

5. Conclusion

In the burning plasma with a high α -particle pressure gradient, Alfvén eigenmode (AE) can be destabilized by alpha-particles. This destabilized AE can induce the enhanced transport of alpha-particles from the core region and can cause the degradation of the performance of a fusion reactor. Loss of alpha-particles may also damage the first wall. Therefore the understanding of the alpha particle transport when AEs are destabilized is important.

In JT-60U, AE experiments using NNB with energy of $E_{\text{beam}} > 360$ keV have been performed. So far, bursting modes such as ALEs in the range of TAE gap frequency and drop of total neutron emission rate by bursting modes had been observed. Although this suggested transport of energetic ion due to bursting mode induced by fast ion by N-NB injection, it was not clearly understood yet whether this transport was due to loss or redistribution of energetic ions, or both processes were important.

In this thesis, in order to investigate fast ion transport by bursting modes, the development of neutron emission profile measurement has been carried out. Since the neutron emission profile measurement is one of main diagnostics in next step fusion device such as ITER, the establishment is important theme, too. Then in AE experiments using N-NB, measurements of neutron emission profile were performed for the study of fast ion transport by bursting modes.

In the development of neutron emission profile measurement, to start with NE213 organic liquid scintillator was employed as neutron detectors. However, since this detector itself detect gamma-rays as well as neutrons, investigation of behavior on neutrons only was impossible. Then, Stilbene neutron detector developed by TRINITY laboratory was employed for the first time. This detector combines a Stilbene organic crystal with a neutron-gamma pulse shape discrimination circuit. This has enabled us to detect only neutrons except for gamma-rays in the experiment. For the application of this

detector to JT-60U experiments, the calibration using neutron and gamma sources and the performance test on Fusion Neutron Source (FNS) in JAERI Tokai were conducted. In these tests, good gamma-ray suppression of Stilbene neutron detector was verified, and in range of $10^2 \sim 10^5$ cps., the operation of the Stilbene neutron detector was demonstrated under existence of background gamma-rays. Furthermore, the absolute neutron detection efficiency of the Stilbene neutron detectors was determined on DD operation in FNS. Also by using Monte Carlo Code for Neutron and Photon Transport (MCNP), the effect of shielding and scattering of neutrons for vacuum vessel and neutron emission profile monitor was estimated. Then, neutron emission profile measurement was performed in JT-60U DD experiments. The neutron emission profile obtained by using Stilbene neutron detector is in a reasonable agreement with calculation using TOPICS code. Therefore, measurements of neutron emission profile become routinely to be possible in JT-60U.

In the study of fast ion transport using neutron emission profile measurement, the neutron emission profile measurement was performed in the AE experiments using N-NB to investigate the transport of fast ions by bursting modes in the range of TAE gap frequency such as ALEs. The result of the neutron emission profile measurement suggested to the redistribution of fast ions. Then, we estimated fast ion transport from the result of neutron emission profile measurement by assuming as follow: (1) Fusion reaction is only due to beam-target reaction. (2) The energy distribution function of fast ions obeys the Stix's stationary solution. (3) Fast ions with the energy range satisfying the resonant condition transport by ALEs. As a result of the estimation, it is indicated that a large fraction of fast ion population in the center region ($r/a < 0.4$) is expelled to the outer region, that is a radial redistribution, by ALEs, with a part of the expelled fast ions lost to the wall. Also the decay time of the enhanced neutral particle flux due to ALEs can be explained by the slowing down of fast ions in the peripheral region, which is consistent with the result of the neutron emission profile measurement.

Furthermore transport of fast ions by Reversed-Shear-induced AE (RSAE), recently proposed by Takechi, M. was observed. The RSAE is a global AE near the zero shear region of the RS plasmas. From the result of the neutron emission profile measurement, it is considered fast ions reduced through the plasma entirely, not redistribution. Since the position of q_{\min} is setting as out as possible, it was thought that the eigenfunction of the observed RSAE was in outer region. While in the case of ALE, which cause the redistribution of fast ions, the position of q_{\min} is plasma center. These results suggest the relation between eigenfunction of AE and fast ion transport

In the future, it is necessary to analyze the relation between the fast ion transport and eigenfunction of AEs more detail, together with the relation between the fast ion transport with mode amplitude. We will expect that the results of such as analysis give the useful knowledge in the operation scenario in ITER.