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Plausible model creation by means of data assimilation

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Data assimilation technique has been successfully implemented into the fusion research [1,2], and furthermore, it has been advancing toward real-time control of fusion plasmas, which is the leading progress even in the field of data assimilation research (such as the weather forecast and the oceanology) [3].

During the data assimilation process, given physics-based or empirical models can be optimized by employing the observation data. Thus, for example, in the thermal transport problem of fusion plasmas, the validated model (so as to fit to or to reproduce the observation data) can be obtained. In this presentation, plausible model creation by means of data assimilation is described, taking the thermal transport coefficient of fusion plasmas as an example.

In the previous research in the Large Helical Device (LHD) [4,5], ion thermal transport coefficient was modeled by comparatively referring measured and simulated (by integrated transport analysis by TASK3D [5]) ion temperature profiles (total of only 8 cases: 1 timing each from 8 NBI-heated discharges) to deduce plausible modification to Gyro-Bohm model. The obtained ion thermal transport coefficient is described as follows.

$$\chi_i = C_i \frac{T_i}{eB}\frac{\rho_i}{a}\left(a\frac{\nabla T_i}{T_i}\right)$$

Here, Ci is the radially-constant value, and all other variables follow the conventional notation. It is noted that the deduced model is only valid to limited number of cases (8 time slices, in this case). When this model is provided to TASK3D and the time evolution simulation for other discharge (but with similar NBI-heated discharge) is performed, it hardly reproduces the time-series data of measured ion temperature. This fact clearly shows that “time slice-based” model creation is not enough to provide reasonable prediction to overall behaviour of fusion plasmas.

On the other hand, data assimilation of NBI discharges (12) with even *C*i to be the state variable (allowing variations even radially during the model optimization process, by maintain compatibility with all other state variables [1]) has accumulated radial profiles of *C*i for all data assimilation cycles in these 12 discharges. This accumulated information on *C*i displays the gap between given model (*C*i to be radially constant) and validate model against measured data through data assimilation. It is noted that *C*i=1 in the horizontal axis corresponds to the “radially-constant *C*i model”. Figure 2 indicates a certain trend of *C*i, which provides valuable hints for what was missing in the previous model.

Thus, it is expected that a plausible physics model (or physics interpretation beyond the originally assumed model, GyroBohm in this case) could be created by expressing this recognized trend of *C*i with physics variables. An immediate example for doing this is to conduct multivariate regression analysis for *C*i. This trial has been conducted, and the resultant “statistically-reasonable” expression for *C*i was obtained as,

$$C_i \propto \left(\frac{T_e}{T_i}\right)^{0.38}\left(-\frac{dn_e}{d\rho}/n_e\right)^{0.13}$$

based on the application of Akaike’s Information Criterion (AIC) [6] (more precisely, AICc with a correction for small sample sizes) [7] for selecting statistically important variables among *a priori* prepared physics variables.

As above described, a way of deducing physics models in fusion plasmas could be proposed (not only for thermal transport issues) by means of data assimilation.

References

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Acknowledgements will be described in the presentation.