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Transport Simulations of Plasmas in Thailand Tokamak 1 and ITER with High Impurity Concentration Scenarios

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ABSTRACT

- Simulations of ITER plasma with high helium environment are carried out using the 1.5D BALDUR predictive transport code coupled with fully predictive boundary models.
- Transport of particles and energies are calculated using neoclassical transport together with the Multimode anomalous transport model.
- The pedestal temperature is predicted based on magnetic and flow shear stabilization.
- The pedestal densities of hydrogenic and impurity particles are empically determined from experimental data taken from JET H-mode discharges.
- It is found that helium fraction accumulated in the core is 9.9%, while fusion gains is predicted by the model to be about 3.5.
- As the helium fraction increases to 18%, the fusion gain is reduced to 1.0 due to increasing radiative loss.

BACKGROUND

- As the energetic alpha particles loss their energies in the deuterium-tritium reaction, they ultimately becomes undesirable helium ash.
- If helium is removed too quickly and only small amount of helium is present, the plasma will not be able to gain the energy transferred from the alpha particle and sufficiently maintain the fusion reaction. On the other hand, if there is too much amount of helium, the will dilute the fuel, enhance radiation loss, and possibly disrupt the plasma.
- It has been suggested that helium ash fraction should be kept below 10%. Nevertheless, more attention on this issue is required.

1.5D BALDUR Predictive Simulation Code

- 1.5D BALDUR code is predictive modelling code capable of calculating time evolution of plasma profiles such as ion and electron temperatures, ion and election densities, impurity density, neutral particles and fast ion particles. These quantities are calculated self-consistently by transport code, a combination of neoclassical transport and anomalous transport.
- The neoclassical transport is calculated by NCLASS module which considering a multi-fluid model for the force-balance equation and compute the neoclassical bootstrap current, parallel electrical resistivity, radial transport, and plasma poloidal rotation.
- For the anomalous transport, the mixed Bohm/gyro-Bohm (B/gB) transport model, and the Multimode (MMM95), are used in this study.
- For the B/gB, the anomalous diffusivity of electron, ion, hydrogenic and impurity are :

$$\chi_e = (8.0 \times 10^{-5})\chi_B + (3.5 \times 10^{-5})\chi_{gB}$$

$$\chi_i = (1.6 \times 10^{-4})\chi_B + (1.75 \times 10^{-2})\chi_{gB}$$

$$D = (0.3 + 0.7\rho)\frac{\chi_e \chi_i}{\chi_e + \chi_i}$$

where

$$\chi_B = \rho_s c_s q^2 \frac{(dp_e/dr)}{p_e}\Delta_{T_e}$$

$$\chi_{gB} = \frac{\rho_s^2 c_s}{a}\frac{a(dT_e/dr)}{T_e}$$

SIMULATION RESULTS

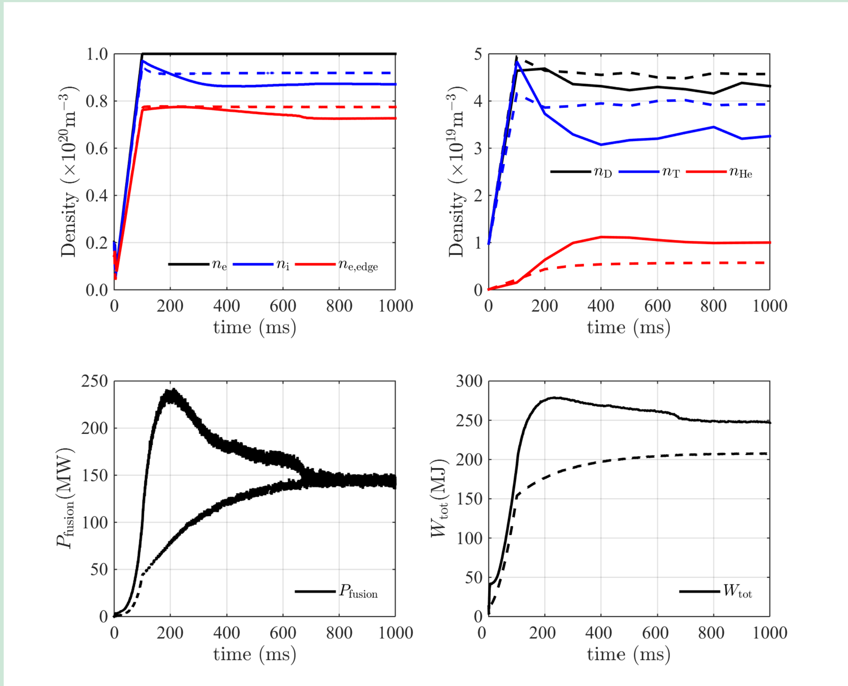

Fig. 1 Time development of n_e ,n_i, n_D , n_T , n_{He} , P_{fusion} , and W_{tot}

