NON-LOCAL PARTICLE DEPOSITION AND PELLET WAKE EVOLUTION IN PELLET-FUELLED TOKAMAKS

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A pellet crossing a sequence of flux surfaces continuously releases neutral particles whose initial expansion velocity is considerably larger than the pellet flight velocity. The particles are ionized and confined to magnetic flux surfaces at some distance from the pellet location. The pellet thus traverses its own cloud. The particles confined to individual flux surfaces expand along the magnetic field lines, forming a characteristic wake whose state parameters are considerably different from those of the background plasma [1]. At the same time, the portion of the neutral cloud ahead of the pellet may form an effective buffer layer shielding the pellet from the incident plasma particles [2].

A numerical code is being developed that describes the time development of the state parameters of the wake behind the pellet and those of the buffer layer ahead of it (size, expansion velocity, temperature, density, bulk ionization degree, etc.) in a self-consistent manner.

The code consists of three parts: an ablation routine based on the neutral gas plasma shielding model of Houlberg et al. [3], the MHD cloud expansion model that computes the expansion and ionization of the pellet particles released at individual flux surfaces [1] and, finally, a routine that calculates the pellet mass fractions deposited at neighbouring flux surfaces in front of and behind the pellet during the residence time of the pellet at any particular flux surface [4]. The wake evolution is thus computed in the following manner: The pellet is advanced to a flux surface of given local plasma parameter values. The local ablation rate is determined [3], being assumed to remain constant during the residence time ($\tau_{res} = \Delta r / v_{pel}$, Δr being the mesh size along the pellet path, it shall be referred to hereafter as flux tube width) of the pellet at the flux surface considered. With the mass source strength (mass deposition rate) thus prescribed, the time evolution of the ablatant cloud formed by the pellet particles locally released is calculated [1]. Next, the ionization ($\approx$ confinement) radius is determined, and the pellet mass locally released is distributed over the flux tubes affected [4] in proportion to the respective volumetric fractions. Once the mass increment ΔM is determined for each flux tube piercing the cloud ($\Delta M \equiv 0$ for all flux tubes outside the cloud boundaries) together with the associated temperature and density increments ΔT and Δn, the state parameters of the plasmoids confined to flux tubes in front of and behind the pellet location are updated for the time increment (represented by the residence time) by means of the cloud expansion routine. The pellet is than advanced to the next flux surface and the procedure is repeated. At some flux surface the pellet mass vanishes (end of the pellet lifetime) and, as of this moment, the calculation of the wake evolution is continued with zero mass source strength specified.

Representative results stemming from preliminary calculations are shown in Figs. 1 and 2. In this scenario, a D_2 pellet 3 mm in dia. is injected into a plasma of $a = 1.2\ m$ radius with

$$T(r) = T_1 + (T_o - T_1)[1 - (r/a)^2]^2,$$
$$n_e(r) = n_1 + (n_o - n_1)[1 - (r/a)^2]^{1/2},$$

$T_o = 3.2$ keV, $T_1 = 0.05$ keV, $n_o = 5 \times 10^{19}\ m^{-3}$, and $n_1 = 5 \times 10^{18}\ m^{-3}$. The assumed pellet velocity v_p is 2 km/s.

Figure 1 shows the plasmoid length measured along the magnetic field lines (wake width) as a function of the radial coordinate (pellet flight path) for a sequence of time instants. At time $t = 0$ pellet ablation begins at the plasma periphery ($r = a = 1.2\ m$). As time goes on, the mass source (pellet) moves towards the plasma centre, and both the longitudinal (r) and lateral (z) dimensions of the wake steadily increase. The ablation is complete at $t = 0.48$ ms (the duration of the pellet lifetime, the corresponding length of the particle deposition region is, as can be seen, 96 cm). Figure 2 shows the time evolution of the plasmoid density along the centre line of the wake produced by the flying pellet. The pellet location is marked by the density maximum at any particular time instant. After the pellet ablation is completed, the peak density values continuously decrease (not shown in this plot).

[1] L.L. Lengyel, Nucl. Fusion **29** (Jan.-Febr. 1989), see also Phys. Fluids **31** (1988), 1577.

[2] L.L. Lengyel and P.J. Lalousis, Proc. IAEA Techn. Comm. Meeting on Pellet Injection, Gut Ising, Fed. Rep. Germany, Oct. 24-26, 1988.

