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SIMULATION OF ELECTRON POWER LOAD DISTRIBUTION IN SMALL SIZE DIVERTOR TOKAMAK

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Abstract. The divertor electron power load distribution in SSD (Small Size Divertor) tokamak was simulated with B2SOLPS5.0 2D multifluid transport code, including the effects of drifts due to electric and magnetic field gradients. The simulation results demonstrated the following results: change the plasma density, strong influence on poloidal electron heat flux and increasing the plasma density lead to additional electron poloidal heat flux across the separatrix which provides the energy source for confined plasma and increasing in/out asymmetries; the expected reduction in temperature and poloidal electron heat flux in the high-field side plate was obtained in this simulation; the strong "ETB" is located between the position of the maximum and the minimum characteristic length of electron poloidal heat flux; the change of plasma density doesn't influence in the radial electric field which is the order of the neoclassical radial electric field $E^{(NEO)}$. The poloidal $(E \times B)$ drift is larger and led to large in/out asymmetry of poloidal electron heat fluxes to the plates; when activated all drifts ($(E \times B)$ and diamagnetic drifts) leads to a reduction of poloidal electron heat flux to divertor plates and carries the poloidal electron heat flux from inner to outer plate across the main SOL; switch on all drifts influence on the characteristic length of electron poloidal heat flux and ETB formation.

Keywords: poloidal electron heat flux, $E \times B$ drifts, ETB, characteristic length.

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1 Introduction

The increase of electron heat flux expansion of divertor leg would be effective in reducing divertor electron heat flux, and therefore reducing the damage of divertor target (Zhang et al., 2016). Dissipation of electron heat flux in small size divertor SSD tokamak is one of the key challenges for divertor tokamak operation in SSD tokamak. Of particular concern is the mitigation of strongly peaked or asymmetrically distribution, electron power heat load on low-and high-field side target plates. For the designing of SSD tokamak, the temperature heating is large, but tolerable heat load on the divertor target is restricted below the engineering limit 10 MW. m-2 which is a future design target. Handing the huge exhaust electron heat power in SOL/divertor regions is one of the key issues in validating the design parameters of SSD tokamak. In this contribution, we simulate the distribution of electron heat loads in the edge plasma of SSD tokamak. The simulation was performed by the multifluid transport code B2SOLPS5.02D (Bekheit, 2008; Rozhansky et al., 2001) for NBI shots of tokamak SSD. The result of the simulation shows that the expected reduction in temperature and poloidal electron heat flux at high field side was obtained in this work.

2 Simulation Results

SOLPS5.0 2D simulation has been carried out to understand the asymmetries diverter condition which observed in medium and high line density in SSD tokamak discharge. The technical parameters of this modeling are line average density of $n_e = n_i = n = (5, 8) \times 10^{19} m^{-3}$, the plasma current of $50kA$ and toroidal magnetic field B_T of $1.7T$. The temperature heating T^{heating} is $0.59keV$ Ohmic heating in addition to $0.53keV$ NBI heating. The simulation results are:

1. The first result of simulation shows that, the radial distribution of electron poloidal heat flux at low/high line density as shown in Fig. 1. Fig.1 show that, the inner divertor plate (HFS) receives significantly less electron heat flux than the outer divertor plate (LFS). At a high plasma density, the recycling of neutrals at HFS plate is stronger and characteristic electron poloidal heat flux length (Bekheit, 2016) is smaller as shown in Fig. 2, this leads to colder and denser plasma with increased radiation losses for pure plasma as shown in Fig. 3-4. The increasing of plasma density leads to the addition, the electron poloidal heat flux across the separatrix provides an energy source for confined plasma and increasing the in/out asymmetries.

