Effect of Nuclear Elastic Scattering on Neutral Beam Injection Heating in Thermonuclear Plasmas

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An intense neutral beam injected into thermonuclear plasmas plays important role in various stages of fusion reactor operations. The beam particles slow down, deposit most of their energy via Coulombic collisions, and create a tail (non-Maxwellian component) in velocity distribution function of the same ion species as the one injected. It is well known that for suprathermal ions, the Nuclear Elastic Scattering (NES) by thermal ions contributes to the slowing-down process. According to the recent scaling up of the fusion experimental devices, the use of beam energy more than 1 MeV is considered. In this case, the NES effects on the slowing down process of injected beam particles may be important to understand device performance during plasma heating operations. The purpose of this paper is to quantitatively estimate the NES effect on neutral-beam-injection (NBI) plasma heating.

The NES is a non-Coulombic, large-energy-transfer (LET) scattering process. Devany & Stein[1] first pointed out the necessity of taking account the contribution of the nuclear-forces, including their interference with the Coulomb process, to ion-ion scattering, and presented an expression for the energy loss rate of fast ions due to the NES. In their expression, however, thermal motion of the background ions was neglected (background ions were assumed to be stationary), thus effect of the large-angle nuclear collisions which scatter the slowing-down ion itself up to the higher energy range, i.e. LET up-scattering effect, is not incorporated. Recently we have derived the energy loss rate of high-energy ions due to the NES, including the LET knocking-up of background ions from thermal to higher energy range[2]. On the basis of the derived expression, we have estimated the NES effect on the fraction of beam energy deposited to ions. In this paper we further estimate the NES effect on the penetration length of injected beam and the in-flight fusion reaction rate coefficient of suprathermal beam ions. It is shown that when the beam energy is higher than 1 MeV, the NES effects on NBI heating becomes appreciable.

[1] Devany, J.J. and Stein, M.L., Nucl. Sci. Eng. **46** (1971) 323.
[2] Matsuura, H., Nakao, Y., Kudo, K., Nucl. Fusion, **39** (1999) 145.