*29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, P-4.081 (2002)*

THE ROLE OF GRAD B-INDUCED DRIFTS ON PELLET ABLATION

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1. Introduction

In recent years, several experiments were performed where pellets were injected from the high field side of tokamaks. This method of injection turned out to be more effective than injection from the low field side. A possible explanation of this phenomenon may be the grad B-induced drift of the ablated material in the low field side direction. Such drift transport ablated particles from the locus of ablation on a time scale comparable with the pellet lifetime, changing deposition profile and fueling efficiency.

However, the effect of drift on the ablation rate is not so obvious. As was shown in [1] by running the LLP code by ignoring drift phenomena [2], the penetration depths obtained in the ASDEX-Upgrade both for low and high field side injections can be predicted by the same code with reasonable accuracy.

In the LLP code, neutral and ionized gas expansion, ionization, magnetic confinement, collisional energy transfer, radiation losses, electrostatic and magnetic shielding are taken into account. For a given set of background plasma and pellet parameters, and magnetic flux surface topology, this approach allows the determination of the cloud evolution and the ablation rate history in a self-consistent manner. In this model, the pellet is shifted from flux tube to flux tube, the latter being defined by the local ionization radius, and kept there stationary for the local residence time given by $\tau_{res} = 2r_i/v_p$, where r_i is the local value of the ionization radius and v_p is the pellet velocity.

The code consists of three major modules. The first module calculates the perpendicular expansion dynamics and the resulting ionization radius. The second module calculates the longitudinal expansion in a channel of radius r_i, the dumping of energy by the incident energetic plasma particles and the resulting ablation rate in a self-consistent manner. In both these modules a Lagrangian coordinate system is used. These two modules are operated in an iterative manner. A third module controls the iterative procedure and the reduction of the pellet mass while it moves along its trajectory.

In the present paper a model for the grad B–induced drift of the ablated particles for the case of low field side injection is developed and included into the LLP code. Such an approach allows not to consider the 'precooling' of background plasma in the regions ahead of pellet, because the directions of the pellet motion and drift are opposite. Drift motion was included in a following manner. In the second module an accelerating motion was introduced in the LFS-direction. The acceleration was given by $a = 2c_s^2/R \cdot (n_h - n_a)/n_h$ [3], where c_s denotes the local ion sound velocity and R the major radius of the tokamak considered, n_h and n_a represent the heavy particle and neutral densities, respectively. The multiplier assures zero drift for neutral particles surrounding the pellet and a continuous transition to a full acceleration of the fully ionized wing. The local density in the Lagrangian cells was reduced proportionally to the mass shift caused by the drift.

2. Results

The main result obtained is the significant reduction of the ablating cloud size in the direction along magnetic field lines in comparison with the result of scenario calculations by means of original LLP code, i.e. without drift (Fig. 1).