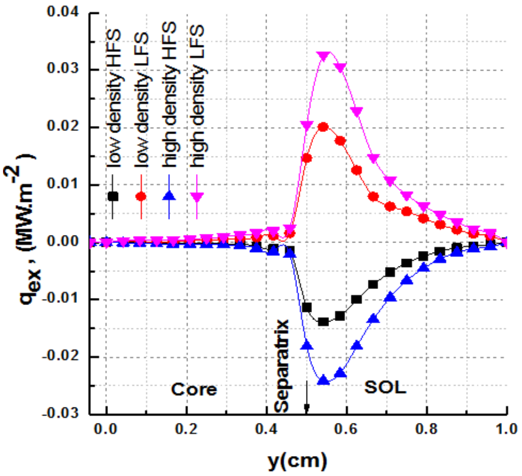

Figure 1: Radial distribution of poloidal electron heat flux of HFS and LFS plates of SSD tokamak at low/ high line density

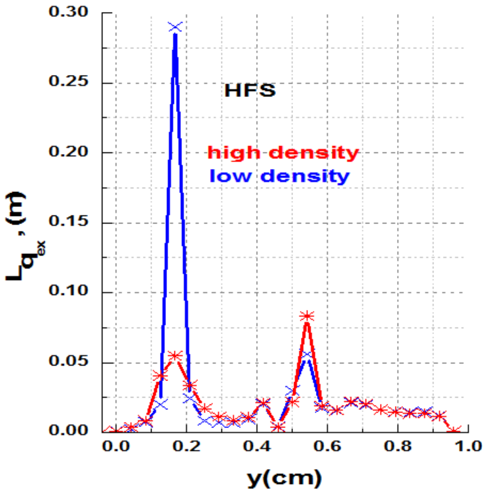

Figure 2: Radial distribution of electron poloidal heat flux characteristic length at low/ high line density in SSD tokamak

The second result of simulation shows that, the distribution of the radial electric field at low/high plasma density as shown in Fig. (5). In Fig.5 near separatrix, the radial electric field at low/high plasma density is of the order of the neoclassical radial electric field $E^{(NEO)}$. The degree of divertor electron poloidal heat flux asymmetries due to poloidal $E \times B$ and diamagnetic drifts is increased for the normal toroidal magnetic field.

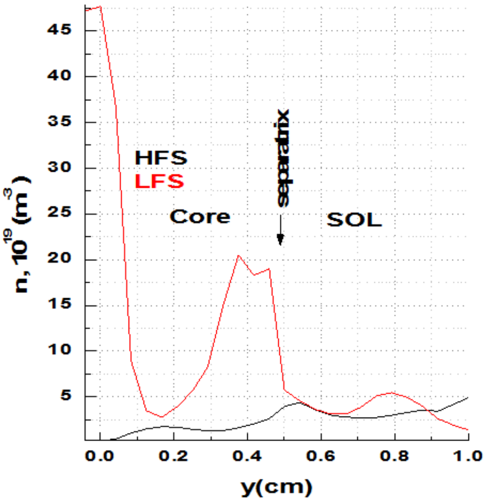

Figure 3: Radial distribution of plasma density at HFS and LFS plates of SSD tokamak

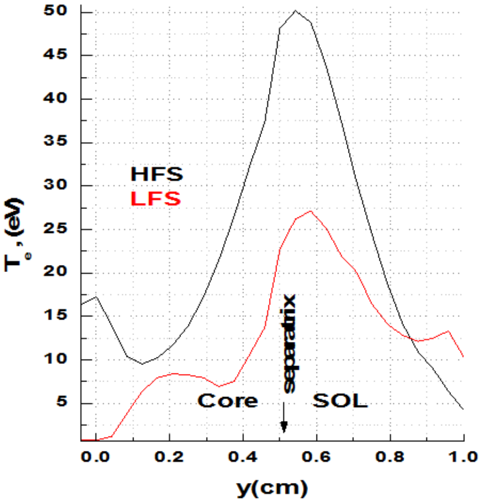

Figure 4: Radial distribution of electron temperature at HFS and LFS plates of SSD tokamak

To investigate the degree of in/out asymmetries of electron poloidal heat flux as a function of line density, we carried out the simulation with a switch on ($E \times B$ and diamagnetic) drifts and varying the core-edge densities. The result of this simulation is shown in Fig.6. Fig.6 shows that the in/out electron poloidal heat flux asymmetry dependent on plasma density. From this result, we conclude the effect of poloidal $E \times B$ and diamagnetic drifts on electron poloidal heat flux must be larger at a higher density than that at low density. It's interesting to note when switch on the $E \times B$ and diamagnetic drifts the in/out asymmetry appears to be strongly dependent on plasma density or function in plasma density.

