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Development of Impurity Seeding and Radiation Enhancement at Helical Divertor in LHD

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Reduction of heat and particle loads to the divertor is crucial to the realization of a fusion reactor. Divertor detachment is a favorable mode of operation for this purpose. In this study, impurity seeding was conducted in the Large Helical Device (LHD) using neon (Ne) puffing. Enhanced radiation loss and reduction of the divertor heat load were observed without significant changes in stored energy and line averaged density. In LHD, the radiated power fraction against the heating power, P_rad/P_heating, where P_rad and P_heating are the total radiation power and the heating power, respectively, is limited up to around 30% in hydrogen plasmas even for high density plasma just below the radiative collapse (n_e,bar>1×10^20 m^-3), where n_e,bar is the line averaged density. With Ne seeding, the ratio could be raised to 30-53% in spite of the much lower density (n_e,bar~1.3-5.5×10^19 m^-3),. The energy confinement parameter is defined as W_p/(P_heating^-0.61 n_e,bar^0.54) based on the ISS04 scaling, where W_p is the plasma stored energy, and the normalized energy confinement parameter is defined as the ratio between during the radiation enhancement and that just before the Ne seeding. The confinement degradation during detachment remains less than 20% over the operation regime in this study. P_rad/P_heating is limited by the radiative collapse of the plasma, and the achieved fraction with impurity seeding is 53% during relatively low density discharges (n_e,bar just before the seeding ~ 1.3×10^19 m^-3), while in hydrogen plasmas before the seeding, the fraction is up to around 15% regardless of n_e,bar. P_rad/P_heating during the seeding decreased with increasing density. At high density (n_e,bar>4×10^19 m^-3), the radiated power fraction is less than 40%. Radiation profile measurement with an InfraRed Imaging Video Bolometer (IRVB) was conducted during Ne seeding in relatively high density plasmas in this study (n_e,bar~4×10^19 m^-3). The localized supplemental radiation was observed along the helical divertor X-point (HDX). Since the radiation enhancement is localized in the SOL during the Ne seeding, and the degradation of the plasma confinement is relatively small. On the other hand, in hydrogen plasmas just before the radiative collapse, the radiation enhanced region is localized on the inboard side and does not follow the HDX.

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