1-dim Collisional Radiative impurity transport code with internal particle source for TESPEL injection experiments in RFX-mod2.

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Introduction

Clear evidences that, due to a strong outward impurity convection, impurity core penetration is prevented have been found in the RFX-mod RFP device. A comparable convection of the main gas has not been observed [1] so that a favorable situation with peaked or flat density profiles and hollow impurity profiles is produced.

Analysis of impurity transport relies on best reconstruction of impurity emission pattern with a 1-dim Collisional-Radiative code in which the radial impurity flux is schematized as a sum of a convective and a diffusive term [2,3]. The diffusion coefficient D and the velocity V, which are input to the simulation are varied until the experimental emission is reproduced. While the steady-state impurity profile is determined by the ratio V/D (peaking factor), the discrimination between D and V requires transient perturbative experiments.

The experimental evidence of impurity outward convection in RFX-mod Single Helicity helical regimes occurring at high plasma current (I>1.2 MA) has been found in Li and C solid room temperature pellets experiments [4], Ne doped D2 cryogenic pellet injection, Ne gas puffing and Ni LBO experiments [5](W LBO didn't show accumulation effects too). Similar D and V have been found for all the considered impurity species, without strong dependence on mass/charge.

RFX-mod is now being upgraded to RFX-mod2, aiming at reducing secondary tearing mode amplitude which affects the performances of the improved confinement Single Helicity states [6]. In order to perform more detailed analysis of the impurity transport inside the outward convection barrier, the impurity source should be further inside the plasma. With this aim, Ni-tracer encapsulated solid pellet (Ni-TESPEL) experiments are foreseen in the new device [7]. The available 1-dimensional, time dependent Ni Collisional Radiative code, used to reconstruct experimental Ni emissions in RFX-mod [3] has been upgraded in preparation of such experiments in RFX-mod2 including the possibility of a Ni source (boundary condition) inside the plasma, placed in a time dependent position.

The solid pellet injector already used in RFX-mod to inject C and Li solid pellets, has been adapted to inject TESPEL in RFX-mod2 (0.7/0.9 mm polystyrene ball with Ni powder inside) with velocity up to 300 m/s. In this contribute after a brief description of the pellet injector, simulations of the pellet ablation [8] in RFX-mod2 plasma will be presented and the modified Ni 1-dimensional transport code described.

Solid pellet injections in RFX-mod2

In RFX-mod2 TESPELS will be injected through a room temperature pellet injector (RTPI)[9], sketched in Fig 1. Each TESPEL is contained in a sabot pneumatically accelerated along a barrel by a driver gas until it reaches a hollow bumper where it is stopped; the TESPEL continues its free flight with the velocity reached at the sabot-bumper impact. Once the pellet enters the chamber its trajectory will be monitored by a system based on two absolutely calibrated 2-D Position Sensitive Detectors (PSD) installed on the pellet injector section [10]. They collect the radiation coming from the ablated particles surrounding the pellet, the *ablation cloud*, providing a measurement of the coordinates of the pellet's radial trajectory which is then used by the transport code.

