§11. Simulation Analysis of Transport of Dusts in the Large Helical Device

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Long pulse plasma discharge experiments have been performed in the Large Helical Device (LHD) for more than one decade. The plasma discharges have often been terminated with the emission of large amounts of dusts released from closed divertor regions and ICRF antennas, which are observed with plasma monitor CCD cameras and fast framing cameras.[1)] Thus, in addition to the control of the emission of dusts, understanding of the physical mechanism of the transport of dusts is one of the critical issues for extending the duration time of the long pulse discharges in LHD.

Figure 1 shows one of the typical examples of the image of the emission of dusts observed with a fast framing camera installed in an upper port (4.5-U) just before the plasma termination of a long pulse discharge in the 17th experimental campaign in FY2013. The dusts are identified as small incandescent moving spots on the image. The plasma discharge was stopped by the large amounts of dusts released from the closed divertor region near a lower port (4.5-L) in the inboard side of the torus. It was found that the dusts consist of carbon-rich mixed material layers exfoliated from brittle iron-rich layers.[2)] The dusts moved to the upper-left side from the lower-right corner (the position of the closed divertor region) in this figure. After the times of this image, a bright stripe appeared from the position of the closed divertor (the lower-right corner) on the image.

The dust transport simulation code (DUSTT), which was modified to the analysis in fully three-dimensional geometries such as LHD plasmas, was applied to the analysis of observed dust trajectories.[3)] In the simulation, spherical carbon dusts are released from a position of the closed divertor (dust source) with an initial velocity of 5m/s and with the direction to the plasma center. The radii of the dusts (r_d) are changed from 1μm to 20μm. The initial velocity of the dusts corresponds to the typical observation with stereoscopic fast framing cameras installed in an upper port and an outer port.[4)] The simulations of the trajectory of the various sized dusts viewed from the upper port (4.5-U) are presented in Figure 2. The three-dimensional profiles of the background plasma parameters (the ion and electron temperatures and density, the plasma flow velocity, etc.) for the simulation are from the calculation of the EMC3-EIRENE code under a typical long pulse discharge condition in which the plasma heating power at the last closed flux surface (LCFS) is 1.0MW, and the plasma density at the LCFS is $1.0\times10^{19}\mathrm{m}^{-3}$.[5)] The simulation indicates that the small sized dusts (r_d<4μm) are flown to the downstream side (the upper-left side in this figure) of the plasma flow on a divertor leg close to the dust source. On the other hand, large sized dusts ($r_d\geq$10μm) penetrate the divertor leg, and reach to the ergodic layer and the core plasma near the positons of the dusts source to sublimate by the high heat load in the peripheral plasma to the dusts.

The simulations of the small sized dusts explain the observations of the trajectories shown in figure 1. It strongly suggests that the observed bright stripe, which appeared from the closed divertor region, was caused by the large sized dusts released from the dust source. It is possible that the dusts including impurities (mainly carbon) penetrated into the ergodic layer and the core plasma induced the radiation collapse to terminate the long pulse discharge.

1) Shoji, M. et al.: Plasma Fusion Res. (to be published).
2) Tokitani, M. et al: J. Nucl. Mater (to be published).
3) Shoji, M. et al.: Plasma Fusion Res. **9** (2014) 3403132.
4) Shoji, M. et al.: Nucl. Fusion (to be published).
5) Kawamura, G. et al.: Contrib. Plasma Phys. **54** (2014) 437.

Fig. 1. Image of the emission of the large amounts of dusts observed with a fast framing camera installed in an upper port just before the termination of a long pulse discharge in the 17th experimental campaign.

P^{LCFS}=1.0MW, $n_e^{LCFS}=1.0\times10^{19}\mathrm{m}^{-3}$

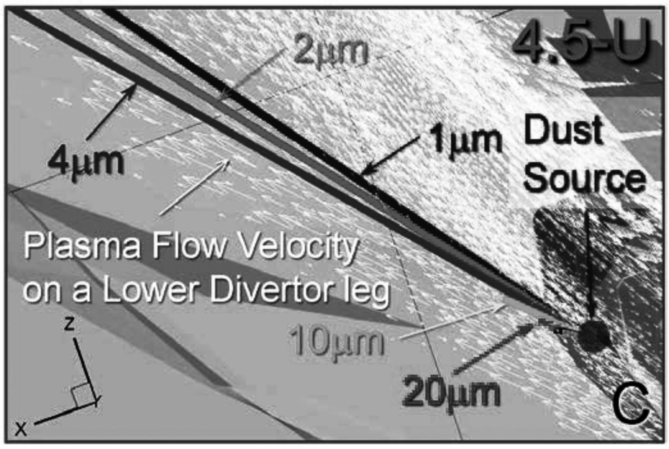

Fig. 2. The simulations of the trajectories of spherical various sized carbon dusts released from the closed divertor region (dust source), which are viewed from the position of an upper port (4.5-U).