Avalanche effect: The necessary condition for auto-sustained fusion process in Hydrogen-Boron fuel

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Abstract

The main goal of the present work is the investigation of the "chain reactions" effect occurring during the $p^{11}B$ (Hydrogen-Boron) nuclear fusion process, in two different schemes (a non-thermal and a thermal one). The main advantage of the Hydrogen-Boron ($p^{11}B$) fusion [1] is the production of three alphas with total energy of 8.7 MeV, which could enhance the alpha heating effect of the species (protons, Boron) and allow the development of "clean" devices for power generation, avoiding neutron radiation. The "chain reactions" effect described also as the avalanche effect [2] is the necessary condition for "fast ignition enhancement" of fusion process in the medium by continuous elastic central collisions, where proton and ^{11}B particles gains energy from the produced alpha particles. This alpha heating effect increases the medium species energy in an auto-sustained operation, as well as the gain of the output fusion power.

The "chain reactions" effect in the non-thermal scheme [3, 4], is ignited by energetic protons (~10^9 cm/sec) interacting with a low temperature Hydrogen-Boron medium. The produced alpha particles from the nuclear fusion reaction, transfer energy to the low energy particle of the medium and generate relatively high energy protons with energies corresponding to the maximum $p^{11}B$ fusion cross section (~ 600 keV). This process improves the fusion reaction probability and produces a new cascade of energetic alphas. The protons energy losses due to frictions with the medium electrons (stopping power) is sustained up to 600 keV, applying a periodical pulsed external electric field. Evaluation on the stooping power enables the optimization of the fusion power as a function of the medium electron density. The result of the aforementioned operation is an important enhancement of the alpha particle production and consequently of the energy transfer to protons which in turn improves the fusion energy output.

In the thermal scheme the "chain reactions" effect is investigated numerically, calculating the temporal evolution of the $p^{11}B$ plasma parameters (density, temperature and reaction rate) with initial density ~ 10^{19} $m^{-3,}$ and relatively low initial temperature of the order of 30 keV, using a multi-fluid, global particle and energy balance code [5, 6], including collisions between all species (p, B, e, alpha). The code allow to study the temporal production of alphas in the $p^{11}B$ plasma, as well as the temporal energy transfer from the alphas to the plasma ions. The latter increases the ions (p, ^{11}B) initial temperatures to values corresponding to the optimum value of the cross section (600keV) and maximizes the reaction rate (RR). The temporal evolution of the RR enables the definition of the necessary time interval for the appearance of strong alpha heating effect, which generates a "fast ignition enhancement" of fusion process, until the fuel depletion. An important numerical result is that the effect of the "fast ignition enhancement" of the RR, is initiated when the density of the produced alphas in the plasma is approximately one order of magnitude lower than the initial plasma ion density.

The analysis of the two above mentioned schemes shows important physical process similarities with emphasis on the "chain reactions" effect [or avalanche effect] which is proved to be the necessary condition to ignite an auto-sustained fusion process in the $p^{11}B$ fuel. The important increases of the alpha density enables to overcome the energy losses of the species in the fusion medium through the increase their temperature up to the optimum cross section values for fusion

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