The Development of Pedestal Temperature Model with Self-Consistent Calculation of Safety Factor and Magnetic Shear

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Introduction

It is widely accepted that the height of the pedestal is an important element for predicting core temperature and density profiles in *H*-mode plasma. Many pedestal models have been developed in recent years. This work aims to modify an existing pedestal temperature model proposed in Ref. [1], mainly by improving the calculation of safety factor and magnetic shear. This pedestal model is used together with two core transport models: Multimode (MMM95) [2] and Mixed Bohm/gyro-Bohm (Mixed B/gB) [3] in the BALDUR integrated predictive modeling code [4] to carry out the time evolution of plasma profiles. The predictions from BALDUR with the modified pedestal model are compared with the experimental results obtained from DIII-D and JET experiments.

A pedestal temperature model based on magnetic shear and flow shear stabilization width model ($\Delta = C_W \rho s^2$) in Ref. [1] takes the following form:

$$T_{\text{i, ped}} = 0.323 C_W^2 \left(\frac{B_T}{q^2}\right)^2 \left(\frac{M_i}{R^2}\right) \left(\frac{\alpha_c}{n_{\text{ped,19}}}\right)^2 s^4, \tag{1}$$

where C_W is the width constant, B_T is magnetic field, q is safety factor, M_i is the ion mass, R is major radius, α_c is normalized pressure gradient, $n_{\text{ped,19}}$ is the electron density at the top of the pedestal in units of 10^{19} m^{-3}, and s is magnetic shear. In this work, the values of safety factor and magnetic shear are taken directly from BALDUR code, which allows the effect of bootstrap current to be correctly included in the pedestal calculation.

Simulation Results

In this work, simulations are carried out in two steps. First, preliminary simulations are performed using the MMM95 core transport model to make sure that the pedestal points match with those from experiments. Having chosen the pedestal points, hence boundary conditions, simulations are carried out using both Mixed B/gB and MMM95 to determine the optimal value of C_w in each discharge.

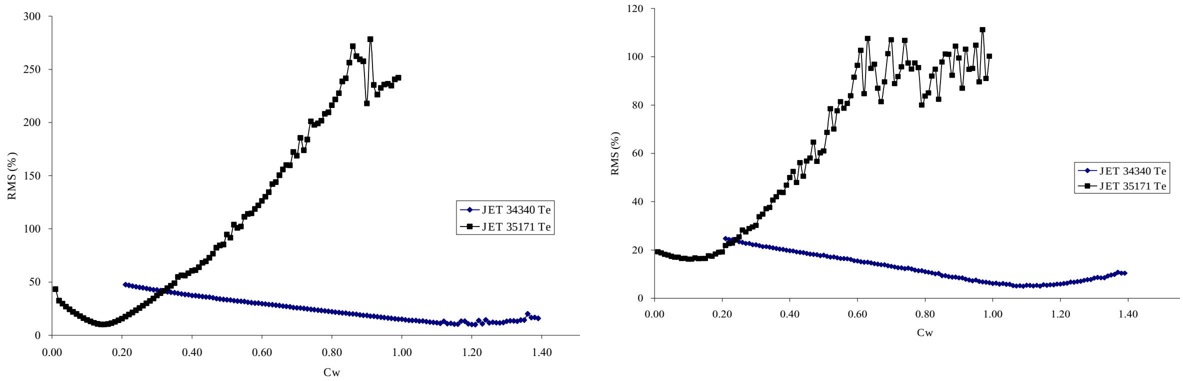

Figure 1: Examples of RMS (%) from simulation using Mixed B/gB (left) and MMM95 (right). These graphs illustrate a common behavior that optimal values of C_w from discharges do not coincide in a suitably small range.

Figure 1 shows the RMS from simulations using Mixed B/gB and MMM95 as a function of width constant C_w. It can be seen that there is an optimal value for each discharge and that the optimal values of C_w for each discharge vary widely from one discharge to another. This observation holds for both ion and electron temperatures. From Figures 2–3, one also discovers that the simulation results match the experimental results very well in many discharges, as the RMS errors are acceptably low, suggesting that the pedestal model in Eq. (1) can give satisfactory boundary conditions. However, it is rather discouraging that the same model does not seem to explain all experimental results. Previously, many authors have used the averaged RMS errors to determine the optimal value of C_w. Our simulations suggest that taking an average of the RMS values may not be valid because the range of optimal C_w is too wide; hence, the average RMS value is skewed by relatively high RMS from only few discharges, as seen in Figure 1.

However, since one would prefer to have one model to explain all experiments, it is important to derive one *central representative* from this collection of results to be used in Eq. (1). To that end, one may choose other central representatives, such as a median or a mode, which our simulations seem to indicate that the same problem persists. Taking a weighted average gives rise to the problem of what should be an appropriate set of weights.

Alternatively, one may want to find a range of C_w that will yield RMS less than, say, 30% for all discharges. This may give an alternative measure of how well a model, like Eq. (1), can explain experimental data. However, our simulations show that there does not exist such a value of C_w from 0.01 to 1.60 with RMS of 30 % or lower. On the other hand, one may modify the current model, for instance, by including the second instability region in the calculations or consider other existing pedestal models [1]. All these matters are currently being investigated.

