§17. International Stellarator Database

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An international stellarator database on global energy confinement time has been integrated from data from the heliotron/torsatrons ATF, CHS and Heliotron E and the shearless stellarators W7-A and W7-AS. The database contains ECH and NBI-heated plasmas. A total of 859 observations is stored in the database, each consisting of data for 56 parameters. While a variety of enhanced confinement modes such as the H-mode and the reheat mode have been realized in the experiments, they are not included in the database. The confinement mode represented here is referred to as L mode. In the linear regression analyses an ansatz is used of the form:

$\tau_E = 10^{\alpha_x} a^{\alpha_a} R^{\alpha_R} B_t^{\alpha_B} \bar{n}_e^{\alpha_n} P^{\alpha_P} \iota_{2/3}^{\alpha_\iota}$

The units used here are: a and R in m, density in $10^{19}m^{-3}$, power in MW, magnetic field in T and confinement time in s. The rotational transform at the two-thirds radius is used, because a value in the outer region is more relevant for confinement than the central or edge value. CHS is the only device with the major radius being clearly different from 2 m. In this case, the R or aspect-ratio scaling will be determined mainly by CHS. ATF will be important for the minor radius scaling in the heliotron/torsatron line and a comparison of ATF and Heliotron E will give information about the scaling with ι. For W7-AS, data from limiter and ι scans are available. Therefore, the dependence on a and ι can also be studied in a single device.

The general trend which is described in Table 1 is similar for all devices: the energy confinement time improves strongly with magnetic field and density and it degrades with heating power. Besides CHS, which shows the strong correlation between $\bar{n}_e$ and P, the parameters of the single-device regressions overlap in almost all combinations within one standard deviation.

Device	α_x	α_a	α_R	α_P	α_n	α_B	α_ι
ATF	-1.58	2	1	-0.59	0.51	0.77	0
CHS	-1.71	2	1	-0.89	0.72	0.89	0
Hel.E	-1.50	2	1	-0.62	0.56	0.59	0
W7-AS	-1.02	2.21	1	-0.54	0.50	0.73	0.43

Table 1 Regression results for the individual devices. Parameters constraint to a fixed value are underlined.

Regression analyses have been carried out for the combined dataset as well. The heliotron/torsatron data are consistent with the expression,

$\tau_E \propto a^{2.11} R^{0.73} B_t^{0.78} \bar{n}_e^{0.53} P^{-0.62} \iota_{2/3}^{0.44}$

and, if the R dependence is assumed, the shearless stellartors with

$\tau_E \propto a^{2.21} R^{0.8} B_t^{0.73} \bar{n}_e^{0.5} P^{-0.54} \iota_{2/3}^{0.43}$.

For a combined analyses of the dataset it is very satisfactory that the dependence of the two individual expressions on plasma parameters are very similar. Also both expressions are close to the theoretical scaling constraint. However, the regression analysis of whole dataset gives the following dependence,

$\tau_E \propto a^{1.87} R^{0.89} B_t^{0.98} \bar{n}_e^{0.51} P^{-0.53} \iota_{2/3}^{-0.19}$.

Although this is, indeed, the best fitted expression of the present dataset, the dependence is not easily understandable and contradicts with the constraint from the theoretical investigation. The unified scaling law is still an open issue and it suggests that there exist hidden parameters which might be attributed to magnetic configuration and/or experimental condition.