§32. Geometrical Effects on Pellet Ablation

Ishizaki, R., Nakajima, N., Parks, P.B. (General Atomics)

Refueling is one of essential methods in order to control plasma density and sustain steady state plasmas. A gas puffing has been successful for building and sustaining a plasma density in an experimental system of past generation. However, in a large scale experimental system, e.g., LHD, the plasma sources induced by the gas puffing are strongly localized near the plasma surface. Then, a pellet injection is placed as a fundamental tool and has been mainly used to obtain a high density plasma and control a density profile [1].

When a pellet is injected into torus plasma, it is essentially heated by electrons in the bulk plasma along B-field. Then, physics of the pellet ablation is different from one in so-called ablation models assuming isotropic heating [2]. In order to investigate such a geometrical effect, two dimensional simulation is carried out, where the cylindrical geometry (r, θ, z) is used. A spherical pellet is placed at the center of it and the plasma heat flux propagates along the magnetic field (z) to the pellet. Physical quantities are assumed to be uniform in the θ-direction. No effect of the magnetic field (except for setting the direction of the electron heat flux) is included. The contrast in Fig. 1 shows the isodensity contour at 8 μs. The parameters used as an initial condition are the pellet radius $r_p = 2$ mm, electron temperature $T_{e\infty} = 2$ keV and number density $n_{e\infty} = 10^{20}$ m^{-3} in the bulk plasma. $T_{e\infty}$ and $n_{e\infty}$ are assumed to be constant through temporal evolution. The white region at the center represents the pellet. It is clear that the pellet changes to the shape as a disk in temporal evolution. This fact comes from nonuniform ablation pressure on the pellet surface. The heat flux around the pole of the pellet ($r = 0$) is almost completely absorbed before it reaches the pellet surface. On the contrary, the heat flux around the equator of the pellet could penetrate the cloud before its significant absorption. Then, the ablation pressure at the pole becomes much higher than one at the equator due to the difference of deposition energy from the heat flux. The difference of these pressure is found to reach more than 10 MPa in the simulation. The pellet is possible to deform by such an ablation pressure because it is known that solid deuterium behaves like incompressible fluid in the pressure more than 0.5 MPa [3], However, since this calculation dose not include thermal conduction, viscosity and elastic-plastic effect in the pellet, calculation by an advanced code including those effects is required in order to predict more detail about the deformation. The pellet size is reduced as the ablation proceeds, and finally ablation is almost completely reduced up to 110 μs. A spherical shape contrast produced around the pellet ($r, z \simeq 10$ mm) shows the shock wave driven by ionization. Since ionization is most induced around there, neutral particles loose their energy. Then, their kinetic and internal energies are hard to increase compared with ones in other regions. Ionization reduces the expansion of the ablation cloud and a shock is driven.

Two dimensional fluid code treating with a neutral in various states of matter and plasma simultaneously, has been developed to investigate the pellet ablation with atomic processes and nonuniform heating from bulk plasmas. It is shown that a stationary shock wave is induced by ionization. The pellet is deformed by nonuniform ablation pressure on its surface coming from the nonuniform heat flux along B-field, so that the pellet life time could be shorter than one in spherical symmetry case assumed in the ablation models.

REFERENCES

[1] L. R. Baylor et al., Nucl. Fusion **32**, 2177 (1992).
[2] P. B. Parks and R. J. Turnbull, Phys. Fluids **21**, 1735 (1978).
[3] P. C. Souers, *Hydrogen Properties for Fusion Energy* (University of California Press. Ltd., Berkeley and Los Angeles, 1986), p. 85.

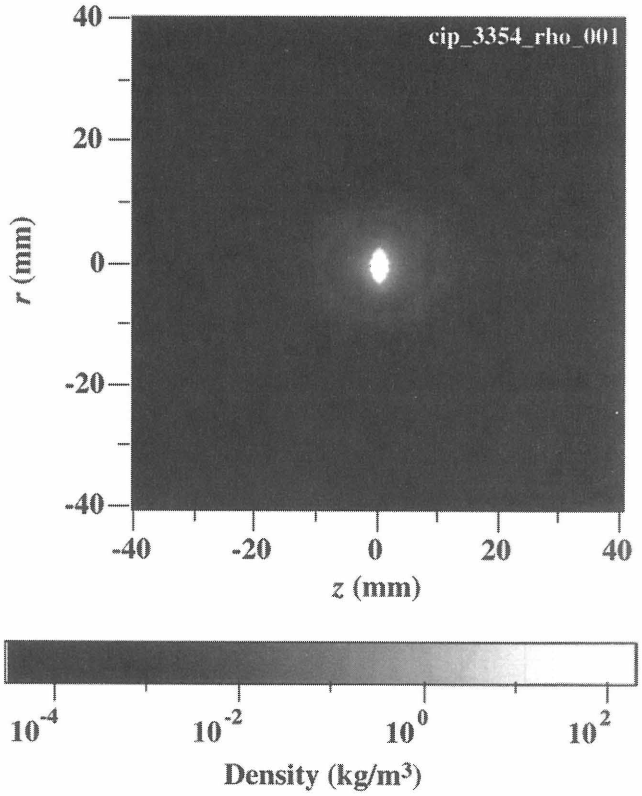

FIG. 1: Isodensity contour on the r-z plane in the cylindrical symmetry at 8 μs.