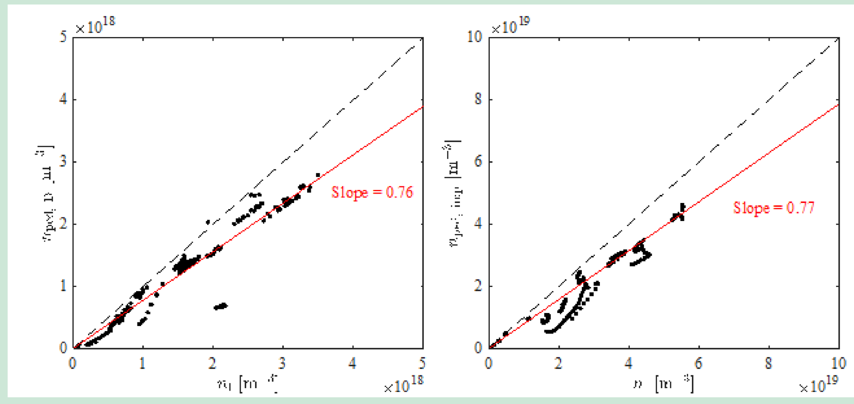

Fig. 2 The relationships of $n_{ped,D}$, $n_{ped,imp}$, as functions of n_l.

