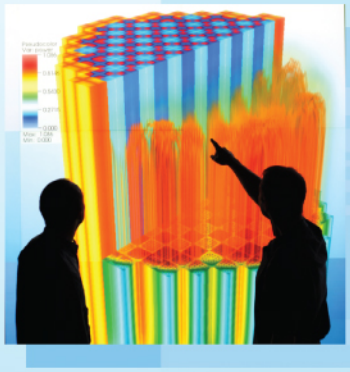
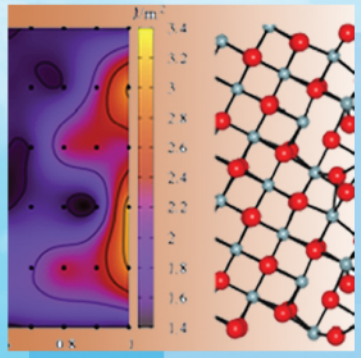
CASL-U-2014-0132-000

Power uprates
and plant life extension



Engineering design
and analysis

Science-enabling
high performance
computing



Fundamental science

Plant operational data

Consortium for Advanced Simulation of LWRs

Presentation Poster: HYDRA-TH Conjugate Heat Transfer (CHT)

Konor Frick
North Carolina State University

August 4, 2014

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

HYDRA-TH Conjugate Heat Transfer (CHT)

Konor Frick – North Carolina State University: Department of Nuclear Engineering

Mentor: A. Stagg **Program:** NESLS - CASL Division

Conjugate Heat Transfer Verification

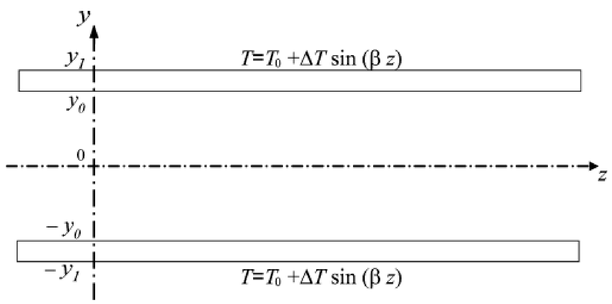


Figure 1: Longitudinal section of channel with boundary conditions

A. Barletta et al./ International Journal of Thermal Sciences 47 (2008) 43-51.

- Shows heat conduction through outer walls into moving fluid.
- Hydra CHT capability proven when compared with Barletta et. al results.

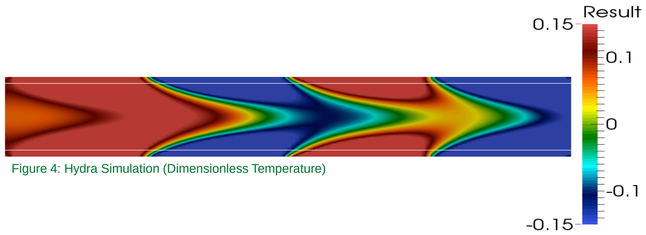


Figure 4: Hydra Simulation (Dimensionless Temperature)

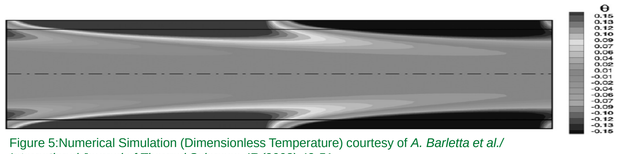


Figure 5:Numerical Simulation (Dimensionless Temperature) courtesy of *A. Barletta et al./ International Journal of Thermal Sciences 47 (2008) 43-51.*

Native Conjugate Heat Transfer Comparison

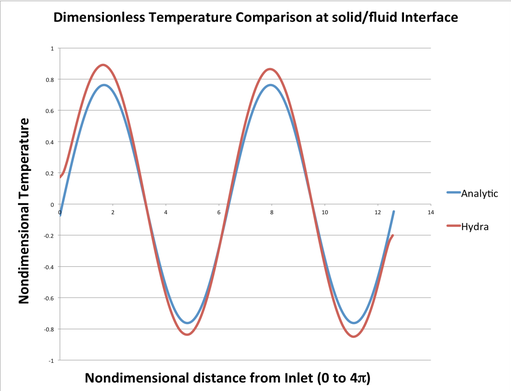


Figure 2: Analytic solution courtesy of: A. Barletta et al./ International Journal of Thermal Sciences 47 (2008) 43-51. Pe = 100, $\eta = 1$, $\gamma = 3$, B=100.

