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# MHD simulation of pellet injection in LHD

LHDにおけるペレット入射のMHDシミュレーション

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In order to clarify the difference on the motion of a plasmoid induced by a pellet injection between tokamak and helical plasmas, MHD simulations have been carried out in a tokamak and Large Helical Device (LHD) configurations. It is found that the plasmoid motion depends on the initial location of the plasmoid in the LHD, whereas the plasmoids drift in the direction opposite to that of the curvature vector in a tokamak. It is also verified that there are two main forces acting on the plasmoid, and the connection length determines the dominant force.

## 1. Introduction

It is well known that an ablation cloud; a high density and low temperature plasmoid, drifts to the lower field side in tokamak plasmas, which leads to a good performance on fueling in tokamak [1]. Such a good performance, however, has not been obtained yet in Large Helical Device (LHD) experiments [2]. In order to clarify the difference on the plasmoid motions between tokamak and LHD, the tree-dimensional (3D) MHD code of ablation processes (CAP) [3] has been developed to investigate plasmoid motions.

## 2. Plasmoid motion in the LHD

An initial plasmoid is located inside the torus on the horizontally elongated cross section in the LHD as shown in Fig. 1. A circle is an initial plasmoid whose peak values of density and temperature of the plasmoid are 1000 times the density and 1/1000 times the temperature of the bulk plasma, respectively. The plasmoid, whose half width is 0.03, encounters electrons with a fixed temperature of 1.0 keV and density of 0.8 x $10^{20}$ $m^{-3}$ [4]. The helical plasma has a saddle point of the magnetic pressure on the poloidal cross section. Then, the plasmoid is located at the lower field side than the saddle point and the curvature vector is positive in the major radius direction. The simulation result is shown in Fig. 2. It is found that the plasmoid drifts slightly back and forth in the direction of the major radius. This result is different from one in the tokamak because the plasmoid drifts to the lower field side in the tokamak. The dominant force acting on the plasmoid is expressed by the following equation [5]:

$$\boldsymbol{F_R} = -\frac{\boldsymbol{B_{\varphi 0} B_{\varphi 1}}}{\boldsymbol{R}} + \boldsymbol{B_0}\frac{\partial \boldsymbol{B_{R1}}}{\partial \ell} \quad (1)$$

where the cylindrical coordinate ($R$, $\phi$, $Z$) is used. $B_0$ is the equilibrium magnetic field and $B_1$ is the perturbation of the field induced by the plasmoid. The first term represents 1/$R$ force due to the toroidal field. The second term is the force induced by the dipole field around the plasmoid. Figure 3(a) shows $\langle \partial \boldsymbol{B_{R1}} / \partial \ell \rangle$ and $\langle \boldsymbol{B_0^2} \rangle$ along the toroidal angle, where brackets show the average on the poloidal cross section within the plasmoid. It is found that $\langle \partial \boldsymbol{B_{R1}} / \partial \ell \rangle$ and $\langle \boldsymbol{B_0^2} \rangle$ have similar behaviors. Figure 3(b) shows those values in a conventional tokamak. The connection length in the LHD is shorter than one in the tokamak because the LHD has ten toroidal pitches. $\langle \partial \boldsymbol{B_{R1}} / \partial \ell \rangle$ and $\langle \boldsymbol{B_0^2} \rangle$ have similar behaviors also in the tokamak. Therefore, the characteristic length of $\langle \partial \boldsymbol{B_{R1}} / \partial \ell \rangle$ can be regarded as the connection length. The second term in Eq. (1) can be approximately expressed by $B_0 B_{R1}/L_c$. $L_c$ is the connection length which depends on the magnetic configuration.

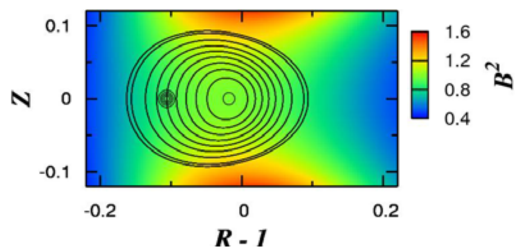


Fig.1. Horizontally elongated poloidal cross section. Colors and contours show the magnetic and plasma pressures. Circle represents initial plasmoid.

Since $L_c$ is long in the tokamak, the first term becomes dominant in $F_R$. On the other hand, since $L_c$ is short in the LHD, the second term becomes dominant. Then, the plasmoid motions between in the tokamak and LHD are different.

