NUMERICAL SIMULATION BY A RANDOM PARTICLE METHOD OF DEUTERIUM-TRITIUM FUSION REACTIONS IN A PLASMA

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Abstract. One of the goals of the futur International Thermonuclear Experimental Reactor is to obtain fusion reactions between two isotopes of hydrogen in a confined plasma. We study here one of the possible reaction: T(d,n)^{4}He, between Deuterium (D) and Tritium (T) ions producing an α particle and a neutron (n) with the following scheme:

$$D + T \to \alpha + n + 17,59 \text{ MeV}.$$

In [2], Dellacherie and Sentis introduced a kinetic model to describe nuclear collisions, which writes in a spacially homogenenous context

$$(1) \qquad \begin{cases} \dfrac{\partial f_D}{\partial t} = -P_D(f_D, f_T), & \dfrac{\partial f_T}{\partial t} = -P_T(f_D, f_T) \\ \dfrac{\partial f_\alpha}{\partial t} = G_\alpha(f_D, f_T), & \dfrac{\partial f_n}{\partial t} = G_n(f_D, f_T), \end{cases}$$

where $f_a : \mathbb{R}^+ \times \mathbb{R}^3 \mapsto f(t, x, v) \in \mathbb{R}^+ \geq 0$, $a \in \{D, T, \alpha, n\}$, corresponds to the number densities in ions Deuterium, ions Tritium, neutrons, and α particles respectively at time $t \in \mathbb{R}^+$ at velocity $v_a \in \mathbb{R}^3$. In (1), operators $P_a(f_D, f_T)$, $a \in \{D, T\}$ and $G_a(f_D, f_T)$, $a \in \{\alpha, n\}$ are integral operators (on the domain $\mathbb{R}^3 \times \mathbb{S}^2$), which modelize respectively the disappearing of a D or T particle and the creation of a neutron or an α particle.

Because of the large number of dimensions, the discretization of equations of the model (1) by a deterministe method such a finite differences method is too expensive. We propose and we justify here a numerical method to solve model (1) based on a particle method and a Monte-Carlo simulation of the integral operators. This method is adapted from random particles method for solving Boltzmann equation [3].

The proposed algorithm is validated with the use of explicit solutions of the kinetic model obtained by replacing the fusion cross-section of operators P_D, P_T, G_n and G_α by a Maxwellian cross section.

Keywords: Kinetic model, particle method, Monte-Carlo simulation, Boltzmann operators.

Mathematics Subject Classifications (2000): 35Q20, 65C05, 65M75, 65Z05, 65R20, 45L05

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