Validation & Verification: Fluent/RELAP5-3D© Coupled Code

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2001 RELAP5 User’s Seminar
Sun Valley, ID
September 2001
The Fluent RELAP5-3D Coupling..

• What we’re doing

• Why we’re doing it

• How we’ll make sure it is OK

• Our future plans
Overall Perspective...

- **DOE’s Generation IV Roadmap effort is a part of national strategy to gain public acceptance of nuclear power, and to encourage vendors and utilities to consider nuclear power as an option again.**

- **The roadmap program has received nearly a hundred reactor plant designs to evaluate including water-cooled, gas-cooled, liquid-metal cooled and other concepts.**

- **With the process underway to winnow the concept number down to 6 or so, a parallel effort is underway to evaluate our infrastructure:**
  - **Analytical tools**
  - **Regulatory & licensing practices**...etc.
Analytical Tools for Advanced Systems

- Further development is needed—particularly for working fluids other than water.

- Recent developments—particularly in the CFD world—need to be considered and used if advantageous.
Fluent & RELAP5-3D Are Being Coupled to...

- Enable an entire system to be modeled using 1-D features of RELAP5
- While modeling some sections of systems in great detail using Fluent
Development Underway Using Gas-Cooled Reactors as Basis

- **PBMR is focus**
- **Working fluid: helium**
- **Work to couple codes is ongoing by Walt Weaver. He will use PVM & same techniques described in papers by himself & Aumiller, et al.**
Once Coupling Is Completed...

• Validation & Verification* will be used to:
  – Check that Fluent and RELAP5/ATHENA have been coupled properly
  – Examine the strengths and weaknesses of the coupled code

• Important features that will be examined:
  – Behavior at interfaces between Fluent and RELAP5/ATHENA
  – Using neutronics with Fluent
  – Modeling flow through packed beds

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“Verification” is solving the equations right while “validation” is solving the right equations.
# A Portion of V&V Matrix

<table>
<thead>
<tr>
<th>Experiment or Case</th>
<th>Working Fluid</th>
<th>Phenomena of Interest or Objective</th>
<th>PBMR Region of Interest</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbulent flow in pipe section</td>
<td>Helium</td>
<td>Mesh coupling between Fluent &amp; RELAP5</td>
<td>PBMR inlet pipe</td>
<td>Streeter, V., 1961</td>
</tr>
</tbody>
</table>
| Turbulent flow in backward facing step with heat transfer | Air           | 1. Mesh coupling between Fluent & RELAP5  
2. Flow profile calculated by Fluent | PBMR inlet pipe and inlet plenum | Baughn, J. W., et al, 1984 |
| Neutronics-fluid Interaction in core region (LWR) | Water         | RELAP5/ATHENA neutronics coupling with Fluent mesh                      | Core; although this data set is for geometry unlike PBMR | Bovalini, R., et al, 2001 (used by permission of Y. Hassan) |
| Countercurrent two-phase flow              | Water & SF$_6$| 1. Mesh coupling between Fluent & RELAP5  
**Data (V&V Cases) Not Always Ideal**

- German data (AVR & THTR at Uentrop-Schmehausen) not available to public
- **Currently:**
  - No neutronics-fluid interaction data for PBMR core—but Fluent can’t model a packed-bed very well yet anyway.
  - Haven’t found countercurrent flow data more applicable (for CFD code) than Stewart, et al, 1992
- Working fluid and scaling usually not desirable.
References

Turbulent Flow in Straight Pipe

- **Purpose:** Study mesh coupling between Fluent and RELAP5/ATHENA. Determine factors which may detrimentally influence flow.
- **Assume well-developed flow (left to right); study mesh couplings and influence on velocity profile at Fluent/RELAP5 interface.**
Backward-Facing Step: Expanding Flow with Heat Transfer

- **Purpose:** Study coupling between Fluent—RELAP5/ATHENA and validate Fluent’s capability to model flow distribution downstream of step.

- **Region of applicability:** Entrance flow into PBMR core.
Backward-Facing Step (Cont-2)
Backward-Facing Step (Cont-3)

Ratio of local Nu to Nu for fully-developed flow as function of length for various turbulence models in Fluent—compared to Baughn data
Backward-Facing Step (Cont-4)

Typical velocity profiles calculated by Fluent.

Study not yet completed
Neutronics (RELAP5)-Fluent Coupling

- Perhaps best approach is to use OECD, CSNI-NSC PWR MSLB benchmark.
- Approach not defined. Perhaps model only portion of core using Fluent.
Countercurrent Steam-Water Flow Modeled Using Subcooled Water & $\text{SF}_6$

- **Purpose:** Examine capability of Fluent to model countercurrent flow of two different fluids
- **Test performed by Westinghouse** to study movement of superheated steam into SG and return of saturated water to core
- $\text{SF}_6$ (sulfur-hexafluoride) used to model superheated steam at high pressure.
- **Virtue of these data** are the nice temperature distribution measurements in leg, SG plenum, and core
Interim Plans: Use These Data Unless Better (More Applicable) Data Can Be Found
Fluent Calculation of Flow Through Pebble Bed

- Calculation was performed using CFX5
- Agreement with data within 10%.
- Both laminar flow and turbulent flow were modeled.
V&V Packed Bed Data-CFX5 Comparison: Within 10%
Summary

• *The Fluent-RELAP5 coupling is underway.*
• *A preliminary V&V matrix has been constructed.*
• *A search is underway for better data—but data are not readily available*