-beta Torus Plasma

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A formation and a confinement of a high beta plasma are one of key issues for a magnetic confinement fusion study, including a helical system to make the MHD characteristics clear. Non-ideal effects (dissipation and kinetic effect) have mainly determined the MHD behavior in the experimentally generated plasmas. A field-reversed configuration (FRC) plasma, which belongs to a compact toroid, has a high beta value and a large normalized plasma radius (r*). By theoretical approach, it has been found that ion and electron flow and a large Larmor radius of ion have important roles in the MHD stability for the FRC plasma. It is also found experimentally that an interchange instability with toroidal mode number $n = 2$ have never grown in the FRC plasma with a large r* formed by a translation technique. These characteristics of the FRC plasma have a relation with the stability of a burning state of the helical system where a self-induced plasma current is significant. This project aims to reveal the MHD characteristics of the burning plasma by a comparison of MHD behavior between the FRC and the helical device.

This project has been performed on a negative biased theta pinch at Nihon University, called NUCTE-III. Typical plasma parameter of averaged beta value, normalized plasma radius (s-value), and averaged electron density are 0.6 - 0.9, 0.9 - 2 and 10^{20} - 10^{21} m^{-3}. This device has recently been modified and a quasi-steady state confinement section has been installed. This makes the achievable plasma parameter range wider[1].

The MHD behavior has been investigated by using the computed tomography technique. A time evolution of two dimensional emission profile of the bremsstrahung was reconstructed by the ART method. By Fourier analysis, a troidal mode structure has also been estimated[2]. In the latter phase of equilibrium, the FRC has a well-known global rotational instability with toroidal mode number $n = 2$. It has been believed that elliptical deformation of the FRC induces the interaction between a chamber wall and the plasma, and which terminates configuration lifetime. However, these observation indicates that the FRC deforms into a dumbbell-like structure before the edge hits the chamber wall prior to the disruption phase. In addition, an internal shift mode with a toroidal mode number $n = 1$ has been observed in the equilibrium phase followed by growth of $n = 2$ rotational instability. To separate an internal and an external deformation mode, the Fourier analysis of the reconstructed profile inside the separatrix has also been performed. Tomographic profiles of the presented method have detected the toroidal mode deformation especially inside the separatrix. However, it is difficult to investigate a time evolution of the internal structure, especially around the magnetic axis with the spatial resolution of the presented system. For more detailed investigation, the improvement of spatial and/or reconstruction technique is necessary.

To investigate an effect of a toroidal ion flow, an ion Doppler spectroscopy (IDS) system with a first response has been constructed. The ion Doppler shift of impurity ions C^{4+} has been measured with the newly built IDS sytem. The toroidal flow inside the separtrix start to increase just after the formation and the flow velocity is gradually increased. The velocity is comparable with the ion diamagnetic velocity.

Several new diagnostics have also been developed to investigate the MHD behavior. By a optical fiber with a large numerical aperture covering the entire plasma, a detector system for a plasma position and structure measurement has been improved. A time evolution of a center position of the separatrix and $n = 1$ and 2 mode deformation along the z axis has been observed for the first time.

A magnetic fluctuation measurement system for the MHD activity has also been developed[3]. To exclude the effect of the confinement field, the magnetic probes has figure-eight-wound structure. The spatial structure of the magnetic fluctuating can be obtained from a Fourier analysis of the probe signal. The fluctuating field with 0.1% of the confinement field is successfully detected with this method. It is planned that the toroidal flow and a large orbit effects of the FRC plasma will be investigated on newly modified NUCTE-III/M device using the above diagnostics.

Reference

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3) Kanamaru, Y. *et al.*, Rev. Sci. Instrum. **78**, (2007) 036105