Where $\eta=y/y_0$; $\gamma=k_s/k_f$; Pe = Peclet Number
and the analytic solution shown in Figure 2 is given by equation 1 below

$$\theta(\eta,\zeta) = \theta_0(\eta) + \theta_1(\eta)\sin(B\zeta/Pe) + \theta_2(\eta)\cos(B\zeta/Pe) \quad (1)$$

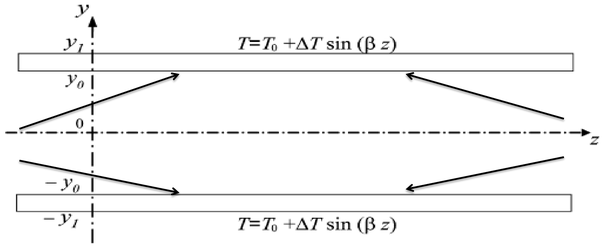


Figure 3: Solid Fluid Interface

- Preliminary Hydra CHT results with comparison to analytic solution
  - ✧*Conjugate forced convection heat transfer in a plane channel: Longitudinal periodic regime (A. Barletta et al. 2008).*
- Conjugate heat transfer through wall into fluid. Results at fluid/solid interface as shown below.

User Defined IC's/BC's Control File Setup

```
New Layout
# user velocity BC's in legacy block
velocitybc
   user velx fn fnid [dir direction] sideset  setid [A val] [B val] [C val] [D val]
   user vely fn fnid [dir direction] sideset  setid [A val] [B val] [C val] [D val]
   user velz fn fnid [dir direction] sideset  setid [A val] [B val] [C val] [D val]
end

# user temperature BC's in legacy block
temperaturebc
   user fn fnid [dir direction] sideset  setid [A val] [B val] [C val] [D val]
End
```

```
# Integrated in IC's block
Initial
    user velx fn fnid [dir direction] [A val] [B val] [C val] [D val]
    user vely fn fnid [dir direction] [A val] [B val] [C val] [D val]
    user velz fn fnid [dir direction] [A val] [B val] [C val] [D val]
    user temperature fn fnid [dir direction] [A val] [B val] [C val] [D val]
    …
End
```

- Direction is the desired direction of the function.

Ex: fn 1 dir x ➔ $A*x^3 + B*x^2 + C*x + D$
fn 1 dir y ➔ $A*y^3 + B*y^2 + C*y + D$
fn 1 dir z ➔ $A*z^3 + B*z^2 + C*z + D$

Functions available to User

3 Function classes available using A, B , C , and D

1. $A*x^3 + B*x^2 + C*x + D$
2. $A*\cos(B*x) + C*\sin(D*x)$
3. $A*e^{B*X} + C$

Also available is the ability to input several user defined functions using case structure and simply add on another case for each new user defined function.

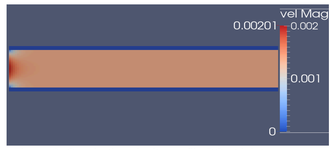


Figure 6: Quadratic velocity profile BC at inlet

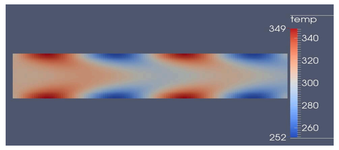


Figure 7: Sinusoidal temperature boundary conditions

Figure 8: Quadratic velocity profile global initial condition with rigid constraint.

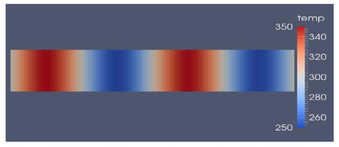


Figure 9: Sinusoidal temperature profile global initial condition.

Block Initial Conditions

Implementation of block initial conditions as opposed to the current globally defined initial conditions allows for different initial conditions to be applied to different regions of the problem. I.E. Different initial conditions at the top and bottom of the core.

Initial condition application order in Hydra-TH

1. Apply Global Initial Conditions
   I. Apply Simple Initial Conditions
   II. Apply User-Defined Initial Conditions
   III. Apply Rigid Constraint (based on material)
2. Apply Block Initial Conditions
   I. Apply Simple Initial Conditions
   II. Apply User-Defined Initial Conditions

Figure 10: Block velocity initial conditions (rigid constraint on 2 outer blocks)

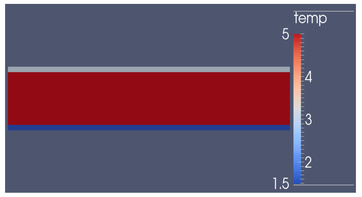


Figure 11: Block temperatures applied Block 1: 3.0
Block 2: 5.0
Block 3: 1.5

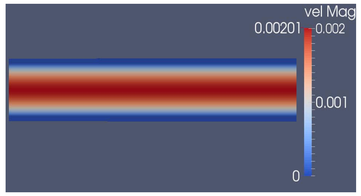


Figure 12: Quadratic velocity profile block initial condition with rigid constraint.

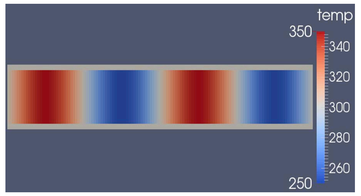


Figure 13: Block temperature initialized with user function.

Future Work

1. Implementation of interface heat flux designation capability.

References

A. Barletta et al. Conjugate Forced Convection Heat Transfer in a Plane Channel: Longitudinally Periodic Regime. *International Journal of Thermal Sciences*, *47*, 43-51. 2008.

Acknowledgments

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OAK RIDGE National Laboratory

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