Energy efficiency of tokamak with neutral beam injection

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Powerful neutral beam injection (NBI) can increase fusion rate essentially in comparison with Maxwellian plasma. This effect increase energy efficiency of the fusion system. In D–T tokamak reactor scaled with DEMO [1], NBI effect is relatively small at *Q* ≈ 10–20. Firstly, fast partical population is lean at NBI power essentially less then fusion power. Secondary, high reactor plasma size do not allow deep penetration of neutral particles into the plasma, if their energies up to 100 keV. Essential effect is possible in fusion system with *Q* ≈ 1 and relatively small plasma radius. Today, tokamak with *Q* ≈ 1 is considered as prospective concept of the fusion neutron generator for hybrid reactor, radioactive waste transmutation, and material tests. Compact neutron source based on spherical tokamak [2] with megawatt power level has commercial advantages.

Fusion power can increase with the increase of aspect ratio and the same radius of the plasma column. In present work, high aspect ratio tokamak (*A* ≈ 5) is considered. In regimes with *Q* ≈ 1, energy efficiency of such a system is estimated by the effect of fusion rate increase driven by fast particles in comparison of the Maxwellian plasma. Fusion power could be maximal at minimal plasma size, also. Integral calculation model [3, 4] includes the relationships of ITER Physics Basis and fast particle Fokker–Planck modeling [5, 6]. The effect of fast particle driven fusion rate increase allows potentially realize *Q* ≈ 1 and neutron yield up to 100 MW in the system with parameters of the existing devices: small radius *a* ≈ 0.8 m, plasma volume *V* ≈ 100 m3, magnetic field *B*0 ≈ 4.5 T, plasma current *Ip* ≈ 3 MA, averaged beta β ≈ 1.5 %, injected particle energy ~ 100 keV. In such regimes, beam relaxation time ~ 3 s, energy confinement time ~ 0.15 s (electrons), electron temperature *Te* ≈ 10 keV.

References

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