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大型ヘリカル装置(LHD)におけるエルゴディック層によるダスト遮蔽効果のシミュレーション解析

Simulation Analysis on the Dust Shielding Effect in Ergodic Layers on the Large Helical Device

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In the Large Helical Device (LHD), typical long pulse plasma discharges were interrupted by release of large amounts of dusts from the divertor region or from surfaces inside of the vacuum vessel. Non-axisymmetric magnetic components in the peripheral plasma region intrinsically form ergodic layers around the main plasma, which can have a property of preventing the plasma from the dust emission. The effect of the ergodic layers is investigated using an edge plasma transport simulation code (EMC3-EIRENE) coupled with a dust transport simulation code (DUSTT).

The simulation analysis was performed in three different typical magnetic configurations in the LHD (the radial position of the magnetic axis R_{ax}=3.60, 3.75, and 3.90 m). The width of the ergodic layers is wide in outward magnetic axis configurations such as R_{ax}>3.75m. The trajectories of a number of iron dust are traced by DUSTT in which the emission rate of the total iron atoms included in the dust is set to 4.38×10^{19} particles/s, which is released from a dust source at a point on the surface on a helical coil can in the inboard side of the torus with a constant velocity of 5 m/s in a three-dimensional model illustrated in Figure 1.

The content (total number) of the iron ions by the dust emission contained in the peripheral plasma for one-half helical pitch angle (toroidal angle ϕ=18°) is calculated. Figure 2 shows the dependence of the iron ion content Q_i^{Fe} on the plasma heating power at the Last Closed Flux Surface P_{LCFS} for a plasma density at the LCFS n_e^{LCFS} of 2×10^{19} m^{-3}. It indicates that the impurity content significantly rises for low plasma heating power (P_{LCFS}<2 MW) in all magnetic configurations, which can be due to the penetration of dust into the peripheral plasma because of the low heat load onto the dust due to the low peripheral plasma temperature. It also reveals that plasma discharge operation with moderate heating powers (P_{LCFS}=4~5 MW) in the magnetic configuration with wide ergodic layers (R_{ax}=3.90 m) is advantageous for reducing the impurity content in the plasma.

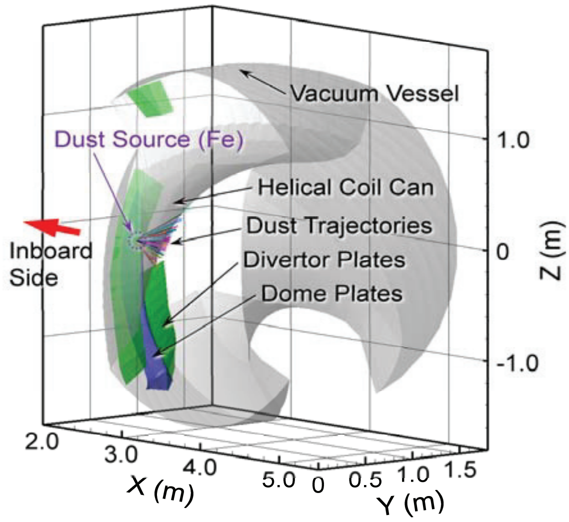

Fig.1 A three-dimensional model of LHD for edge plasma and dust transport simulation.

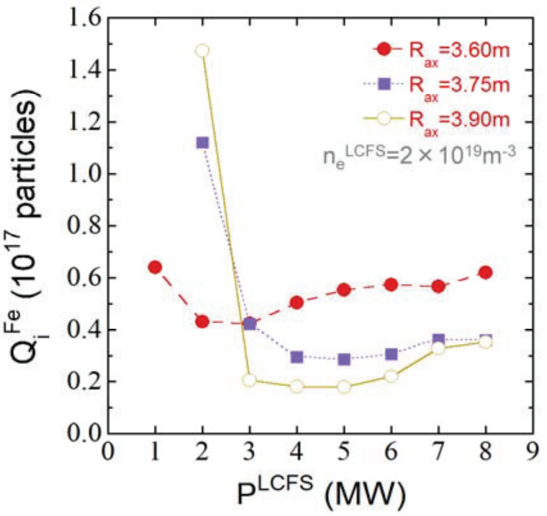

Fig.2 The dependence of the iron ion content in the peripheral plasma on the plasma heating power.