The third result of simulation shows that strong "ETB" is located between the position of the maximum and the minimum characteristic length of poloidal electron heat flux $L_{q_{ex}}$ is shown in Fig.7. This result is interesting since they might help explain for the normal toroidal magnetic field the easier transition to the H-regime and strong "ETB" formed in the edge plasma of SSD tokamak. Also, this result shows that the effect of a switch on/off drifts on the formation of

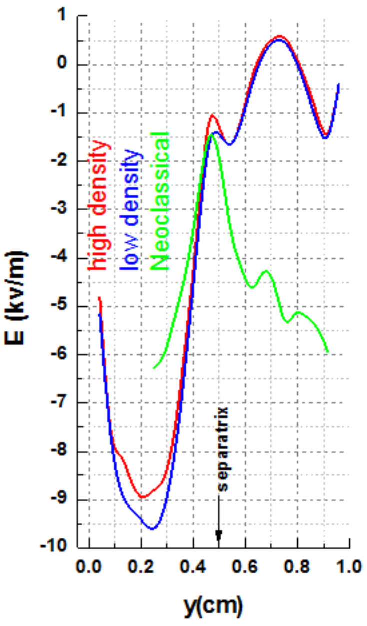

Figure 5: Radial distribution of radial electric field at low/high plasma density in edge plasma of SSD tokamak

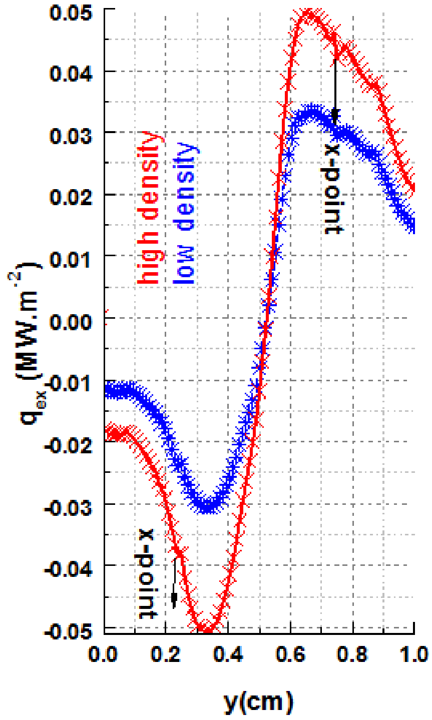

Figure 6: Poloidal distribution of poloidal electron heat flux field at low/high plasma density of SSD tokamak

"ETB" becomes important as shown in Figs.8-10. The characteristic length of poloidal electron heat flux, electron temperature, and plasma density were plotted in Figs.8-10. The Figs.8-10 show that in the case of $E \times B$ and diamagnetic drifts switch on the divertor plates colder and receive lower energy than in the case of $E \times B$ and diamagnetic drifts switch off. The electron temperature, plasma density, and characteristic length of poloidal electron flux are

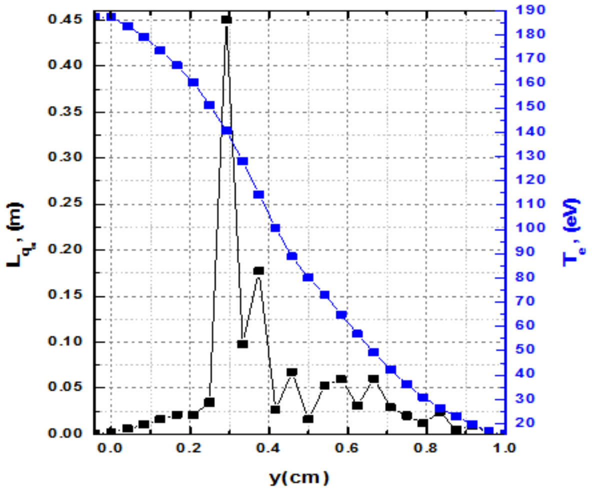

Figure 7: Radial distribution of electron poloidal heat flux characteristic length and electron temperature in edge plasma this tokamak

