Fully Three-Dimensional Simulation of Neutral Particle Transport in an ICRF Heated Long Pulse Discharge

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An ICRF heated long pulse discharge was terminated by uncontrollable plasma density rise at 150 sec. in the 6th campaign. Toroidally non-uniform increase of Hα intensity and divertor plate temperature was observed in the later phase of the discharge (after 90s). These toroidal distributions were peaked around port-3. A CCD camera observed local heating of a vertically installed divertor plate (hot spot) at 2.5-L port during ICRF heating. ICRF antennas for proton heating in long pulse discharges are installed in the upper and lower port at port-2.5. The above three experimental results strongly suggest that the uncontrollable plasma density rise was caused by hydrogen outgas from divertor plates heated by the accelerated protons by ICRF waves excited with the ICRF antennas.

We applied a fully three-dimensional simulation code for neutral particle transport (DEGAS ver.63) to the analyses of neutral density profile in the long pulse discharge. The simulation code tracks the trajectory of neutral particles (neutral hydrogen molecules and atoms) in a grid model by using the Monte-Carlo technique on the basis of the database of neutral-plasma and neutral-wall interactions. We constructed a three-dimensional grid model of the LHD vacuum vessel and the plasma. Figure 1 shows the grid model (for two toroidal pitches) with the line of sight of Hα emission detectors installed in all outer ports and the trajectories of neutral particles.

The following three possible cases of the outgas source are investigated by using the simulation code:

1. vertically installed divertor plate locally heated by the accelerated protons (hot spot).
2. carbon protectors for the ICRF antennas heated by a RF current and a plasma heat load.
3. some divertor plates heated by the accelerated protons.

The toroidal distribution of the Hα intensity was calculated by integrating the Hα emission along the line of sight of the detectors. The distribution of the outgas rate on the divertor plates in case 3 was determined from the calculations of proton trajectory analyses. Figure 2 (a) gives the calculation of the toroidal distribution of the Hα intensity in the above three cases, which are normalized to the Hα intensity measured at port-3. Figure 2 (b) shows observed toroidal distribution of the ratio of the Hα intensity rise during the long pulse discharge (I_{Hα}^{150s}/I_{Hα}^{90s}). Here, the parameters I_{Hα}^{150s} and I_{Hα}^{90s} mean the Hα intensity observed at 150s and 90s, respectively. Comparing the calculation and the observation, we should subtract the background ratio induced by usual plasma-wall interactions (except for the effect of the accelerated protons). We ascribed the background ratio as the averaged one observed in port-6, 7 and 8 as shown in this figure. The toroidal distribution of the observed Hα intensity rise (with the subtraction of the background ratio) is qualitatively consistent with the calculated distribution in case 3.

Neutral particle transport analyses using the simulation code contribute to the investigation of the outgas source in the ICRF heated long pulse discharge. It strongly recommends that outgas from the divertor plates installed in the strike points of the accelerated protons should be suppressed in order to extend the duration time of long pulse discharges with controlled plasma density.

**Fig. 1. Three-dimensional grid model for the neutral particle transport simulation code (for two toroidal pitches).**

**Fig. 2. Calculated Hα intensity distribution due to the accelerated protons by ICRF waves (a), and, the observations of the ratio of Hα intensity rise (b).**

Reference