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The Study of Transport in ISTTOK and HL-2A Using Integrated Predictive Modeling Code

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Abstract

Self-consistent simulations of plasmas in small tokamak experiments like ISTTOK and HL-2A are carried out using the 1.5D BALDUR integrated predictive modeling code. In these simulations, the plasma core is described by using Multi-mode core transport model. The plasma temperature and density profiles, as well as other plasma parameters, are obtained as the predictions in each simulation. Both plasma temperature and density profiles are found to peak near the plasma center. As for the ion thermal transport, the drift-resistive ballooning term is dominant in most region of the plasma; while the ion temperature gradient and kinetic ballooning modes dominate in some regions near center of the plasma. In addition, it is found that the increasing of electron density results in an increase of the drift-resistive ballooning mode and a decrease of the kinetic ballooning mode.

Introduction

A BALDUR integrated predictive modeling code [1] has been developed to simulate the time evolution of the tokamak plasma current, temperature, and density profiles. This code computes the sources, sinks, and transport of thermal energy and particle fluxes, as well as the equilibrium shape of the plasma and the effects of large-scale instabilities. The simulation results using this code has successfully reproduced many experiments in a wide range of plasma scenarios from various tokamaks. They result in a better understanding of the physical processes and the inter-relationships among these physical processes that occur in tokamak plasma experiments and, finally, results in advance of plasma study.

In this work, a BALDUR integrated predictive modeling code has been used to carry out preliminary simulations of small-size ISTTOK tokamak and a medium-size HL-2A tokamak. Multi-Mode (MMM95) anomalous core transport model [2] is utilized for the core region to describe the effects of turbulence. In addition, the neoclassical transport calculated using NCLASS module [3] is combined with the anomalous core transport to describe the core transport. General plasma parameters for both tokamaks are used, which are shown in Table 1. The simulations results in an insight understanding of plasma behaviour in both tokamaks, especially about the energy and particle transports.

Results and Discussion

The BALDUR integrated predictive transport modeling code is used to carry out the simulations of ISTTOK-like and HL-2A-like parameters. Figures 1 and 2 show the ion and electron temperatures profiles as a function of major radius for ISTTOK and HL-2A, respectively. It can be seen that both ion and electron temperature profiles are peak. Note that electron profile is also a peak profile. The electron temperature profiles in both tokamaks are higher than ion temperature profiles. The central and average values of both temperature and density for both tokamaks are summarized in Table 2.

Figures 3 and 4 show the ion thermal diffusivity and particle diffusivity as a function of minor radius for ISTTOK from a simulation using the MMM95 transport model. Note that the Multi-mode transport model consists of the ion temperature gradient (ITG) and trapped electron modes (TEM), the drift-resistive ballooning modes (RB), and the kinetic ballooning modes (KB). It can be seen that for the ion thermal transport, the RB mode is the main contribution to most of the plasma region, while ITG and KB modes are dominant in small regions closed to the center. It is also found that the neoclassical transport plays a small role in the transport. For the particle transport, the KB mode is dominant near the center; while the RB mode is dominat in the rest for the rest of the plasma. The ITG contribution is quite small for the particle transport. It is also found that the transport behavior in HL-2A has a similar trend with ISTTOK.

Figures 5 and 6 show the ion thermal diffusivity from the RB model and KB mode as a function of minor radius in ISTTOK, respectively. It can be seen that the contribution from RB mode increases with the minor radius; while the contribution from KB mode decreases with the minor radius. When average electron density increases, it can be seen that KB contribution decreases. On the other hand, the contribution of RB increases as average electron density increases.

Conclusions

Self-consistent simulations of plasmas in small tokamak experiments like ISTTOK and HL-2A are carried out using the 1.5D BALDUR integrated predictive modeling code. In these simulations, the plasma core is described by using Multi-mode core transport model. Both plasma temperature and density profiles are found to peak near the plasma center. As for the ion thermal transport, the drift-resistive ballooning term is dominant in most region of the plasma; while the ion temperature gradient and kinetic ballooning modes dominate in some regions near center of the plasma. In addition, it is found that the increasing of electron density results in an increase of the drift-resistive ballooning mode and a decrease of the kinetic ballooning mode.

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References

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Table 1: Plasma parameters for ISTTOK and HL-2A used are shown.

Parameter	ISTTOK	HL-2A
R (m)	0.46	1.65
a (m)	0.085	0.45
I (kA)	300	300
B_T (T)	2.80	2.43
κ	1	1
δ	0	0
Z_{eff}	3.0	3.0
P_{aux} (MW)	0	1

Table 2: Ion and electron temperatures and electron density are shown for ISTTOK and HL-2A.

