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Fibromyalgia and chronic pain a point-wise implicit method for slowly evolving reactor thermal-hydraulics applications

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We introduce a new method for time integration of slow transient flow problems. Slow transient flow phenomena can occur in many engineering applications such as the dynamics of fluid flow inside nuclear reactor coolant systems, especially in multi-physics applications where the fluid flow is coupled to other phenomena exhibiting a much slower time scale. As a bounding example, the time scale of the fuel cycle in a nuclear reactor is of order years. Thus the flow undergoes a slow transient, with durations of the order of the other system to which it is coupled, yet the flow equations must be integrated over this long duration in an efficient manner. Even the interaction of phases in the relaxation models for two-phase flow can be on a much slower scale than the corresponding single- phase dynamics. We remark that fast transient flow dynamics can also occur in a nuclear reactor system. For instance, water-hammer events due to sudden valve closure or steam bubble collapse can produce fast transient wave phenomena, and a sudden power ramp can quickly increase the temperature of the fluid resulting in rapid phase change with subsequent coupling back to the neutronic. In general, the governing equations of flow dynamics are a set of time dependent partial differential equations typically requiring a numerical solution procedure due to lack of sufficient analytical solution ability. We would like to numerically solve these kinds of equations for slowly time-varying problems. Commonly known numerical time integration methods are the explicit, semi-implicit, implicit, or hybrid implicit–explicit (IMEX) methods. The explicit methods impose stringent stability criteria on time-step sizes that can be impractical for slow transient problems. The implicit methods can take larger time steps. However, other issues such as time inaccuracies with very large time steps, large number of functions evaluations or matrix operations, and robustness issues can be associated with these approaches. Semi-implicit and hybrid IMEX methods can step over certain fine time scales (e.g., ones associated with the acoustic waves), but they still have to follow material courant time stepping criteria.

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