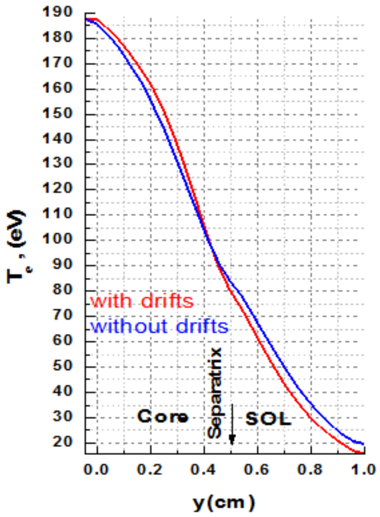

Figure 8: Radial distribution of electron temperature at switch on/off $E \times B$ and diamagnetic drifts

shifted inward, consistent with the directions of polodial $E \times B$ drift.

The fourth result of simulation shows that switch on/off $E \times B$ and diamagnetic) drifts a strong ${}^{(q_{in})_{ex}}/_{(q_{out})_{ex}}$ asymmetry is observed at the target plates as shown in Table 1 and Figs. (11-12). The individual drifts strong influence on asymmetry as follows: (1) the diamagnetic drifts which directed towards the X-point gives an overall increase to electron heat flux near the divertor plates, compared to the simulation without drifts as shown in Figs.11-12. In the case of switch off all drifts, the effect on ${}^{(q_{in})_{ex}}/_{(q_{out})_{ex}}$ asymmetry at divertor plates is, negligible as observed as shown in table1 yield in 0.000422. (2) In contrast, then activate $E \times B$ and diamagnetic drifts) and only diamagnetic drift change this ratio to 0.45 and 0.11 at the divertor plates. From this result, we conclude the switch on $E \times B$ drift leads to large account for asymmetry observed in this tokamak. The switch on $E \times B$ drift carries the poloidal electron heat flux from the inner divertor plate to outer divertor plate across the main SOL and increasing the asymmetry in poloidal electron heat flux. The increasing of the asymmetry in poloidal electron heat flux leads to enhance the toroidal plasma viscosity and of toroidal flow damping according to Shaing (2003).

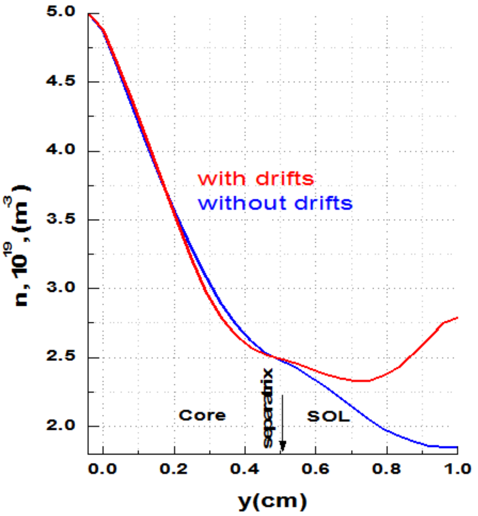

Figure 9: Radial distribution of plasma density at switch on/off $E \times B$ and diamagnetic drifts

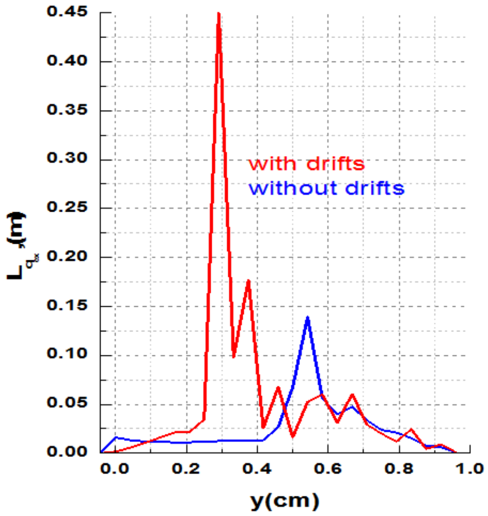

Figure 10: Radial distribution of characteristic length of electron poloidial heat flux at switch on/off $E \times B$ and diamagnetic drifts

The fifth result of simulation shows that, the electron poloidal heat flux on the target plates as shown in Figs.13-14. In Figs.13-14 at high plasma, density the peak poloidal electron heat flux on the inner plate is $0.0241 MW, m^{-2}$ as well as 0.0326 MW.m-2 on the outer plate. When the plasma density decreases the inner divertor plate is working in detached plasma regimes, and peak electron poloidal heat load onto the inner target plate decrease to $0.00752 MW, m^{-2}$. Otherwise, the peak electron poloidal heat flux load onto an outer target plate could be decreased to $0.0199 MW, m^{-2}$. We conclude the electron poloidal heat flux is a function of the plasma density.

