Contribution ID: **36** Type: **Oral (Regular)**

First wall Heat flux estimations with THEODOR –an update: 3D solver, material inhomogeneities, resolved surface layers

Tuesday 9 September 2025 14:55 (25 minutes)

In plasma experiments heat loads to material surfaces are of interested, which involves solving an inverse problem given temperature information. Infrared cameras can provide surface temperature information at high spatial and temporal resolution. To determine the heat flux density to the material the heat diffusion equation in the solid needs to be solved, respecting relevant boundary conditions and non-linearities of the transport.
At ASDEX Upgrade (AUG) the idea for the THEODOR code (THermal Energy Onto DivertOR) was established 1995 [1] to estimate surface heat loads on the divertor for investigations of plasma physics [2] and used in a Bayesian Framework [3] for high fidelity reconstructions. In recent years improvements have been made, such as a transition from an explicit to an implicit solver, inhomogeneous and optimised depth discretisation, an extension to 3D, and mixed material properties leading to better treatment of surface layers.
These developments are presented using the example of the new upper divertor in AUG for Alternative Divertor Concept (ADC) scenarios. The result is a non-toroidally symmetric heat load pattern on tiles with a trapezoidal plasma-facing surface and voids in the material due to mounting points. The finite difference solver provides an efficient scheme with simple setup and application. While finite difference schemes generally restrict the tile geometry to orthogonal grids, modifications to the local coefficients can be used to introduce spatially variable material parameter, or features like voids.
The currently predominantly used version is a Python implementation with uniform interfaces for the 1D, 2D, and 3D solver, core components compiled with numba for comparable speed to the C++ version, and parallelisation providing about 100 Hz evaluation speed for 3D geometries (200x100x50 cells), making it compatible with online analysis. It is also easy to extract in-tile temperatures for comparisons to thermocouples, for which of course also the borehole can be included in the geometry. The default non-uniform depth resolution allows for high resolution –and good response –on the surface, while saving computational resource towards the rear of the tile.

References

[1] A Herrmann et al 1995 Plasma Phys. Control. Fusion 37 17
[2] B Sieglin et al 2013 Plasma Phys. Control. Fusion 55
[3] D Nille et al 2017 Springer Proceedings in Mathematics & Statistics, vol 239

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Session Classification: Inverse Problems and Image Processing

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