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Uncertainty Quantification for gyrokinetic validation study in KSTAR

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It is recognized that transport is mainly governed by turbulence in magnetic fusion plasmas. Since turbulence affects transport and confinement efficiency, turbulence study in fusion plasma should be preceded for predicting plasma performance.

Gyrokinetic [1] is a theoretical tool used to describe turbulent transport. A validated transport model is required to predict future fusion plasma performance and design the fusion device. Therefore, validation of the gyrokinetic transport model is an essential work in fusion research. Validation studies on gyrokinetic transport models have been conducted in various tokamak [2-4], but gyrokinetic validation study is at an initial stage in KSTAR. The discrepancy between the experiment and gyrokinetic simulation can be determined through an uncertainty quantification of measured and simulated quantities. Thus, an uncertainty quantification process is one of the essential tasks in the validation study.

In this study, the uncertainty of heat fluxes and input parameters of gyrokinetic simulations are quantified. Experimental heat transport levels are estimated from power balance analysis using TRANSP [5], and gyrokinetic simulated heat transport levels are analyzed using CGYRO code [6]. Uncertainty of $n_e, T_e, T_i, \frac{a}{L_{ne}}$, $\frac{a}{L_{Te}}$, $\frac{a}{L_{Ti}}, V_{tor}$, and ω_{EXB} are required to calculate uncertainties of experimental and simulated heat flux levels. Here, $\frac{a}{L_X}$, normalized inverse gradient length scale, denotes $\frac{a}{X}\nabla X$ and ω_{EXB}, the shear rate of E×B flow, is $\frac{r}{q}\frac{d}{dr}\left(\frac{q}{r}\frac{E_r}{B}\right)$ where q is the safety factor, and E_r is the radial electric field.

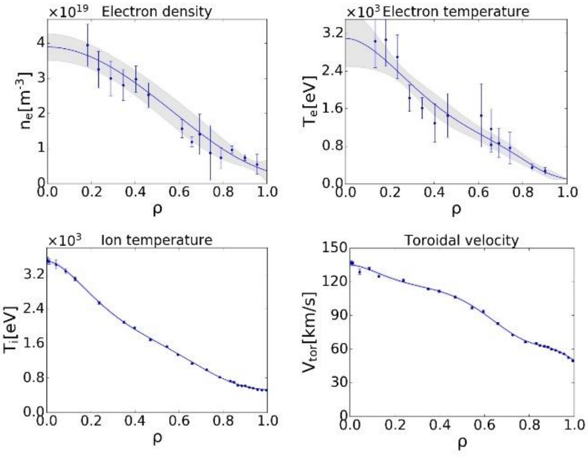

Figure 1. n_e, T_e, T_i, and V_{tor} profiles and uncertainty quantified results of KSTAR L-mode discharge (shot 21631, time=2050ms)

It is possible to generate profile samples by fitting the random data weighted by a normal distribution with the measurement value as a mean and the uncertainty of the measurements as the standard deviation. By averaging these profile samples and calculating the standard deviation, mean profile values and their uncertainties can be obtained. Figure 1 shows the n_e, T_e, T_i, and V_{tor} profiles with quantified uncertainties of KSTAR L-mode discharge. Here, n_e and T_e were measured from Thomson scattering diagnostic. Charge exchange spectroscopy was used to measure T_i and V_{tor}.

Each generated profile sample is used as the input profile for power balance analysis using TRANSP. By calculating the standard deviation of the TRANSP results obtained from randomly generated input profile sets, the uncertainty of experimental heat flux is quantified. By applying the error propagation technique to the numerical calculation process of $\frac{a}{L_X}$ and ω_{EXB}, their uncertainties are quantified. The covariance term, which is required in the propagated error calculation, is evaluated from the generated profile samples. In the calculation process of ω_{EXB}, V_{pol} and its uncertainty are calculated using NEO code [7], a neoclassical solver.

Using generated profile samples and error propagation technique, the uncertainty quantification scheme for the gyrokinetic validation study will be presented. The uncertainty of simulated heat flux using CGYRO propagated from uncertainties of input parameters will be discussed as well.

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