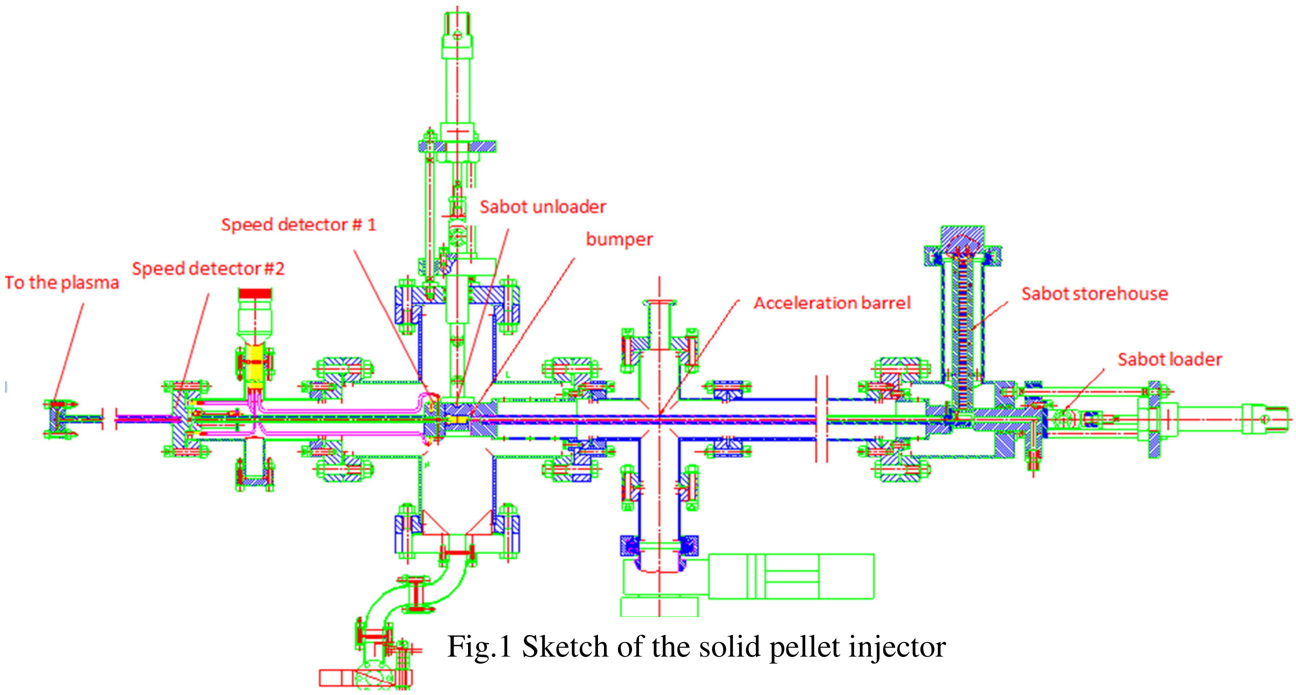

Fig.1 Sketch of the solid pellet injector

The RTPI and the sabots used in RFX-mod to inject with a velocity up to 200 m/s cylindrical pellets bigger than TESPEL [4] have been modified to provide reliable operations.

To avoid the accidental escaping of the TESPEL ball from the carrying sabot a fine tuning of pneumatic actuators has been obtained for a smoother loading of the sabot in the injector; the diameter of the hole in the sabot hosting the TESPEL has been optimized to prevent TESPEL being lost when the sabot is stopped at the bumper . The sensitivity of the two gate optical detectors used to measure the TESPEL speed will be increased by replacing the led light sources with stronger diode lasers. Modification of the sabots could allow increase of the pellet injection speed. The speed is nearly equal to the velocity reached by the sabot before hitting the bumper. Since on the sabot is acting a constant force due to gas pressure, neglecting sabot friction with the pipe, the final sabot velocity is: $V_f = \sqrt{\frac{2LpA_s}{m}}$, where L is acceleration path length, p is the gas pressure, A_s, the cylindrical sabot section, m its mass. A higher speed at fixed pressure could then be reached by reducing the sabot mass. It is foreseen to increase the speed up to about 300 m/s by drilling a hole on the back surface of the sabot, while maintaining the sabot material (light and resistant peek) and external shapes (compatible with the sabot loader and responding to stability requirements).

The 900microm polystyrene + 100 microm Ni ablation has been simulated following [8], in a typical scenario of T_e,n_e for RFX-mod and the results have been reported in Fig 2: the polystyrene shell is completely ablated within r/a =1 and r/a=0.6,and Ni reaches about r/a=0.2. Ni is deposited inside the outward convection barrier (showed in figure: in red in the multiple Helicity scenario, in green in the Single Helicity one) and it will be possible to better probe the Ni transport in the central region.

