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Characterization of Isotope Effect on Confinement of Dimensionally Similar NBI-Heated Plasmas in LHD

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Energy confinement and thermal transport has been widely regarded as gyro-Bohm in tokamak as well as stellarator-heliotron for a single kind of ion. However, this gyro-Bohm model predicts confinement degradation in deuterium (D) plasmas because of larger normalized gyro radius than in hydrogen (H) plasmas, which conflicts with major experimental observations. This study aims to quantify a peculiarity in dependence on normalized gyro radius in H and D plasmas in order to address this unresolved issue. The first deuterium plasma campaign in LHD reveals definitive characteristics of isotope effect on NBI-heated plasmas from elaborated experiments. Stationary uneventful plasmas, which are accompanied by neither ITB nor transition, have been assessed here. Thermal energy confinement time gives the regression expression scaling with the isotope mass (A) as A to 0.15, which shows moderate improvement in D plasmas. This positive isotope dependence contradicts with gyro-Bohm and is similar to the recent result from L-mode plasmas in JET-ILW. Operational flexibility of magnetic field, density, and heating power enables adjustment of three major non-dimensional parameters, those being normalized gyro radii, collisionality and beta , and dimensionally similar plasmas of H and D in all these three parameters can be obtained. Then TASK3D-a / FIT3D is used for analysis of heating power deposition, power balance and local thermal transport. If gyro-Bohm nature predominates in these plasmas, thermal diffusivity normalized by Bohm diffusion should be the same in a pair of dimensionally similar plasmas of H and D. Different characteristics have been found in electron and ion loss channels. Electron heat diffusivity normalized by Bohm diffusion in H is lower than that in D and even lower by a factor of 1 over square root of 2 which means net improvement. This trend is robust and insensitive to parameters such as normalized gyro radii, collisionality, beta, scale length of density gradient, etc. In contrast, ion thermal diffusivity shows a same characteristics as in the electron channel in low collsionality regime while that in D compared with the case with H degrades with the increase of collsionality. These results have shown definitively that the gyro-Bohm nature is violated in the comparison of H and D plasmas in a large scale stellarator-heliotron.

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