Parameter	ISTTOK	HL-2A
$T_{i,0}$ (keV)	1.90E-03	4.43E-01
$T_{e,0}$ (keV)	1.17E+00	1.61E+00
$n_{e,0}$ (m^{-3})	1.30E+18	4.56E+19
$T_{i,ave}$ (keV)	1.24E-03	1.38E-01
$T_{e,avg}$ (keV)	1.36E-01	2.49E-01
$n_{e,avg}$ (m^{-3})	9.97E+11	1.98E+13

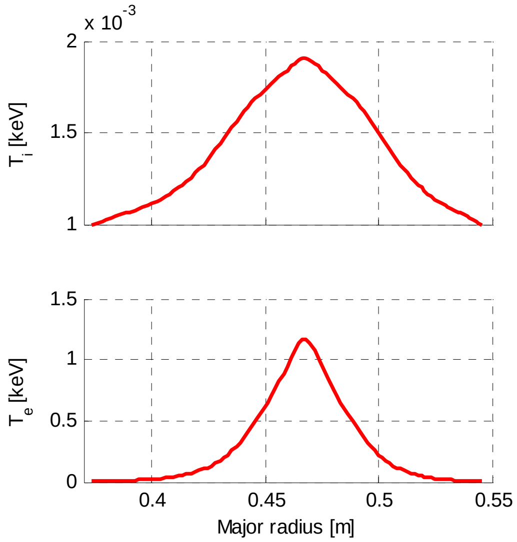

Figure 1. Ion (top) and electron (bottom) tempurature profiles of ISTTOK.

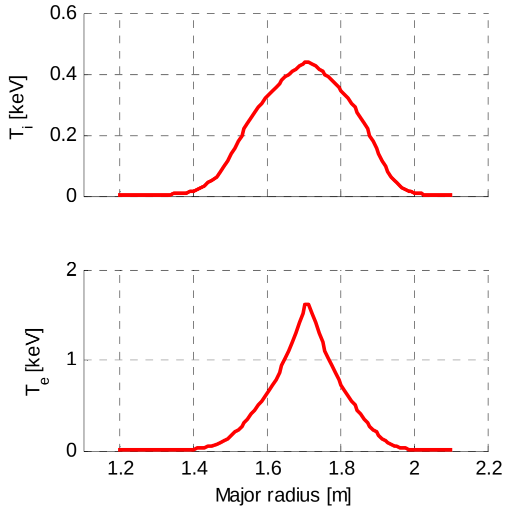

Figure 2. Ion (top) and electron (bottom) tempurature profiles of HL-2A.

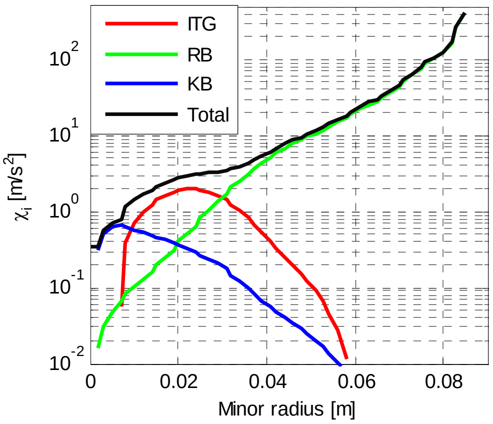

Figure 3. The ion thermal diffusivity plotted as a function of minor radius for ISTTOK.

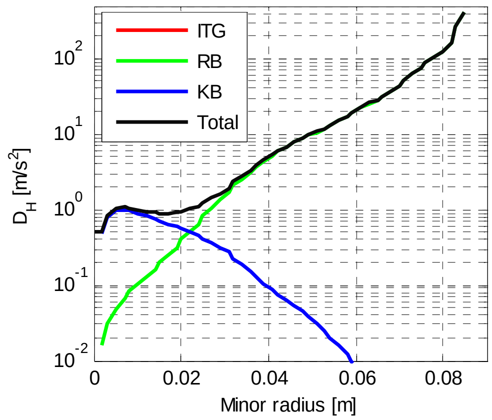

Figure 4. The particle diffusivity plotted as a function of minor radius for ISTTOK.

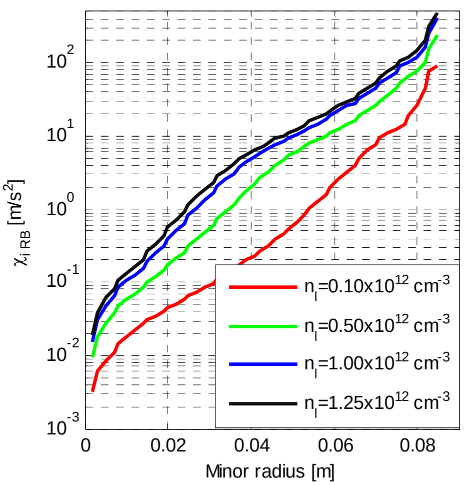

Figure 5. The resistive ballooning contribution plotted for different electron density in ISTTOK.

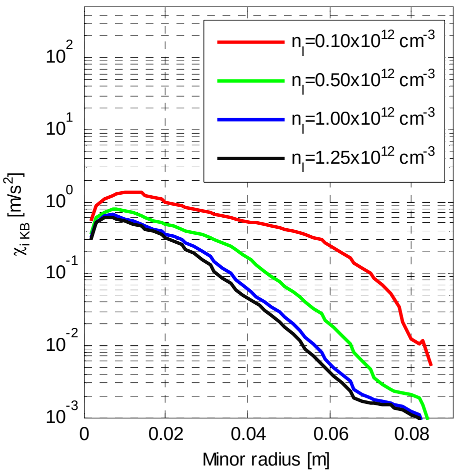

Figure 6. The kinetic ballooning contribution plotted for different electron density in ISTTOK.