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Status of Divertor/SOL modelling in PROCESS

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Systems codes, such as PROCESS, model all systems of a power plant to investigate large numbers of design points. They are used for scoping studies and to identify areas of feasible design points.

Multi-dimensional modelling of the plasma Scrape-Off-Layer (SOL), divertor and seeded impurities is too computationally intensive to be incorporated directly into a systems code. Divertor protection parameters such as P_{sep}/R_0 and $P_{\mathrm{sep}}B_{\mathrm{T}}/q_{95}AR_0$ have been used as a constrait for capturing the divertor problem in previous studies instead. A 1-D SOL/divertor model has been implemented in PROCESS to try and produce more accurate information regarding the divertor conditions. The aim of the 1-D model is to determine if the divertor is detached, whether the power crossing the separatrix is consistent with required conditions at the target, and to model the loss of power and momentum along the 1-D flux tube.

The following physical processes are included: convected heat flux; thermal conduction; momentum conservation; radiation by deuterium, tritium and impurities; charge exchange; electron impact ionisation; and surface recombination. Pumping is not included –all particles striking the target are recycled. The strong shearing of the flux tube near the X-point is not taken into account.

As the seeded impurity concentration is increased a discontinuous transition is observed between an attached state, where the plasma temperature at the target is $50\,\mathrm{eV}$, and a state where the temperature at the target hits the lower bound of the simulation, $1.1\,\mathrm{eV}$. We interpret this as a detached state, within the limitations of the model.

The 1-D model has been compared to 2-D models (e.g. the Japanese code SONIC) for European DEMO-like machines. However, a large database of DEMO-like runs using the detailed codes is not readily available, so benchmarking the 1-D model against detailed codes is an ongoing process.

PROCESS now also allows for a double-null divertor configuration as an alternative to the single-null considered standard for conventional aspect ratio tokamaks, but to achieve worthwhile power sharing between the upper and lower divertors would seem to require a high degree of control of the plasma position.

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