Pradeep Kumar Pavalavanni, Ph.D.

Research Scientist | Reactive-Flow CFD & Digital Twins

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SUMMARY

Computational scientist (PhD) with 9+ years of research experience, including 5+ years post-PhD, in high-fidelity reactive-flow CFD, explosion hazard modeling, and data-driven machine learning. Built and deployed ML-based surrogates and digital-twin-ready workflows that couple CFD, experiments, and control frameworks to predict complex thermal-fluid behavior. Previously co-developed and validated explosion-hazard CFD solvers at Shell, and now extending this expertise toward battery safety, mentoring thermal-runaway modeling research. Lead author of peer-reviewed publications, collaborating across academia and government labs. Seeking to bring science-based AI and hazard-modeling expertise to ESRI's mission of advancing safer energy storage.

EDUCATION

Doctor of Philosophy, Aerospace Engineering | *Pusan National University, Busan, South Korea* **2015 - 2021**

Master of Science, Aerospace Engineering | *Pusan National University, Busan, South Korea* **2013 - 2015**

Bachelor of Engineering, Aeronautical Engineering | *Anna University, Tamil Nadu, India* **2008 - 2012**

CORE COMPETENCIES

- **AI/ML Surrogates & Digital Twins:** Developed bi-fidelity neural-network surrogates (TensorFlow) that fuse CFD and experimental data to accelerate prediction of combustion and thermal behavior; coupled with control frameworks for hardware-in-the-loop digital-twin testing.
- **Reactive-Flow CFD & Physics-Based Modeling:** Developed and applied high-fidelity solvers for compressible, reacting flows, spanning detonation, shock-induced combustion, and engine combustion (OpenFOAM, Converge CFD, in-house Fortran).
- **Explosion Hazard Modeling:** Co-developed and validated PDRFOAM-R, a compressible reactive-flow solver for industrial-scale explosion and deflagration, against experiments from 2 m to 100 m scale.
- **Battery Safety Applications (Emerging):** Initiated a preliminary, self-directed project on heat-induced thermal-runaway modeling in LFP and NMC lithium-ion cells; developed a Python tool that derives reaction rates from experimental data as inputs for battery fire CFD, and mentor undergraduate research on this work.
- **HPC, Solver Development & Validation:** Customized and ran CFD solvers (Fortran, OpenFOAM, Converge CFD) on Linux and Windows high-performance computing (HPC) clusters (MPI/OpenMP); built Python automation for post-processing, calibration, and cross-solver integration between OpenFOAM and Converge CFD.
- **Research Collaboration & Mentorship:** Collaborate with CFD, experimental, and controls teams across multiple universities and U.S. Army DEVCOM ARL; lead author on peer-reviewed and AIAA conference papers; mentor student researchers.

TECHNICAL SKILLS

Programming & ML: Python (TensorFlow, deep learning, workflow automation), Fortran, C/C++, MATLAB, LaTeX

CFD & Post-Processing: OpenFOAM, Converge CFD, in-house Fortran solvers; ParaView, Tecplot

Digital Twins & HPC: Digital-twin and HIL control frameworks; Linux and Windows HPC clusters (MPI/OpenMP)

LEADERSHIP & PROFESSIONAL IMPACT

- **Research Featured by AIAA:** Work on AI-driven experimentation and simulation (feature-focused bi-fidelity surrogate modeling for engine control) selected by the AIAA Propellants and Combustion Technical Committee for Aerospace America's Year-in-Review (January 2027 issue).
- **Invited Seminar Speaker:** Delivered an invited seminar on reactive-flow and combustion modeling to faculty and graduate students at the Department of Mechanical and Industrial Engineering, University of Minnesota-Duluth (Spring 2026).
- **Session Chair:** Served as session chair for combustion and detonation sessions at the AIAA SciTech Forum (2025, 2026).
- **Peer Reviewer:** Reviewed 20+ manuscripts for international journals, including Proceedings of the Combustion Institute, International Journal of Engine Research, and MDPI journals (Energy Storage and Applications, Batteries, Energies).

