Min-Tsung Kao

Email: kaom@ornl.gov

Education

University of Illinois at Urbana-Champaign

Ph.D.	Department of Nuclear, Plasma and Radiological Engineering, Aug 2012 - May 2020.
Advisor	Rizwan-Uddin
Dissertation	A Lattice Boltzmann/S_N Framework for Coupled Heat Transfer and Neutron Transport Problems

National Tsing Hua University, Hsinchu, Taiwan

M.S.	Department of Engineering and System Science, Jun 2007 - Jul 2009
Advisors	Ching-Chang Chieng and Min Lee
Thesis	Heat Transfer Deterioration in a Supercritical Water Channel
B.S.	Department of Engineering and System Science, Sep 2003 - Jun 2007

Academic and Research Experiences

- Oak Ridge National Laboratory
  - **STS Target Systems Engineering Analyst**, 11/01/2022 - present
  - **Postdoctoral Research Associate – Computational Fluid Dynamics (CFD) application engineer**, 05/04/2020 - 10/31/2022
  - **Participant** of the ASTRO program at ORNL, 01/07/2019 - 12/13/2019
- Department of Nuclear, Plasma, and Radiological Engineering, UIUC
  - **Teaching Assistant** of NPRE 247 for Prof. Tomasz Kozlowski, 2012.
- Department of Engineering and System Science, NTHU
  - **Research Assistant** for Prof. C. C. Chieng, Nov 2009 - Jan 2010 & Dec 2010 - Aug 2012.
- Westinghouse Electric Company, LLC
  - Participant of a training program (supervised by Prof. C. C. Chieng), May 2009 - Nov 2009.

Other Experiences

- **Serving Alternative service for military duty in Bureau of Foreign Trade**, Jan 2010 - Dec 2010

Computational Skills

- CFD Software: STAR-CCM+, ANSYS Fluent, COMSOL Multiphysics
- Programming tools: Matlab, Python, C
- Others: Wolfram Mathematica, OriginLab, AutoCAD, SolidWorks, SpaceClaim, Visit, ParaView, Tecplot

Publications

- **M.T. Kao**, T. McManamy, I. Remec, and L. Zavorka,"CFD Analyses for Various STS Early Target Cooling Channel Concepts," 8th Thermal and Fluids Engineering Conference (TFEC), October 2022 (Accepted).
- P. Jain, **M.T. Kao**, V. M. Rao, E. L. Popov, D. T. Nguyen, J. Wilson, V. Badalassi, W. D. Pointer,"Computational Fluid Dynamics Modeling to Simulate a Combined Reforming Process for Syngas and Hydrogen Production," ORNL Report, November 2021.
- **M.T. Kao** & R. Uddin,"S_N and LBM to solve coupled transport and energy equations for temperature-dependent cross sections," Transactions of the American Nuclear Society, vol. 119, p. 572-575, 2018
- **M.T. Kao**, P. Jain, S. Usman, I.A. Said, M.M. Taha, Muthanna M. Aldahhan and Rizwan Uddin, "Investigation of Plenum-to-Plenum Heat Transfer and Gas Dynamics under Natural Circulation in a Scaled-Down Dual Channel Module Mimicking Prismatic VHTR core using CFD," International Topical Meeting on Nuclear Reactor Thermal Hydraulics 2015, NURETH 2015, vol. 2, p. 979–995, 2015.
- **M.T. Kao** & R. Uddin, "Temperature in a Fuel Rod with a Coated Clad and Temperature Dependent Thermal Conductivity," Transactions of the American Nuclear Society, vol. 110, p. 712–715, 2014.
- **M.T. Kao**, Y. H. Tung, Y. M. Ferng, C. C. Chieng, "Investigating effects of sphere blockage ratio on the characteristics of flow and heat transfer in a sphere array," Energy Conversion and Management, vol. 81, p. 455–464, 2014.
- **M.T. Kao**, Y. H. Tung, Y. M. Ferng, C. C. Chieng, M.K. Chyu, "3D measurements and numerical computations of heat transfer coefficients on spheres in an array," International Journal of Thermal Sciences, vol. 68, p. 110–118, Jun. 2013.
- Y. Xu, M. Conner, K. Yuan, M. Dzodzo, Z. Karoutas, S. Beltz, S. Ray, T. Bissett, C.C. Chieng, **M.T. Kao**, C.Y. Wu, , "Study of impact of the AP1000® reactor vessel upper internals design on fuel performance," Nuclear Engineering and Design, vol. 252, p. 128–134, Nov. 2012.
- **M.T. Kao**, C.Y. Wu, C.C. Chieng, Y. Xu, K. Yuan, M. Dzodzo, M. Conner, S. Beltz, S. Ray, T. Bissett, "CFD analysis of PWR core top and reactor vessel upper plenum internal subdomain models," Nuclear Engineering and Design, vol. 241, no. 10, p. 4181–4193, 2011.
- **M.T. Kao**, M. Lee, Y. M. Ferng, and C. C. Chieng, "Heat transfer deterioration in a supercritical water channel," Nuclear Engineering and Design, vol. 240, no. 10, p. 3321–3328, 2010.
- Y. Xu, K. Yuan, M. B. Dzodzo, M. E. Conner, S. A. Beltz, S. Ray, T. A. Bissett, C. C. Chieng, **M.T. Kao**, and C. Y. Wu, "Computational fluid dynamics analysis of AP1000™ reactor vessel upper plenum and top core slab," LWR Fuel Performance Meeting/Top Fuel/WRFPM, p. 779–786 2010.
- Y. Xu, M. E. Conner, K. Yuan, M. B. Dzodzo, Z. Karoutas, S. A. Beltz, S. Ray, T. A. Bissett, C. C. Chieng, **M.T. Kao**, and C. Y. Wu, "Study of Impact of the AP1000® Upper Internals Design on Fuel Performance," Proceedings of 2010 LWR Fuel Performance Meeting/Top Fuel/WRFPM, p. 772-778, 2010.
- **M.T. Kao**, Y. M. Ferng, M. Lee, and C. C. Chieng, "CFD analysis of heat transfer enhancement in supercritical water channels," Transactions of the American Nuclear Society, Vol. 100, p. 719-721, 2009.

