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Linkages of heat, particle and momentum transports in a Torus Plasma

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Understanding of particle, heat and momentum transports is a fundamental issue of plasma physics as well as magnetically confined fusion researches, because the control of transport in the plasma is required for the safe operation of fusion plasma discharges. The linkages among transport processes of different physical quantities such as heat, particle and momentum have been experimentally observed in some torus plasmas. Such so-called off-diagonal term effects in a transport matrix attract much attention in the magnetically confined fusion researches, because the intrinsic rotation driven by gradient of pressure and/or electric field may control MHD stabilities in high beta plasmas. In the conference, the experimental observations of the off-diagonal term effects in the Large Helical Device (LHD) will be presented.
The LHD is a torus plasma experimental device with a pair of helically winding coils around the torus. The confinement property of hydrogen plasma has been investigated in the LHD. An ion internal transport barrier for heat transport (ion ITB), which is characterized by the peaked ion temperature profile with a steep gradient in the plasma core, has been formed in the plasma heated by high power neutral beam injection (NBI). In the ion ITB plasma, the outward transport of impurity ions such as carbon, argon, and iron from the plasma core is observed and consequently an extremely hollow profile of the impurity ions (Impurity Hole) is formed. This outward transport of impurity ions shows a strong dependence on the ion temperature gradient. The ion temperature gradient is developed, followed by the outward transport of impurity ions. This causality implies that the outward impurity transport is driven by the ion temperature gradient, which shows the effect of off-diagonal term in a transport matrix.
The peaked profile of toroidal rotation velocity is also observed in the core region of the ion ITB plasma. The rotation direction is determined by the torque input due to the tangentially injected heating NBI. The momentum diffusivity (viscosity) decreases with the reduction of ion thermal diffusivity in the core region of the ion ITB plasma. However, other momentum transport element is observed and depends on the ion temperature gradient. The ion-temperature-gradient dependent momentum transport is in the opposite direction to the momentum diffusivity, in other words, intrinsic rotation driven by ion temperature gradient, which is also the effect of off-diagonal term in the transport matrix.

Keywords: ion ITB, impurity transport, momentum transport, off-diagonal term in a transport matrix