[3] W.A. Houlberg at al., Nucl. Fusion **28** (1988), 595.

[4] P.J. Lalousis and L.L. Lengyel, in Contr. Fus. Pl. Heating (Proc. 15th Eur. Conf. Dubrovnik, 1988) **12B**, Part I, Europ. Phys. Soc. (1988) 286.

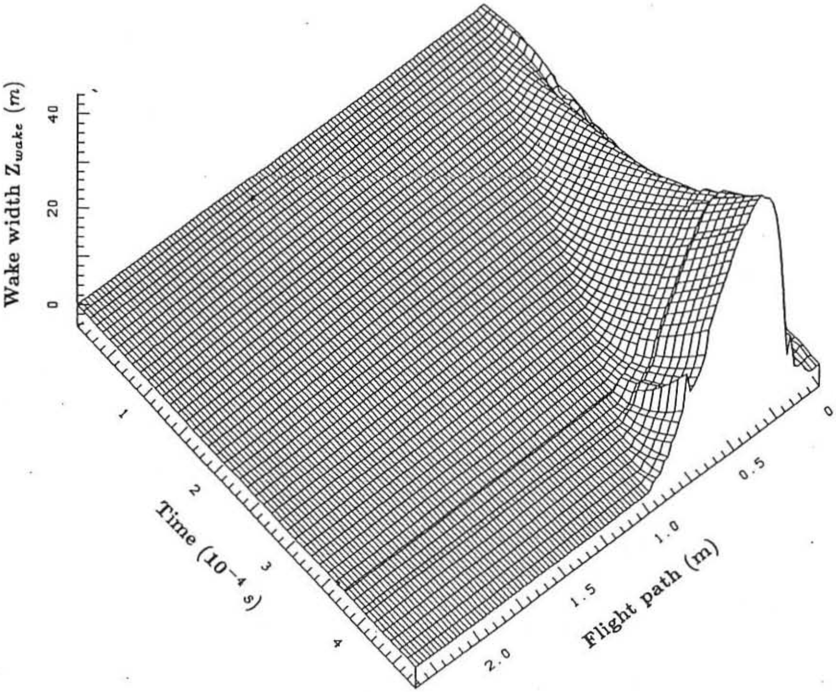

Figure 1:
Pellet wake width measured along the magnetic field lines as a function of pellet path and time.

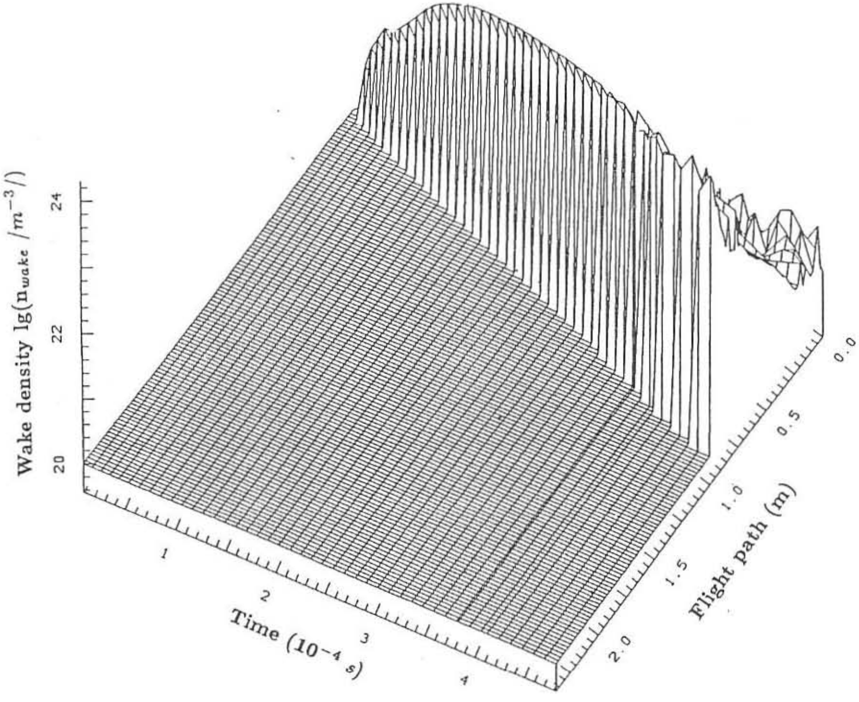

Figure 2:
Plasmoid density in the pellet wake as a function of pellet path and time.