Presentations

- M.T. Kao & R. Uddin, "S_N and LBM to Solve Coupled Transport and Energy Equations for Temperature-Dependent Cross Sections," 2018 ANS Winter Meeting and Nuclear Technology Expo, Orlando, FL, November 11-15, 2018

- M.T. Kao & R. Uddin, "Solving Coupled Neutron Transport and Heat Conduction with Temperature-dependent Thermal Conductivity Using The Lattice Boltzmann Framework," PHYSOR 2018: Reactors Physics paving the way towards more efficient systems Cancun, Mexico, April 22-26, 2018

- M.T. Kao & R. Uddin, "Temperature in a fuel rod with a coated clad and temperature dependent thermal conductivity," Annual Meeting on Transactions of the American Nuclear Society and Embedded Topical Meeting: Nuclear Fuels and Structural Materials for the Next Generation Nuclear Reactors, NSFM 2014 - Reno, NV, United States, June 15-19 2014.

Current CFD Projects

- **CFD Model Development for the Second Target Station (STS)**: The second target station (STS) at the Spallation Neutron Source (SNS) is designed to produce the world's highest peak brightness neutron source with a short pulse 700 kW proton beam at 15 Hz using solid rotating tungsten target segments. The tungsten is hipped with tantalum clad to minimize corrosion. Advanced Computational fluid dynamics (CFD) approach were developed in STAR-CCM+ to investigate various cooling channel designs for the STS target segment to improve heat transfer performance for different proton beam profiles, including normal, off-center, peaked, and diffuse proton beams. The energy depositions in the target segments were calculated from neutronic analysis. The results from transient heat sources that model all proton pulses and equivalent steady state heat sources were compared and analyzed. The impact of Coriolis and centrifugal forces in the rotating target were also investigated. The impact of reduced thermal conductivity in tungsten due to irradiation damage was also studied with dpa-dependent thermal conductivity in the CFD analysis. Air trapping study was also conducted to ensure the trapped air in the target segment during the initial filled with stagnant water can be evacuated during the normal operation. Several new target concepts, such as Cheese Wedge, Ravioli, Overhead Fondue target designs that aim to optimize both factor of safety (FOS) of engineering design and neutronic performance are under CFD investigations to ensure the pressure drop and the temperature profiles are within the design limits. Several CFD analyses were also performed for the STS shielding block cooling channel designs.

