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Optimization of the beam heating and non-inductive current in NBI plasma for long-pulse operation of EAST

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In fusion devices, the first wall will be hit by lost fast ions and release large amounts of impurities into plasmas, which will affect the operation of experiments. Thus, the beam ions needs to be optimized for the safety and long-pulse operation in neutral beam injection (NBI) plasma.
In our research, the beam heating and loss, neutral beam current drive (NBCD) have been numerically investigated by using NUBEAM, ONETWO and TRANSP. The simulation results show that the heating efficiency is improved by optimizing the tangential radius and injected direction. For co-NBI, the heating efficiency is enhanced with the increasing of tangential radius. Moreover, the prompt loss is obviously reduced when the beam injected direction changes from counter-current to co-current. For the plasma with $\langle n_e \rangle$ ~ 3.5*10*^{19} m^{-3} *(f_{GW} ~ 0.45), the heating efficiency is nearly doubled due to this direction optimization. There is good agreement between the experimental neutron amplitude and the calculated neutrons by using TRANSP/NUBEAM. For NBCD, its efficiency increases with the beam power and tangential radius. By changing the beam injected direction from counter- to co-, the efficiency raises nearly two orders of magnitude. Thus, the efficiency is shown to be about 0.02 for a well optimized system on EAST.*
Furthermore, by changing the gapout, the magnetic configuration has been optimized for higher heating efficiency in different collisional plasmas. The simulation results show that the expansion of gapout helps to improve the beam heating efficiency due to the power deposition moving inward in high collisional plasma. Meanwhile, the fraction of trapped particles is decreased.Then the prompt loss and ripple loss of fast ions are reduced. In low collisional plasmas, the gapout needs to decrease to reduce the shinethrough loss and improve the beam heating. Thus, the gapout needs to be optimized based on the collision rate. Moreover, the gapout affects the current profile. The simulation results illustrate the profiles of NB driven current and bootstrap current move inward with the increasing of the gapout. In EAST discharges 101726 and 101731, the only difference in the magnetic equilibrium is the gapout varing from 8.4cm in #101726 to 6.6cm in #101731. After injected similar deuterium beams, the neutron amplitude and the internal inductance li *are both higher in #101726 (gapout=8.4cm) than that in #101731 (gapout=6.6cm) . In the recent long-pulse NBI discharge 104243 ($\langle n_e \rangle$ ~4.010^{19} m^{-3}*) with about 60s, the gapout is about 9cm which is higher than the normal gapout (~ 6-7cm) on EAST. This suggests the bigger gapout is benefit for the long-pulse operation in high collisional plasma.
In the end, since the beam also has influence on the bootstrap current by affecting temperature profiles. Therefore, we optimized the bootstrap current by varing beam energy, density and composition of the plasma for high $_p$ and fully non-inductive discharges in long-pulse NBI plasma on EAST.
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