The sixth result of simulation shows, at the hotter (LFS) the floating potential is larger than the cold one (HFS) a thermal current arises flowing from hot to the cold divertor plate (Harbour, 1998; Bekheit, 2008; Kiviniemi et al., 2003; Sorokina et al., 2018; Rozhansky et al., 2002) as shown in Fig.15. The thermal current flows upwards at LFS while at HFS it flows downward and thermal current arises following the hotter to the colder plate (i.e. From LFS plate to HFS plate). Hence the convective part of poloidal electron heat flux caused by parallel thermal flux at LFS flows to HFS plate. The convective flux is added to conductive one. This

Table 1: Distribution of electron poloidal heat flux at divertor plates

	$(q_{ex})_{in}\ (MW, m^{-2})$	$(q_{ex})_{out}\ (MW, m^{-2})$	$(q_{in})_{ex}/(q_{out})_{ex}$
Without drifts	1.21E-6	0.00287	4.22E-4
With diamagnetic drifts only	1.12E-6	1.01E-1	1.10E-1
With $E \times B$ and diamagnetic drifts	9.68E-4	4.46E-1	4.46E-1

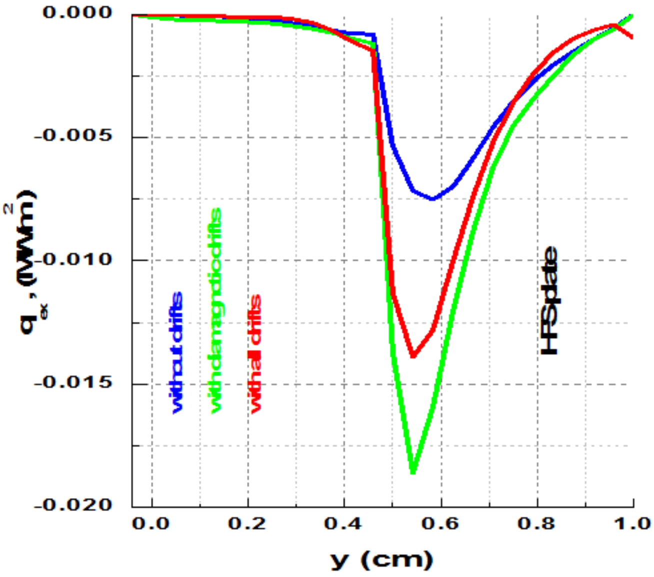

Figure 11: Radial distribution of electron poloidal heat flux at HFS at switch on/off $E \times B$ and diamagnetic drifts

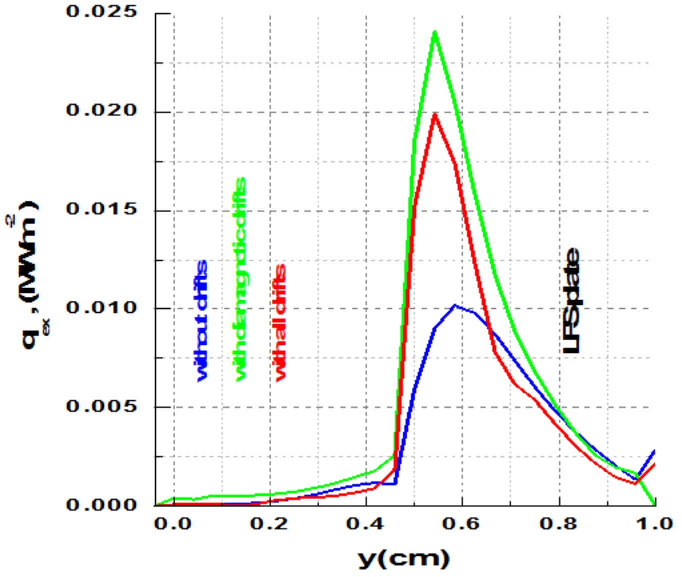

Figure 12: Radial distribution of electron poloidal heat flux at LFS at switch on/off $E \times B$ and diamagnetic drifts

is an additional factor self-enhancing, as it were, the electron power near LFS plate. From this result, we conclude the electron heat flux connected by electron energy with the convective electron energy flow established by the thermal current.