Past CFD Experience/Projects

- **COMSOL Model Supports a Developing Fusion Reactor Design Tool**: The main objective of this project was to develop methods of coupling COMSOL Multiphysics with other software, such as MCNP, CadQuery, PROCESS Code. Several methods had been developed with the "Method Call" feature in COMSOL to automatically import external geometry (assume from CadQuery) and heat source (assume from MCNP) files into COMSOL to perform CFD and thermal stress analysis. The temperature profile and maximum stress for each design were automatically exported, and can be used for further optimization analysis. CadQuery is a python library for generating parametric 3D CAD models. Integrating COMSOL with CadQuery and other software for the thermal analysis allows for geometry exploration and optimization for the reactor design. Some preliminary curve-fitting techniques for the 2-D plasma region (a closed curve) were also developed to adjust the size and the shape of the plasma geometry that was described by a mathematical expression.

- **Thermal Analysis for the RID Imaging System (106090200-DA0004, R00)**: The objective of this thermal analysis was to investigate and understand the heat transfer characteristics of the mirrors in the Ring Injection Dump (RID) imaging system of SNS facitliy at ORNL and quantify their temperature rise to assess any thermomechanical impact. The mirrors reside within a vacuum environment, and are located slightly above and below the nominal beam path; thus, receiving some radiative heat load from the beam. The goal of this analysis was to evaluate if cooling system was a necessity for the mirrors. The heat deposited in the mirrors was conducted to the neighboring components, and then dissipated to the environment, which was climate controlled to about 72 °F (22.2 °C). Five different values of heat transfer coefficient (h = 2, 4, 6, 8, and 10 W/m^2-K were investigated in this study. For the worst case with h = 2 W/m^2-K, the maximum temperature in the mirror was 73.15 °F (22.86 °C), which was 1.15 °F (0.64 °C) higher than the environment temperature, 72 °F (22.2 °C). It was concluded that the temperature increase in the mirror due to the heating from the radiation was not significant, and additional cooling system was not needed for the mirrors in RID.

- **NEUP-12-3730, Probabilistic Multi-Hazard Assessment of Dry Cask Structures (Chapter 4)**: Different degradation mechanisms, including chemical effects in the form of alkali silica reaction (ASR), exist in the spent fuel concrete dry cask storage systems. For accurate simulation of the degradation mechanism, it is important to know the thermal state of the concrete. Thus, the goal of the CFD work was to determine the thermal state of the cask. The VSC-17 cask was chosen for the benchmark calculation of the temperature distribution inside the dry cask. It was found that 70 % of decay heat was removed by natural circulation in annular airflow channel inside the storage system. For the air outlet (115 °C) and concrete outer wall (65 °C) temperatures to be comparable to those in the literature for normal ambient temperature (27 °C), it was determined that thermal radiation and turbulent flow models should both be considered in the CFD simulations.

- **NEUP-13-4953, Experimental and Computational Investigations of Plenum-to-Plenum Heat Transfer and Gas Dynamics under Natural Circulation in a Prismatic Very High Temperature Reactor (Chapter 9)**: To investigate plenum-to-plenum heat transfer under natural circulation conditions in a VHTR, a simplified system—consisting of heated and cooled channels, and upper and lower plenums—was designed as a representative geometry for the Prismatic Block Modular Reactor (PBMR). Experimental data indicated that there is a drop of air temperature occurring near the top of heated channel and that was believed to be the evidence of re-circulation and plumes mixing occurring at the top of heated channel and upper plenum. Due to small tube diameters (0.625 inches) of this scaled down system, it was very difficult to measure the velocity distributions inside the tubes and the upper plenum. The goal of the CFD simulations was to verify that the observed temperature drop was due to the natural circulation in this closed loop system. Preliminary CFD works only considered fluid region for simplicity but no temperature drop appeared in the simulations. Further investigations indicated the importance of conjugate heat transfer (fluid + solid) simulation for such systems; and that it was inappropriate to use boundary conditions, such as heat flux or temperature, on the solid/fluid interfaces and ignoring the solid structure (pipe wall). The conjugate heat transfer in CFD simulations indicated the drop of air temperature observed in the experiments were not due to plumes mixing or re-circulation in upper plenum. The drop of temperature was due to the low temperature maintained on the cooled channel and that this low temperature affects the heated wall temperature because of the high thermal conductivity of the channel wall. This phenomenon was clearly observed when conjugate heat transfer was performed in the CFD simulations.