Scalable Multi-physics for Fusion Reactors with AURORA

H. Brooks[1], A. Davis[1]

[1] *United Kingdom Atomic Energy Authority, Culham, Abingdon, United Kingdom*

To support the design of fusion reactors for energy production, there is an urgent need to develop highly-scalable multi-physics software tools capable of modelling critical tokamak components as a single cohesive whole. Although some loosely-coupled physics tools do exist, these lack fidelity and will fundamentally fail to capture any closed-loop feedback effects between separate physics modules. To address this need, we introduce a new open-source code: AURORA[1]: A Unified Resource for OpenMC (fusion) Reactor Applications. Built using the MOOSE [2, 3] finite-element framework we have coupled the neutronics transport code, OpenMC [4]. In this application, the heat deposited by neutrons is calculated by OpenMC and tallied upon an unstructured mesh, providing a source term for transient heat conduction and thermal expansion. MOOSE calculates the corresponding change in temperature and density on the same mesh, whereafter local temperature and density regions are defined via binning in these variables. Finally these regions are updated within OpenMC as new materials having modified nuclear cross sections. The procedure is subsequently iterated until a desired stopping condition is reached.

We present some proof-of-concept results, as the first step towards our ultimate goal of having a single suite capable of capturing non-trivial couplings between the multiple disciplines (such as neutronics, thermodynamics, fluid dynamics, tensor mechanics, materials science and chemistry) involved in the simulation of a tokamak.

References

[1] H. Brooks and A. Davis. `https://github.com/aurora-multiphysics/aurora`.

[2] C. J. Permann, D. R. Gaston, D. Andrš, R. W. Carlsen, F. Kong, A. D. Lindsay, J. M. Miller, J. W. Peterson, A. E. Slaughter, R. H. Stogner, and R. C. Martineau, "MOOSE: Enabling massively parallel multiphysics simulation," *SoftwareX*, vol. 11, p. 100430, 2020.

[3] D. R. Gaston, C. J. Permann, J. W. Peterson, A. E. Slaughter, D. Andrš, Y. Wang, M. P. Short, D. M. Perez, M. R. Tonks, J. Ortensi, L. Zou, and R. C. Martineau, "Physics-based multiscale coupling for full core nuclear reactor simulation," *Annals of Nuclear Energy*, vol. 84, pp. 45–54, 2015.

[4] P. K. Romano, N. E. Horelik, B. R. Herman, A. G. Nelson, B. Forget, and K. Smith, "Openmc: A state-of-the-art monte carlo code for research and development," *Annals of Nuclear Energy*, vol. 82, pp. 90–97, 2015. Joint International Conference on Supercomputing in Nuclear Applications and Monte Carlo 2013, SNA + MC 2013. Pluri- and Trans-disciplinarity, Towards New Modeling and Numerical Simulation Paradigms.