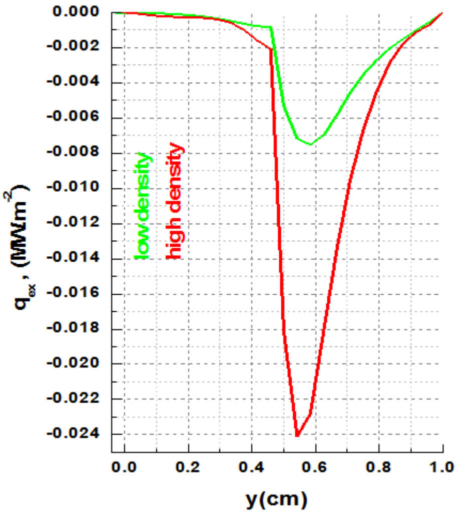

Figure 13: Radial distribution of electron poloidal heat flux at HFS at low/high plasma density

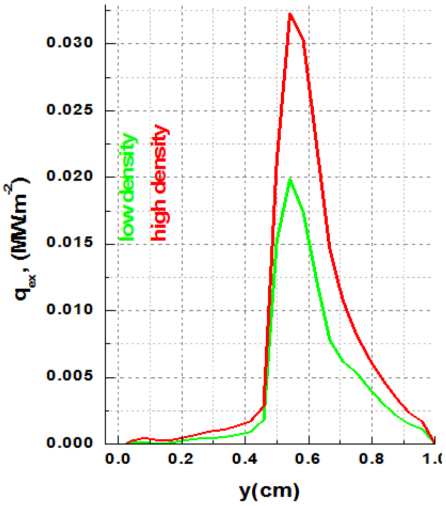

Figure 14: Radial distribution of electron poloidal heat flux at LFS at low/high plasma density

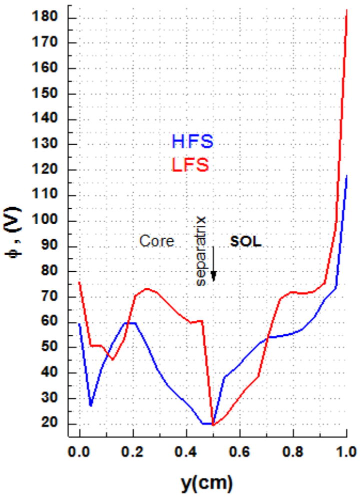

Figure 15: Radial distribution of electric potential at HFS and LFS

3 Conclusion

The electron poloidal heat flux of edge plasma of small size divertor (SSD) tokamak was simulated using the B2SOLPS5.0 2D multifluid transport code with the switch on/off drifts and with an account of 'ETB'. The simulation demonstrated the following results:

A reduction in electron temperature and electron poloidal heat flux in HFS was obtained in this simulation.

Activated drifts led to a reduction of poloidal electron heat flux to divertor plates and carry the poloidal electron heat flux from inner to outer plates across the main SOL and large in/out the asymmetry of electron poloidal heat flux.

An account of drifts led to strong "ETB" which located between the positions of the maximum and the minimum characteristic length of poloidal electron heat flux $L_{q_{ex}}$. In the case of $E \times B$ and diamagnetic drifts switch on the divertor plates colder and receive lower energy than in the case of $E \times B$ and diamagnetic drifts switch off. The electron temperature, plasma density, and characteristic length of poloidal electron flux are shifted inward, consistent with the directions of poloidal $E \times B$ drift. This result leads to strong 'ETB' formation when activated $E \times B$ and diamagnetic.

The poloidal electron heat flux was connected by the electron energy with the convective electron energy flow established by a thermal current.

An account of drifts the poloidal electron heat flux is plasma density function.

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