Considering overall profiles of electron and ion temperatures, we find that the profiles yield reasonable agreement with the data near the pedestal, but show high deviation near the plasma-core region.

Conclusions

Simulations to explain *H*-mode DIII-D and JET tokamak experiments are carried out using the BALDUR integrated predictive modeling code. The results are obtained for ion and electron temperature profiles using the Multimode and Mixed Bohm/gyro-Bohm core transport models together the pedestal width model based on flow shear stabilization width concept. It is found that simulation results agree reasonably well with experimental data near the pedestal region, but show high deviation near the core region. More importantly, it is evident that the constant of proportionality in the pedestal width model Eq. (1) is not uniquely determined within reasonable root-mean square errors.

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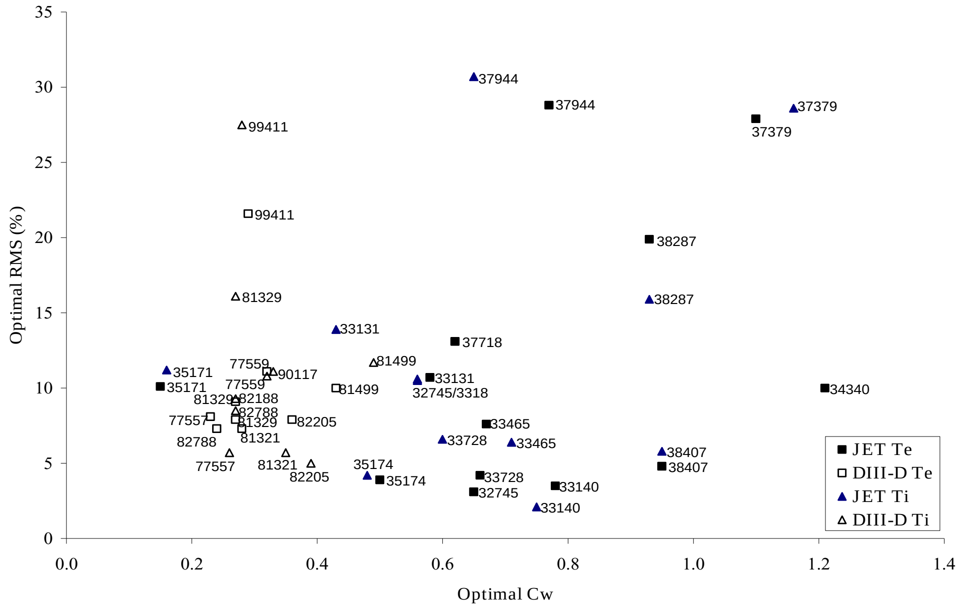

Figure 2: Distribution of optimal values of C_w for electron and ion temperature profiles simulated using the Mixed B/gB core transport model. Some discharges are not included here because their optimal C_w fluctuates or does not lie in the above range.

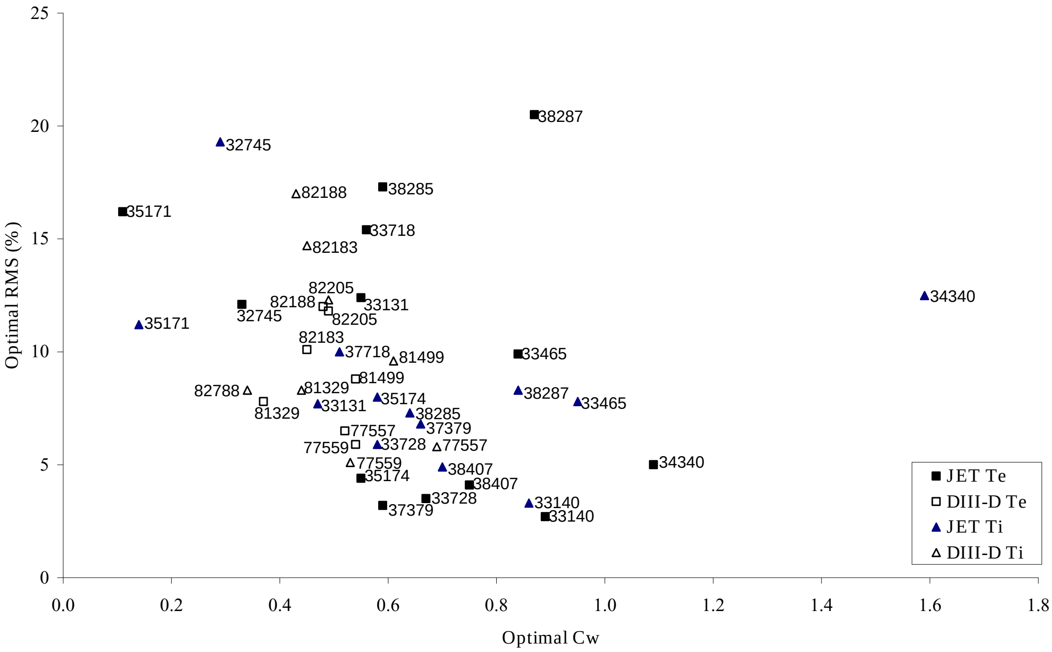

Figure 3: Distribution of optimal values of C_w for electron and ion temperature profiles simulated using the MMM95 core transport model. Some discharges are not included here because their optimal C_w fluctuates or does not lie in the above range.