§5. Compact Toroid Injection into Magnetized Plasmas

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In order to investigate the availability of deep fueling into a fusion device by using the compact toroid (CT) injection method, we have carried out the magnetohydrodynamic (MHD) numerical simulation where the CT is injected into the target magnetized plasma region [1]. We have revealed that (1) the injected CT suffers from a tilting instability which is accompanied by magnetic reconnection between the CT magnetic field and the target magnetic field. It leads to supply of the CT high density plasma into the target region, and (2) the penetration depth of the injected CT becomes gradually shorter than that in the case with the null target magnetic field ($B_{\rm target} = 0$), namely the CT is decelerated by the target magnetic field. The deceleration is larger than that predicted by the conducting sphere (CS) model (see figure 1). Therefore, to understand what leads to such a deceleration, the energy conversion of the CT kinetic energy is examined.

In figure 2 the time history of the difference of the CT kinetic energy between cases with and without the target magnetic field ($\delta E_{\rm k}^{\rm CT} = E_{\rm k}^{\rm CT}(B_{\rm taret} = 0.1) - E_{\rm k}^{\rm CT}(B_{\rm taret} = 0)$) is shown. We can see that the CT kinetic energy in the case with the target magnetic field is smaller with time than that in the case without it. This decrease is larger than that estimated by the CS model. From the MHD equations we use, four energy conversion processes which decrease the CT kinetic energy are derived: the compressional heating $\varepsilon_{\rm k\to t}^{\rm c}$, the viscous heating $\varepsilon_{\rm k\to t}^{\rm v}$, the Lorentz force effect, $\varepsilon_{\rm k\to m}$ and the outflow to the target region $\varepsilon_{\rm k}^{\rm CT\to back}$. The time history of the difference of these conversion is also plotted in figure 2. We can see that the difference of the compressional heating is most dominant.

Therefore, when the target magnetic field exists, the CT is more decelerated through the compressional heating. Such compression leads to the increase of the magnetic energy in the target region. Namely, the decreased CT kinetic energy is finally converted to the magnetic energy of the target magnetic field. In this process, not only the magnetic pressure force effect but also the magnetic tension force effect contributes to the energy conversion. On the other hand, since only the magnetic pressure force effect is considered in the CS model, the deceleration of the CT is smaller. In our simulation, however, both ends of the target magnetic field are line-tied on the boundary, which would overestimate the magnetic tension force effect. In order to investigate this effect in detail, the dependence of the CT penetration on the boundary condition should be considered.

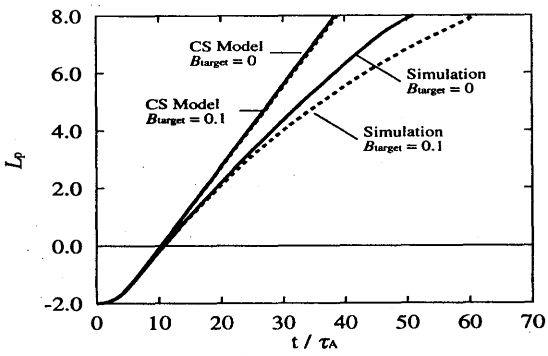

Fig. 1: Time evolution of the CT penetration depth $L_{\rm p}$, which is normalized by half of the CT size.

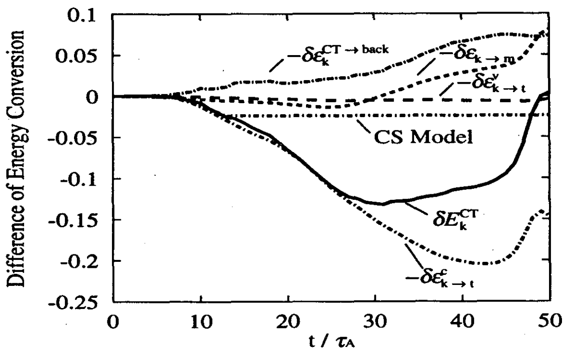

Fig. 2: Time history of the difference of the CT kinetic energy and the energy conversion between cases with and without the target magnetic field.

Reference
1) Suzuki, Y., *et al.*, in Proceedings of the Joint Conference of 11th International Stellarator Conference & 8th International Toki Conference on Plasma Physics and Controlled Nuclear Fusion, ed. Y.Ueda **1**, (1998) 518.