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ネオンガスパフ放電におけるLHD周辺不純物輸送解析
Impurity transport analysis in LHD divertor plasma with neon gas puff

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Modeling of fusion plasma is one of the urgent tasks for an engineering design of a reactor-class device. Especially, the modeling of divertor plasma is strongly required to estimate the plasma parameters and the influence upon components surrounding the plasma. In particular, regarding the heat load issue, application of impurity radiation, optimization of divertor structure, and plasma detachment are the major topics. Impurity seeding experiments with gas puffing have been conducted with different gas species, such as neon, argon, krypton, xenon, and nitrogen. Recently, an experimental analysis with regard to toroidally symmetric/asymmetric distributions of particle flux on divertor plates with neon and nitrogen seeding was carried out [1], and a fundamental modeling for the different transport properties of neon and nitrogen suggested in [1] was performed [2] with a 3D fluid transport code EMC3-EIRENE [3]. We present an EMC3-EIRENE modeling study of impurity-seeded plasma based on multiple measurements such as bolometer and spectroscopy to investigate carbon and neon transport properties in a neon-seeded discharge.

In order to reproduce a plasma distribution such as electron density n_e and temperature T_e in a specific discharge, various input parameters must be determined from measurements. The heat source and particle source in the core region was determined directory from NBI heating data. Cross-field transport coefficients were determined from comparisons of radial n_e and T_e distribution with Thomson scattering measurement. Parameters related impurities involve uncertainty arising from difficulty of direct measurement of impurity source and impurity density in the plasma. We use bolometer measurements and spectroscopy measurements to determine impurity source amount. We simulate carbon arising from the carbon divertor tile and neon seeded from a gas-puff nozzle. From our previous study [2], we assumed that neon gas is well confined in the device and can be treated as recycling source at the divertor plates in the same way as hydrogen. We use the total radiation power evaluated by the 3-O resistive bolometer to estimate carbon and neon source amount at the divertor plates. From the total radiation power before the puff, we estimated the carbon sputtering yield $Y \sim 5\%$. It is higher than a typical sputtering yield of a carbon tile before exposure; therefore influence of erosion and redeposition on the surface is suggested. However, we note that the total radiation power includes hydrogen radiation and also core radiation excluded from EMC3-EIRENE model, and quantitative estimation requires more precise analysis such as a direct comparison of the detector power of the bolometer. The neon source amount was determined from the increase of the total radiation power $P_{rad} \sim 1.4$ MW.

The neon ions are supposed to cause enhancement of carbon sputtering, however spectroscopy measurement gives almost no difference of CIV line intensity after the puff. In order to understand this contradictive result, we performed a parameter scan of neon radiation power with fixed carbon sputtering yield. We found that carbon radiation power from C^{3+} changes inversely as the neon radiation power. The carbon radiation power normalized the carbon source amount also has the same trend. That fact suggests that carbon transport is changed by the intense neon seeding. Figure 1 shows a map of force balance on carbon ions. The thermal force pulls ions toward the upstream region, and the friction force pushes ions toward the downstream region, i.e., the divertor plates. The figure suggests that the carbon ions are screened from the divertor plasma after the puff because neon radiation reduced electron temperature and hence reduced thermal force.

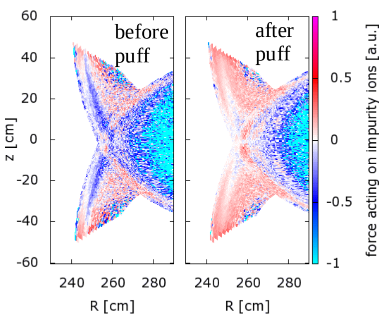

Fig 1: distribution of force acting on carbon ions. The negative region (blue) means thermal force dominant. Positive region (red) means friction force dominant.

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