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Confinement scaling with machine size in the updated ITPA global H-Mode confinement database

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Empirical scaling of the thermal energy confinement time $\tau_{E_{th}}$ in tokamak H-mode plasmas, determined from multi-machine databases, remains a convenient tool for studying the dependencies of $\tau_{E_{th}}$ and for predicting confinement based on experimental data. Based on regression analysis, the approach is essentially data-driven, but this does not prevent the incorporation of physics information to constrain the parameters of the regression model or to guide model improvements beyond the simple power law. Recently, the multi-machine ITPA global H-mode confinement database was updated with additional data reflecting the ITER operational conditions, as well as measurements from devices with fully metallic walls. This has led to the new ITPA20 scalings, updating the IPB98(y,2) law that is often used as a standard for energy confinement scaling in ELMy H-mode plasmas. This has revealed several dependencies that are different to those in the ' 98 scaling, as well as considerable uncertainties on some of the parameters when taking into account model uncertainty. One of the notably different dependencies lies in a considerably weaker scaling with the device's major radius, with an exponent αR reduced from quadratic to almost linear. The present work is aimed at revealing the cause of this reduced size scaling. Using optimization and clustering techniques, a subset of the database has been identified as exhibiting very weak size scaling (α_R = 0.377), hence maximally contributing to the reduced size dependence seen in the overall data set. This subset is localized in dimensionless space, governed by normalized gyroradius, collisionality and pressure, as confirmed by random forest classification. Interestingly, in this space, the operational point of future devices like ITER is situated in a region of higher size dependence (α_R = 1.647). This may at least partly account for a significantly higher ITER confinement time prediction by the scaling with elevated α_R ($\tau_{E_{th}}$ = 2.95s) compared to that obtained from the anomalously low α_R regression ($\tau_{E_{th}}$ = 1.58s). Like ITER, the SPARC experiment also shows up in the region with higher size dependence, although closer to the cluster boundary.

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