Thermal Hydraulics and Computational Fluid Dynamics

Tom Downar
Rizwan Uddin
Vlad Georgevich
Paul Dotson
Martin Bazant
Karen Vierow
Randy Summers
Graydon Yoder
Paul Meakin
Richard Martineau
Yassin Hassan

(John Turner, Hussein Khalil, Andy Siegel)

Summary

- General
  - The nuclear community in general and the CFD/TH community in particular needs to look outside for what has been done elsewhere.
  - ASCI/ASC has stimulated the development of significant advances in the area of CFD and the 7-Labs have developed a suite of codes that exceeds the sophistication of the tools currently being brought to bear on the nuclear reactor problem

Summary

- Define the Problem
  - The first step should be to clearly define the problem and identify what it is **we can not currently do well w/ legacy nuclear codes** (e.g. in the ASCI case it may have been an inability to do component aging?)
  - The ASC CFD codes/researchers should demonstrate the capability of their codes to address these problems.
  - There are some existing benchmarks (e.g. OECD/NUPEC/NRC BWR fuel assembly benchmark (2005) with detailed void distributions measured by computer tomography)

Summary

- Collaborators in CFD/Thermal-Hydraulics development
  - The development of next generation CFD/TH should be a 4-way partnership:

    Theorist
    Computational Scientist
    Experimentalist
    Designer/Analyst

  - The sophistication and instrumentation of new separate effects experiments should be designed with the purpose of validating the models in the code. This would be a subtle shift in the paradigm of experiments in the nuclear power community which have been performed primarily to validate a specific reactor type.
  - The designer/analyst must be integrated into the development as a stakeholder in the process to insure the outcome is a code suite that will address the correct application.

Summary

- The Role of Computational Science
  - High End Computing is important to advance the state of the art in CFD/Thermal-Hydraulics. However, it is important not become enamored with large scale computing.
  - Increases in computing power and the consequent increased spatial meshing that is possible will only be meaningful if the physics are there. (e.g. High end computing should enable the investigation of first principle turbulence, multi-fluid physics models)

Summary

- The Role of Computational Science (Cont.)
  - Improved numerical algorithms for coupling complex, multi-physics nonlinear systems is necessary.

    "The degree to which higher fidelity temporal and spatial coupling interacts w/ numerics is underappreciated."

  - The current methods of explicit coupling and fixed point iterations lead to excessive computational costs. The computational scientist should work closely with the theorists in each area (TH/neutronics/fuels/structural, etc) to investigate new methods for solving complex nonlinear problems for the multi-physics problem (e.g. Matrix Free Newton Krylov)
  - We should benefit from the experience of others in coupling large scale multi-physics codes (e.g. the French experience with SALOME) and also the work at the 7-Labs.

Summary

- Validation
  - Validation of this effort is crucial to success … however

    "the validation of complex non-linear systems is difficult"

  - The theorist, computational scientist, and experimentalist must work together to define intermediate goals to demonstrate success (e.g. every two years within a 10 year plan?)
  - This can have the secondary benefit to provide more sophisticated methods to address immediate problems within the "GEN III+" reactors which would benefit from full physics, high fidelity methods (e.g. crud deposition in LWRs).

Summary

- Grand Challenge to CFD / Thermal-Hydraulics
  - **Develop full physics, multi-scale, description of the multi-fluid field with quantified uncertainties.** Achieve this in a tightly coupled partnership of theorist, computational scientist, experimentalist, and **the analyst/designer**.
  - Seamlessly bridge the multiple scales (e.g. bubble-bubble -> sub-grid -> etc) which will allow the analyst / designer to choose the appropriate scale / physics needed for a particular problem.
  - Extend this to the disrupted core problem where the complexity increases significantly as geometries change and new physics is introduced.

Summary

- Grand Challenge to CFD / Thermal-Hydraulics (Cont.)
  - The objective should be to eliminate unnecessary (i.e. "stupid") experiments. (e.g. can numerical simulation eliminate some of the CHF experiments, or can a new reactor system be built without relying on large scale prototypes?)
  - The overarching goal is to accelerate the design/analysis of the next generation of nuclear plants and to have a significant impact on reducing the cost of nuclear power **with no compromise to the safety of the plant.**

Questions / Comments?