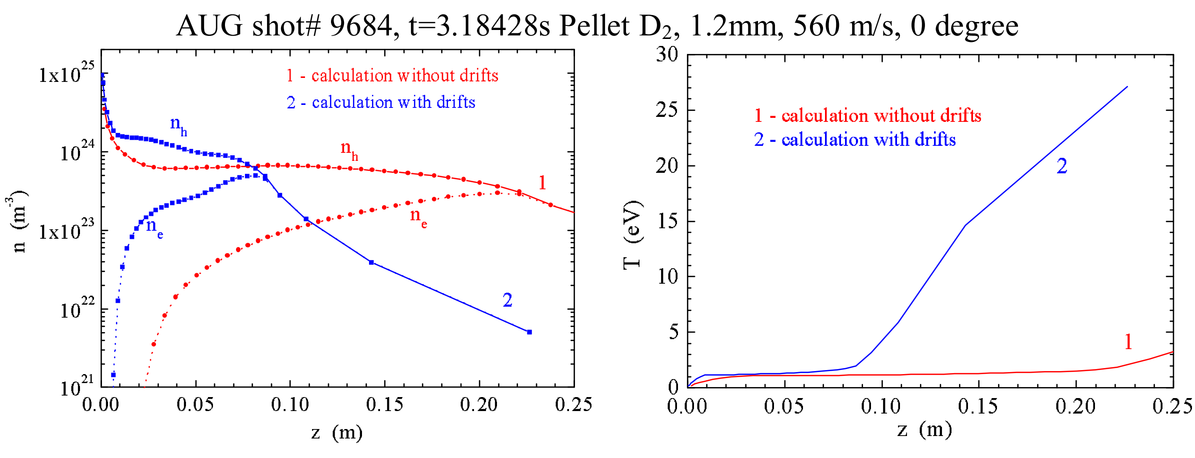

Figure 1. Density (left) and temperature (right) profiles along magnetic field lines at the point of ablation rate maximum (see Fig. 2) without drift (red lines) and with drift (blue lines). It should be noted that in the case without drift cloud propagates up to 6 meters, but only inner region is shown to provide a comparison with calculation with drift.

In the presence of drift, the cloud length along magnetic field lines is defined by the drift motion. Indeed, a time necessary for complete shift from a certain flux tube with the radius r_i may be estimated as $\tau_d = \sqrt{r_i R}/c_s$. For example, for the parameters $r_i = 0.9$ cm,

$T = 1.5\,\text{eV}$ τ_d is equal to $14\mu s$, while the residence time for a considered flux tube is $33\mu s$. So one can conclude that the drift motion plays an important role in longitudinal profile formation. In contrast, the influence of the drift on the ablation rate and the penetration depth is rather modest, see Fig 2.

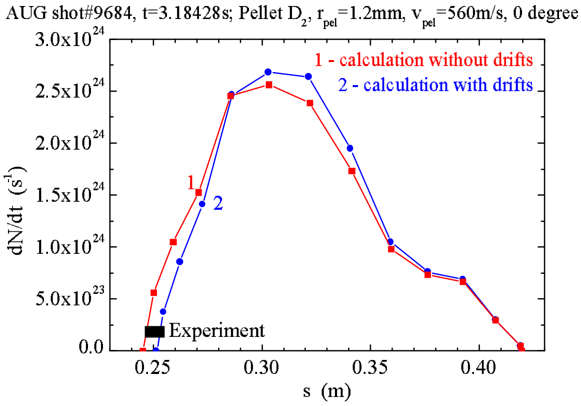

Figure 2. Ablation rate variation along the pellet path for the cases with and without drift.

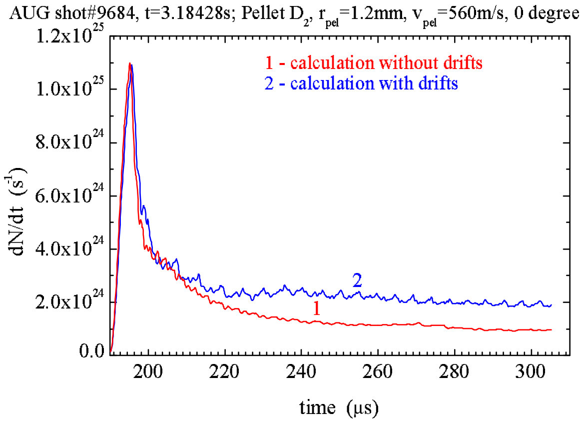

Figure 3. Self-consistent value of ablation rate in a representative flux tube.

In the presence of grad B-induced drift, if the plasma parameters are constant in the whole domain ahead of the pellet and the change of the ablation rate due to the continuous reduction of the pellet size is ignored, the longitudinal profiles in the subsequent flux tubes and thus the ablation rate should approach asymptotic, i.e. stationary, values. In this state, the number of particles 'peeling-off' from the pellet becomes equal to the number of particles removed from the flux tube by drift. To verify this hypothesis, calculations were performed for physical times up to several τ_{res} and the corresponding profiles along the flux tubes were examined (Fig. 3). They were found to be stationary.

Based on this fact an alternative drift model is put forward. In this model, the neutral cloud surrounding a pellet is assumed to move together with the pellet unimpaired by the magnetic field. For the ionized part of the cloud two alternatives are considered: a) the ionized particles are instantaneously confined (stopped) by the magnetic field, i.e., in a reference frame attached to the moving pellet they move backward with a constant velocity $v_R = v_p \dfrac{n_h - n_a}{n_h}$; b) the ionized particles drift with the acceleration $a = 2\dfrac{c_s^2}{R}\dfrac{n_h - n_a}{n_h}$ to the low field side direction. The first condition corresponds to the complete absence of the polarization electric field in the cloud, i.e. short circuiting by the background plasma. On the contrary, the second approach corresponds to the absence of the short circuiting effect of the background plasma. Calculations according to these two alternatives give the same ablation rate profiles and penetration depths (Fig. 4), while the ionization length is in the case b) shorter than in the case a) (see Fig. 5). The explanation is the same as given above: in the case a) the time necessary for the complete shift from a certain flux tube is residence time τ_{res}, while in the case b) it is τ_d, which is shorter.

