Strike Point Pattern on Local Island Divertor Head

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Monte Carlo simulation based on test particle representation is carried out in order to investigate the strike point pattern of ions on the Local Island Divertor (LID) head in the Large Helical Device configuration. The pattern on the LID head is numerically observed by tracing the guiding center orbits of the test particles under the effects of the Coulomb collision, and the observations show that the pattern depends strongly on the collisionality.

Keywords:
edge plasma transport, neoclassical effect, Local Island Divertor, Large Helical Device

The Local Island Divertor (LID) is one of the divertor concepts involved in the Large Helical Device (LHD) configuration [1-3], and it utilizes an $m/n = 1/1$ island formed at the edge region of the LHD. High temperature divertor operation (HT-operation) is expected to be achieved by controlling the edge plasma by means of the LID. In HT-operation, the neo-classical effect on the transport becomes important.

The Monte Carlo simulation based on test particle representation has an advantage of appropriately treating the edge plasma transport in the three-dimensional field line structure containing island and ergodic zones [4]. We trace the orbits of the guiding centers of the test particles in the fixed magnetic field under the effects of the Coulomb collision in order to numerically observe the distribution of the guiding centers in the configuration space [4-6]. By tracing the orbits, the strike point pattern on the LID head can be numerically observed. Here, the vacuum magnetic field is used to calculate the orbits, the magnetic axis is located at $R_0 = 3.6$ m, and the strength of magnetic field at the axis is $B_0 = 3$ T. Let us assume that 1) the test particles are mono-energetic protons with $E_t = 300$ eV, 2) the distribution of the initial pitch angles of the particles is uniform, and 3) the Maxwellian background plasma is uniform in the edge region including the island. We assume that the pitch angle scattering is dominant compared with the other effects of the collisions, and neglect the effects of the electric field. We also assume that all of the test particles start from the magnetic flux surface located at the edge of the core region, which is very close to the island separatrix (see Fig. 1), and that the particles are distributed uniformly on the surface. A three-dimensional view of the LID head is shown in Fig. 2.

When the collision frequency of the edge plasma is estimated as $\nu = 8.4 \times 10^3$ s^{-1}, we find that the strike point pattern is caused by the diffusion to the outside of the torus, and that the peak of the strike point distribution is located at the edge of the head, as shown in Fig. 3. Note that the strength of pattern is not symmetric as shown in Figs. 3 and

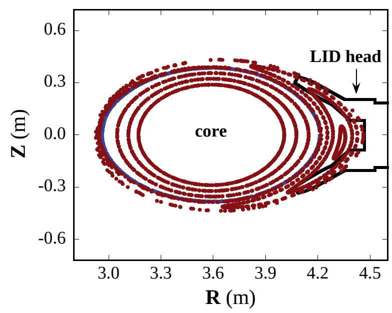

Fig. 1 Poincaré plots of field lines of the vacuum magnetic field and sketch of the LID head on the horizontally elongated poloidal cross section. The connection length is $L_c \sim 100$ m. The magnetic flux surface where the test particles originate is shown by blue dots.

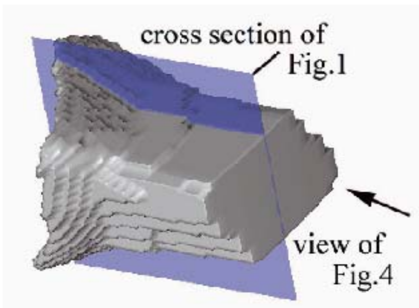

Fig. 2 Three-dimensional view of the LID head. This view is the same as those seen in Figs. 3 and 5.

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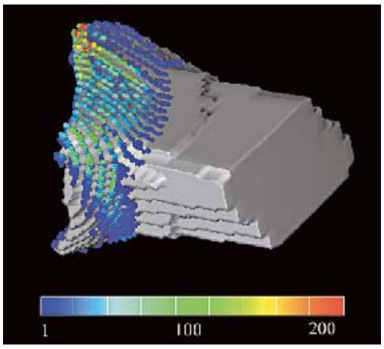

Fig. 3 The rear-view of strike point pattern on the head for the collisional regime. The mean free path is estimated as ℓ_{mfp} ~ 30 m. The total number of the test particles used in the simulation is 1×10^5. The color of the pattern indicates the number of test particles striking the head. The colored pattern is plotted every 0.5 degrees for the toroidal direction.

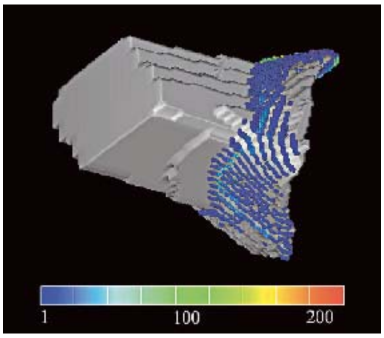

Fig. 4 The opposite-side-view of Fig. 3.

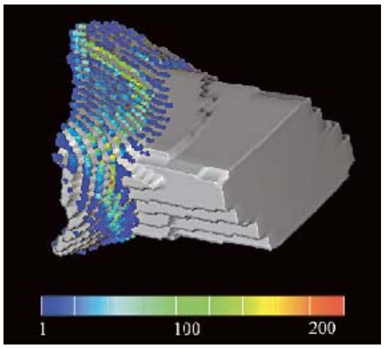

Fig. 5 Strike point pattern for the collisionless regime.

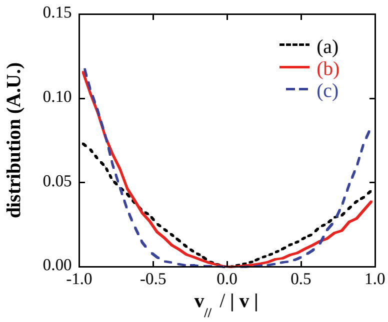

Fig. 6 Distributions of the cosine of pitch angles $v_{\|}/|\boldsymbol{v}|$ of the test particles striking the head. The collision frequencies are given as (a) dotted black line: $\nu = 7.8 \times 10^4$ s^{-1}, (b) solid red line: $\nu = 8.4 \times 10^3$ s^{-1}, and (c) dashed blue line: $\nu = 9.0 \times 10^2$ s^{-1}.

4. Here, the test particles are assumed to be absorbed completely into the head when arriving at the head's surface. On the other hand, when the collision frequency becomes small and is estimated as $\nu = 9.0 \times 10^2$ s^{-1}, the strike point pattern is drastically changed as shown in Fig. 5. The pattern becomes almost symmetric and corresponds to the shape of the island on the LID head. Distributions of the cosine of pitch angles $v_{\|}/|\boldsymbol{v}|$ on the head are shown in Fig. 6, where $v_{\|}$ is the parallel velocity. The distribution for the collisional regime with $\nu = 8.4 \times 10^3$ s^{-1} is not symmetric as shown by the solid red line in Fig. 6, and we can conjecture that the broken symmetry of the strike point pattern in Figs. 3 and 4 is caused by this fact. When the collision frequency becomes small, the symmetry is recovering (see the dashed blue line in Fig. 6). Of course, when the frequency becomes very high, the symmetry is also recovering (see the dotted black line in Fig. 6). A detailed physical elucidation of the patterns will be reported in the near future.

In this article, we neglect the effects of the electric field, energy scattering, charge exchange, etc. These effects will be discussed in future reports.

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