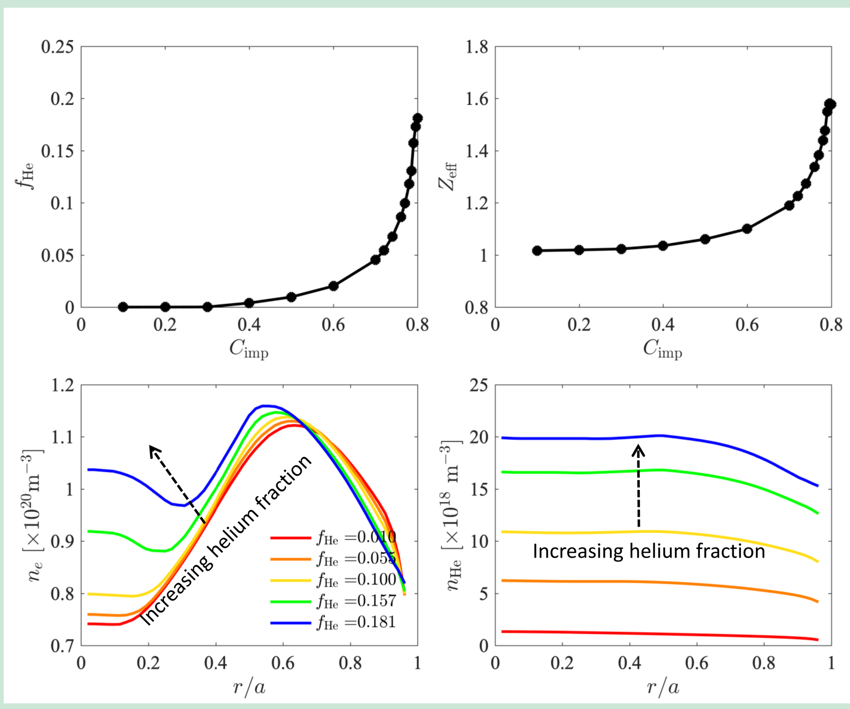

Fig. 3 The effect of variations of the helium fraction on n_e , and n_{He}

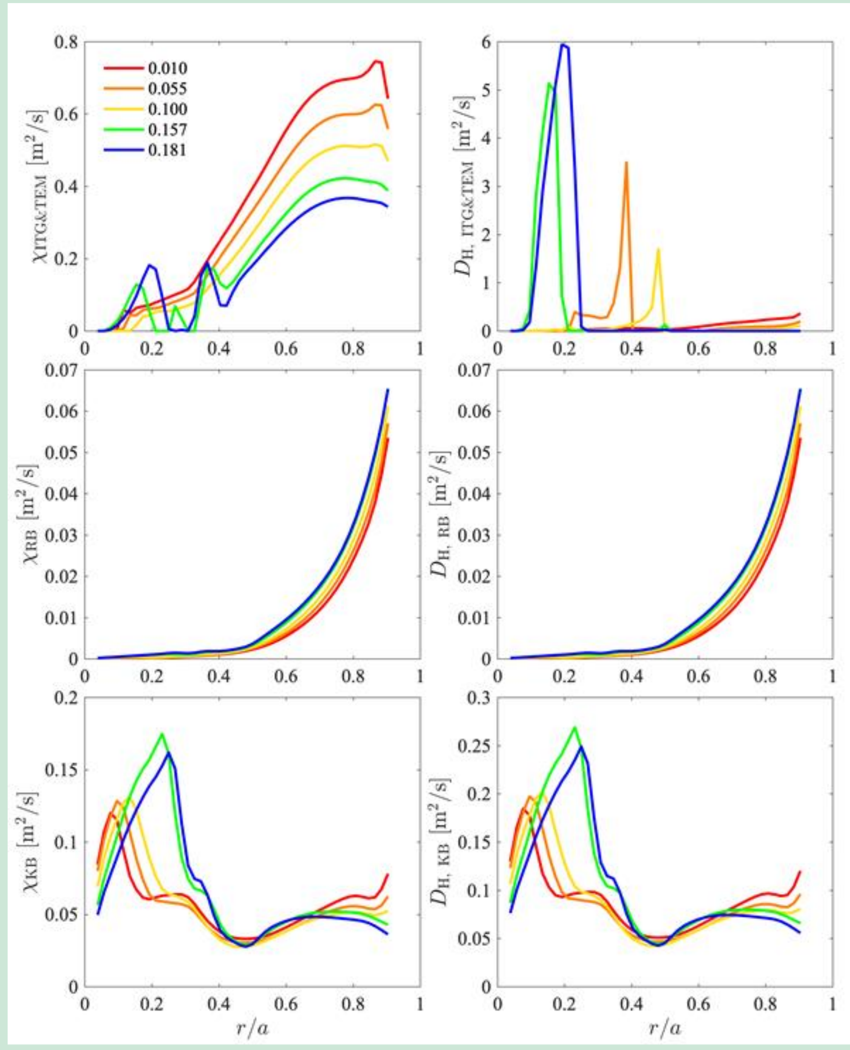

Fig 4. The electron thermal and the hydrogenic diffusivity profile different values of Cimp.

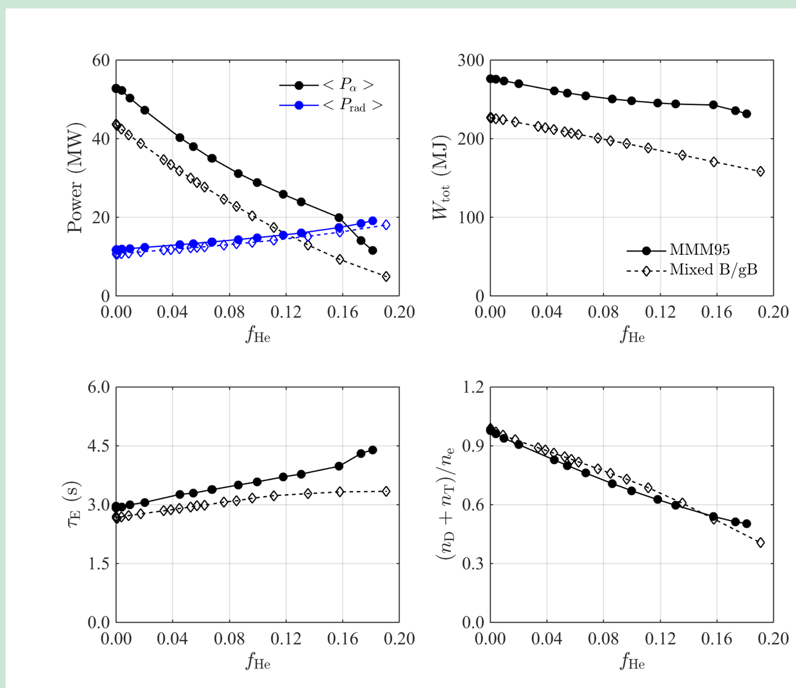

Fig. 5 The effect of variations of the helium fraction on P_{fusion} , P_{rad} , W_{tot} , and τ_E

CONCLUSION

- It is found that the amount of the helium accumulated in the core directly depends on the impurity density at the top of the pedestal.
- Our simulations show that the helium fractions accumulates in the core are 9.9% using MMM95 model with fusion gain about 3.5

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