Structure of Edge Magnetic Field in Heliotron J

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Heliotron J is a \( \ell = 1 \) helical-axis heliotron device newly constructed at Institute of Advanced Energy, Kyoto University. The coil system of this device consists of a highly modulated \( \ell=1/m=4 \) helical coil, two types of toroidal coils, and three pairs of poloidal coils. The main device parameters are \( R = 1.2 \text{ m}, \langle a_p \rangle = 0.15 - 0.20 \text{ m}, B = 1.0 - 1.5 \text{ T}, \) and \( \sqrt{2\pi} = 0.5 - 0.7 \). The goal of this helical-axis device with a continuous helical coil is a demonstration of confinement improvement based on the currentless quasi-isodynamic configuration concept. Besides the performance of plasma confinement, a good capability to handle particle/heat load (divertor) is also required for a fusion device. The most favourable divertor configuration depends on the field structure in the edge region. In helical devices, the structure of edge magnetic field is strongly affected by “natural-islands” near the outermost magnetic surface. Since Heliotron J is a low shear device, the edge field structure is very sensitive to the change of magnetic field components, which can be controlled in a wide range by changing the current ratio of the coil system. This paper discusses the edge field structure in Heliotron J based on numerical analyses.

The edge structure in Heliotron J can be divided into two groups by its topological feature in Poincaré-plots. In one group, Group A, the pattern of the poloidal plot is basically similar to the conventional heliotron configuration, where a convoluted state of edge field lines is observed. In the other group, Group B, a clear magnetic island structure is observed. A rational value of the edge rotational transform divides one group from the other. For example, the former pattern is observed for \( \sqrt{2\pi} < 4/7 \), but for \( \sqrt{2\pi} > 4/7 \) the pattern changes to the latter. To discuss edge plasma behavior, the field tracing starting around the outermost magnetic surface to the material surface is enough since plasmas flowing along edge magnetic field are neutralized on the material surface when the field line crosses it. In this case, the field structure looks rather simple since the field lines cross the wall before the so-called “fold and stretch” effect becomes noticeable in the group A and the field lines cannot make complete islands in the group B. In contrast to Heliotron E, divertor footprints for both groups are localized in toroidal direction. This situation is similar with a magnetic island divertor discussed in W7-AS. It should be noted that the footprints can be positioned both in high and low field sides. Since we can select one of them by setting limiters, effects of the \( |B| \)-gradient along the field line on the edge plasma transport will be examined.