The temporal evolution of the magnetic field perturbation is shown in Fig. 5. The dipole fields appear as shown in Fig. 5(a) at first, and subsequently the deformation of the fields is induced and the plasmoid drifts across the flux surface. However, the poloidal field prevents the plasmoid from drifting. Thus, the poloidal component of the magnetic field perturbation is induced inside the plasmoid in Fig. 5(b). The poloidal component becomes small in Fig. 5(c) and subsequently it is induced outside the plasmoid in Fig. 5(d). They are corresponding to the motion that the plasmoid drifts slightly back and forth in the direction of the major radius.

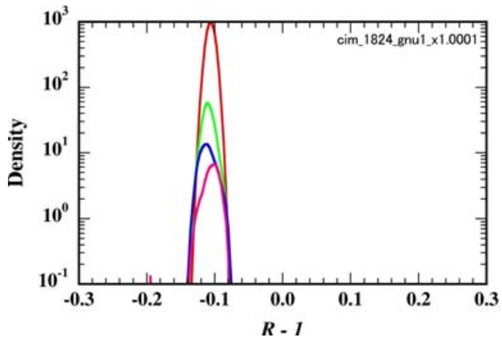


Fig.2. Density profiles at $t$ = 0 (red), 1 (green), 2 (blue) and 3 (pink) as a function of the major radius, $R$.

## 3. Summary

It is verified by simulations using the CAP code that the motions of the plasmoids with a high pressure induced by heat flux are different between a tokamak and the LHD. Although the plasmoids drift in the direction opposite to the magnetic curvature vector in a tokamak, vacuum toroidal field, RFP-like configurations, the plasmoid slightly drifts back and forth in the major radius direction when it is initially located inside the torus on the horizontally elongated poloidal cross section in the LHD. The plasmoid motion is determined mainly by $1/R$ force due to the toroidal field and the force due to the dipole field induced by the diamagnetic effect. The former forces imply drifts in the direction opposite to the curvature vector which are dominant in the tokamak. Since the latter forces are dominant when the plasmoids are located inside the torus in the LHD, the plasmoid motions in the LHD differ from those in a tokamak. It is verified that the connection length determines the force that dominates the plasmoid motion. This may explain the difference in the behavior of the plasmoid motion between in a tokamak and the LHD.

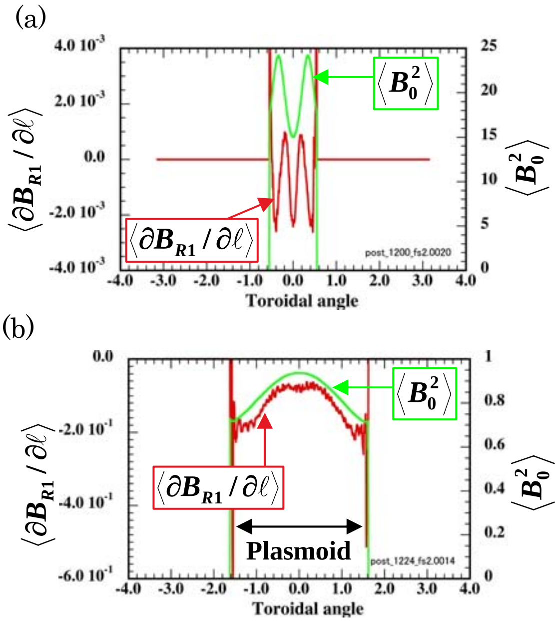


Fig.3. Horizontally elongated poloidal cross section. Colors and contours show the plasma and magnetic pressures. Circles represent initial plasmoids.

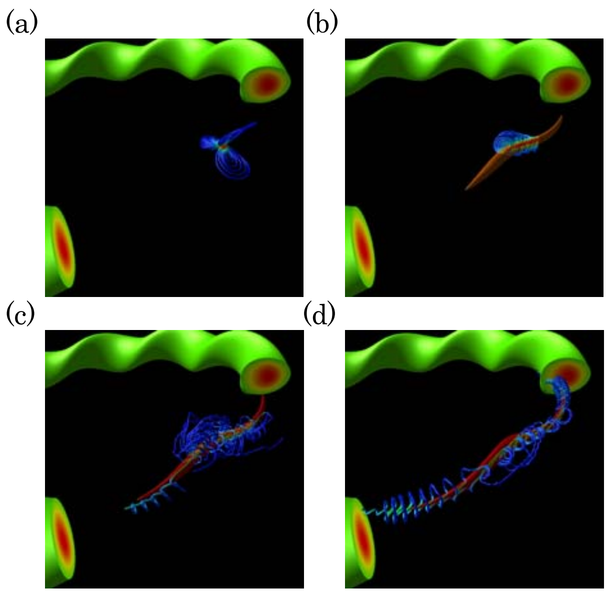


Fig.4. Plasmoids (red) and magnetic field perturbations (blue) at (a) $t$ = 0.16, (b) 1.5, (c) 2.3 and (d) 2.6.

### References


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