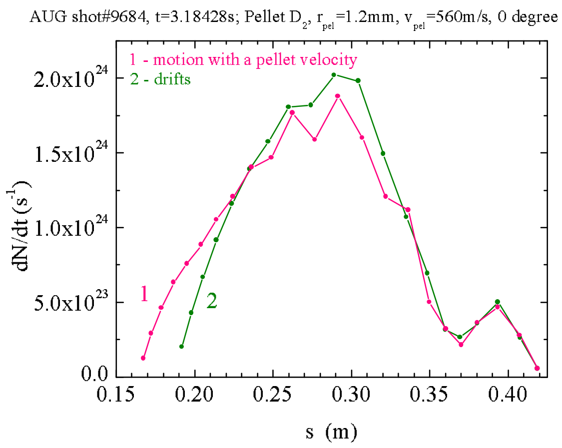

Figure 4. Ablation profiles for alternatives a) and b).

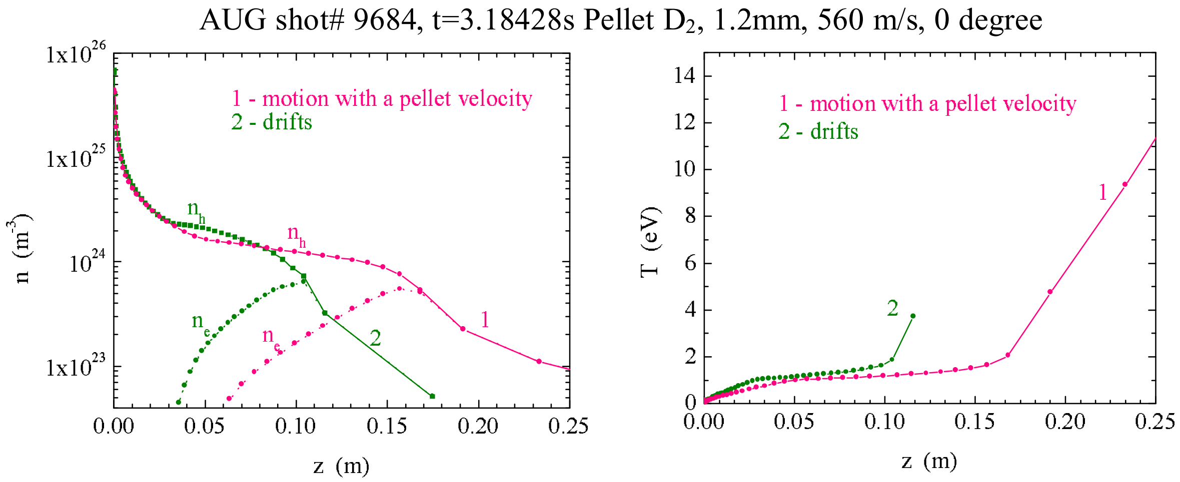

Figure 5. Density (left) and temperature (right) profiles along magnetic field lines at the point of ablation rate maximum (see also Fig. 4) without drift (pink lines) and with drift (olive lines).

3. Conclusions

In the case of LFS pellet injection, the impact of the grad B-induced drift on the ablation rate of the pellet is rather modest. The width of the ionized part of the cloud in the B-parallel direction is significantly shorter than in the case without drift.

Acknowledgments

This work was supported by Russian Foundation for Basic Research (Grant 01-02-16651, Grant 02-02-06062) and Russian Ministry of Education (Grant T00 – 7.4 – 2772).

References

[1] Veselova, I.Yu. et al., Proc. 28th EPS Conf. Plasma Phys. Cont. Fus. P2.059, 2001.
[2] Lengyel, L.L., et al., Nucl. Fusion 39 (1999) 791.
[3] V.Rozhansky, et al., Control. Fusion, Vol.37 (1995) 399-414