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Impact of pellet plasmoid drift on effective pellet fueling properties in LHD
LHDにおけるペレット粒子供給特性に及ぼすペレット溶発雲ドリフトの影響

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In order to investigate a transport of the pellet ablated materials, i.e. plasmoid which governs the effective pellet fueling properties, temporal evolution of the plasmoid has been simulated by a pellet ablation /deposition code; HPI2 taking into account the three dimensional magnetic field configuration of LHD. And it has been verified by comparing with the experimental result in LHD. Direct observations of the pellet plasmoid have been carried out by using a fast stereo imaging camera and Thomson scattering measurement which is triggered in synchronization with a time-of-flight pellet velocity meter. Both results are consistent on the point that the plasmoid drift occur in the early stage of the plasmoid homogenization into the background plasmas.

1. Introduction

Efficient core fueling is indispensable for sustaining burning plasma in fusion reactors. Solid hydrogen (D/T) pellet injection is considered to be prime candidate for the core fueling at the present time, because it is capable to deposit fuel particles beyond the last closed flux surface. On the other hand, a difficulty remains to perform efficient fueling due to an insufficient pellet penetration into high temperature plasmas. The most expected way for solving this problem is to take advantage of the drift transport of the pellet deposited material down the magnetic field gradient, i.e. $\nabla\mathbf{B}$. This drift transport favors a deep fueling and compensates for a part the limited pellet penetration in the case where the pellet is injected from the high-field side (HFS) of the device. It is therefore crucially important to validate these two processes in the pellet fueling. In order to understand the pellet fueling processes, time evolution of the pellet plasmoid which is observed in the LHD has been compared with the time-dependent simulation by the pellet ablation/deposition code HPI2[1, 2], which describes the whole fueling processes, taking into account a three-dimensional magnetic field structure of LHD.

2. Experimental results

Fast stereo observations[3] have shown that high-density plasmoid, which is formed by the pellet ablated materials, intermittently break away from the pellet ablating position and the break-away plasmoid drift to the low field side direction across a confinement field while homogenizing along a field line. The measured maximum drift distance is around 10 cm toward low field side, namely against pellet injection direction. The drift velocity is estimated to be beyond 10 km/s.

The density of the drifting plasmoid before homogenizing to the background plasma has been measured by the Thomson scattering measurement which is triggered in synchronization with a pellet injection timing. The density profile shows extremely in- and out-asymmetric density profiles in which several spikes appeared in the only outboard side. The densities of the transitive spikes are about 6×10^{20} /m^3 and this is about 6 times larger than the final density after the plasmoid homogenization. The positions where the spikes appeared are 20 cm outboard from the pellet ablating position. This distance is longer than the observed drift distance with the fast stereo observation, however there is no contradiction because H_α filter was employed for the fast stereo observation and it is possible to observe only very low temperature part (< 1 eV) of the plasmoid in the initial phase of the drift. This asymmetric density profiles might be due to detecting a pellet plasmoid which is passing through the cross section of the Thomson scattering measurements. The both measurements clearly indicate that the pellet provided particles are promptly expelled from its ablated position in the time scale of several 10 μs. These observations give a reasonable explanation for the difference between the measured pellet ablation position which is estimated by the H_α emission light and the effective particle deposition profile by Thomson scattering measurement.

2. Time evolution of the plasmoid drift

Time evolution of the plasmoid drift is simulated by combining the pellet ablation/deposition code; HPI2 with magnetic field line tracing calculation. A simulation results of the temporal plasmoid evolution is shown in Fig. 1. The red and blue lines show field line which trace from the pellet ablated position and barycenter of the pellet plasmoid expanding along the field line with the $\nabla \mathbf{B}$ drift transport, respectively. Time evolution of the averaged plasmoid density, pressure and velocity are shown in Fig. 2. Since the drift velocity (~5 km/s) is significantly higher than the pellet injection velocity (~1 km/s) although it is shortly (< 50 μs) damped due to a charge compensation inside the plasmoid by the rotational transform, there is large displacement to the outboard side before expanding along field line. This simulation can explain the drift displacement, time scale and plasmoid density of the experimental observations.

References

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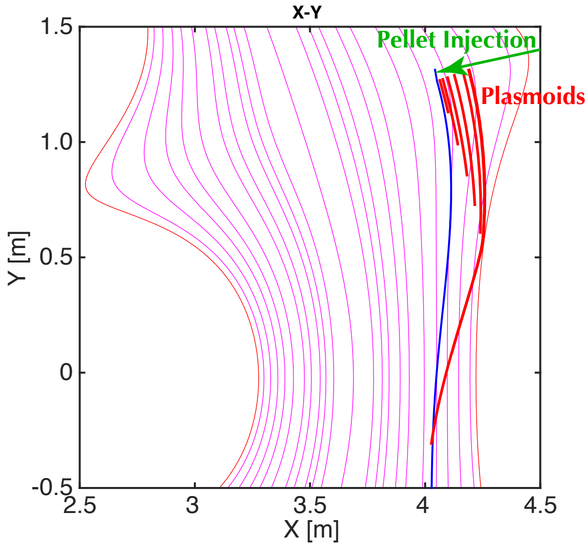

Fig. 1 Time evolution of the plasmoid drift. Red lines denote barycenter of expanding plasmoid every 10 μs. Plasmoid drift is stopped after 60 μs.

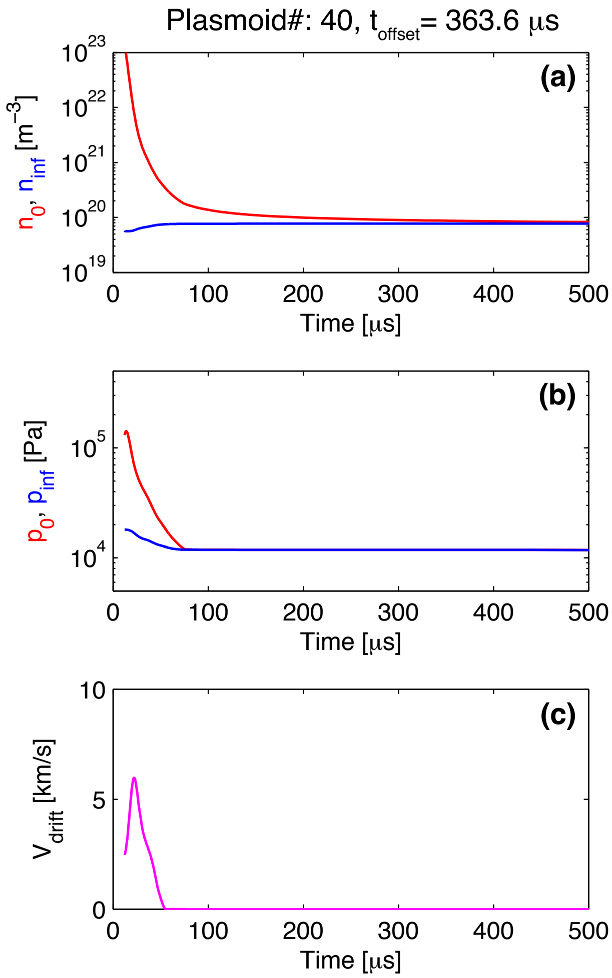

Fig. 2 Time evolution of the averaged plasmoid parameters. (a) plasmoid and back ground plasma density, (b) plasmoid and back ground plasma pressure, and (c) plasmoid drift velocity.