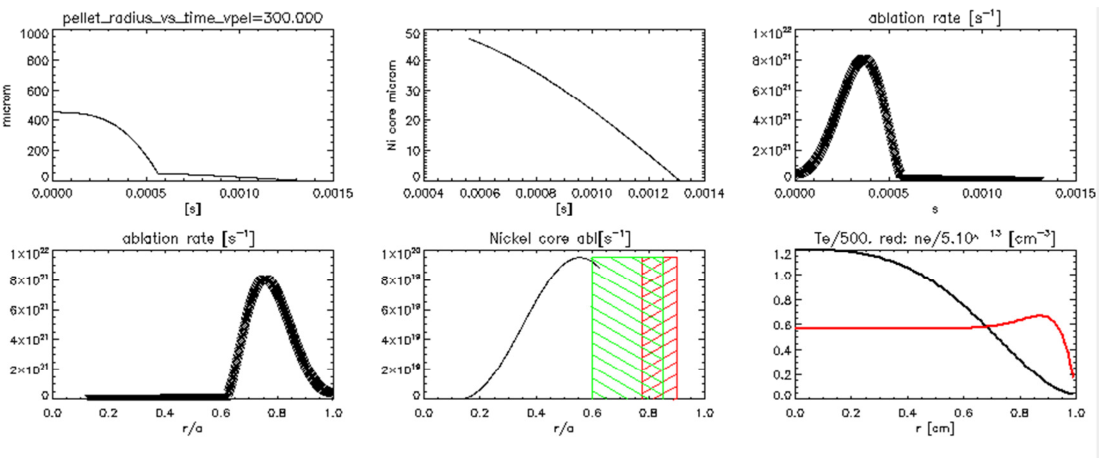

Fig.2 Simulation of ablation of the polystyrene shell and of the Ni core of a TESPEL injected with a velocity of 300 m/s and 'typical' T_e and n_e in RFX-mod.

Ni 1-dimensional collisional-radiative code

The impurity transport results of Ni (Z = 28) contained within the TESPEL will be reproduced with a one-dimensional time dependent collisional–radiative impurity diffusion model. The model solve the impurity continuity equation system

$$\frac{\partial n_z}{\partial t} = -\frac{1}{r}\frac{\partial \Gamma z}{\partial r} + n_e\, n_{z+1}\alpha_{z+1} + n_e\, n_{z-1}S_{z+1} - n_e\, n_z(\alpha_z + S_z) - n_n\, n_z R_z^{cx} + n_n\, n_{z+1} R_{z+1}^{cx}$$

$$Z = 0,..28$$

where Γz is the radial flux density (positive when directed outwards) of the ions of charge $+z$,n_z is the corresponding ion density, S_z is the ionization rate coefficient , α_z is the recombination coefficient ,R^{cx} is the charge exchange ,n_n the neutral Hydrogen density. The impurity flux density Γ_z is expressed as the sum of a diffusive and an outward convective term:

$$\Gamma z = -D \frac{\partial n_z}{\partial r} + v\, n_z$$

where D and v are the radially dependent diffusion coefficient and outward convection velocity, respectively, both assumed to be independent of the charge of the ions.

The collisional–radiative model assumes as inputs electron,ion temperature, electron density radial profiles and time evolutions based on experimental measurements. The diffusion coefficient D and convective velocity v, are assumed as inputs to the code and are varied to best reproduce the experimental emission including line, continuum soft x-ray (SXR) radiation and total radiated power in the RFX-mod2 plasmas [3,4,5].

Transient experiments such as Laser Blow Off (LBO), solid pellets, are necessary to characterize the particle transport as they allow discrimination between the diffusive and convective terms of the fluxes. In contrast, from a steady-state transport analysis for both impurities and deuterium only the peaking factor v/D can be determine. An impurity neutral influx is also considered as input to the code: in the case of LBO the source is at the plasma edge, the time dependence being deduced from the experimentally available time evolution of lines from low ionization stages, in the new version of the code the possibility of neutral particle source inside the plasma has been implemented, representing the ablation of the TESPEL, as discussed above. The source position at each time corresponds to the path of the solid pellet inside the plasma. The presence of a transient particle source inside the plasma will allow to better probe the convection and the diffusion coefficient inside the outward barrier.

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