PROFESSIONAL EXPERIENCE

Research Scientist / Postdoctoral Research Associate — Nov 2022 - Present

University of Minnesota, Twin Cities, USA | Computational Reactive Flow and Energy Lab

- Developed and deployed bi-fidelity neural-network surrogate models (TensorFlow) that fuse 3D CFD and experimental data to predict crank-angle-resolved pressure and combustion characteristics across multi-fuel operating conditions, coupled with control frameworks for hardware-in-the-loop (HIL) digital-twin applications.
- Achieved prediction times of about 1 second per cycle (vs. 24-48 hours for full 3D CFD) with error within 3% of experiment, versus up to 20-30% for CFD in extreme operating cases.
- Designed end-to-end CFD-experiment validation pipelines with Python automation for post-processing, accelerating simulation-to-validation turnaround.
- Built Python tooling that links plasma modeling in OpenFOAM with combustion modeling in Converge CFD, enabling multiphysics plasma-assisted ignition studies across solvers.
- Collaborate with CFD, experimental, and controls teams at University of Wisconsin-Madison, Politecnico di Milano (Italy), and U.S. Army DEVCOM ARL to implement solvers, validate models, and deploy reduced-order models.
- Initiated a preliminary, self-directed project (via UMN's Undergraduate Research Opportunities Program) on modeling heat-induced thermal runaway in LFP and NMC cells; developed a Python tool to derive reaction rates from experimental data as inputs for battery fire CFD.
- Perform crank-angle-resolved 3D CFD of Energy-Assisted Compression Ignition engines on HPC clusters (Converge CFD, OpenFOAM/LibICE), evaluating glow-plug, spark, and plasma-assisted ignition of low-cetane and synthetic aviation fuels.
- Mentor 5+ undergraduate and graduate researchers on CFD methods, simulation workflows, and model validation.

Technical Safety Engineer, Major Hazards Management — Sep 2021 - Oct 2022

Shell Technology Centre, Bangalore, India | Major Hazards Management Team

- Co-developed PDRFOAM-R, a compressible turbulent reactive-flow solver for explosion and deflagration modeling, and performed all testing and validation against experimental data across scales from 2 m to 100 m.
- Quantified overpressure and ignition sensitivity across validation cases, benchmarking predictions of flame acceleration and pressure-wave propagation against experiments.
- Independently identified and corrected case-setup inconsistencies in validation runs, improving agreement with experiments.
- Co-authored a HAZARDS32 conference paper (2022) on CFD simulation of deflagration using PDRFOAM.

Career Break (family commitments) — Feb 2021 - Sep 2021

- Presented doctoral research on detonation cell bifurcation remotely at the AIAA Propulsion and Energy Forum (2021).

Graduate Researcher — 2017 - 2021

Pusan National University, Busan, South Korea | Rocket Propulsion Laboratory

- Developed and validated high-resolution compressible reacting-flow solvers in Fortran, incorporating detailed chemical kinetics and shock-capturing schemes for detonation and shock-induced combustion.
- Benchmarked chemical kinetic mechanisms and performed numerical stability and resolution sensitivity studies to balance fidelity against computational cost.
- Applied Dynamic Mode Decomposition and Chemical Explosive Mode Analysis to characterize detonation instability and transient structures, extracting physics from high-fidelity simulations.
- Proposed a mechanism for detonation cell bifurcation linking shock dynamics, ignition chemistry, and heat release; published as lead author in Aerospace (2023), with related work in Proceedings of the Combustion Institute.

PUBLICATIONS

Peer-Reviewed Journals

- P.K. Pavalavanni, M-S. Jo, J-E. Kim, J.-Y. Choi (2023). Numerical Investigation of the Detonation Cell Bifurcation with Decomposition Technique. Aerospace, 10(3), 318.
- P.K. Pavalavanni, M-S. Jo, J-E. Kim, J.-Y. Choi (2023). Numerical Study of Unstable Shock-Induced Combustion with Different Chemical Kinetics and Investigation of the Instability Using Modal Decomposition Technique. Aerospace, 10(3), 292.

- M. Nejaamtheen, T-Y. Kim, P.K. Pavalavanni, J.H. Ryu, J.-Y. Choi (2021). Effects of the Dimensionless Radius of an Annulus on the Detonation Propagation Characteristics in Circular and Non-Circular Rotating Detonation Engines. Shock Waves, 31(7): 703-715.
- P.K. Pavalavanni, C.H. Sohn, B.J. Lee, J.-Y. Choi (2019). Revisiting Unsteady Shock-Induced Combustion with Modern Analysis Techniques. Proceedings of the Combustion Institute, 37(3): 3637-3644.
- P.K. Pavalavanni, J.-Y. Choi, J. Son, H.S. Chae (2017). Applications of Dynamic Mode Decomposition to Unstable Shock-Induced Combustion. Journal of the Korean Society of Propulsion Engineers, 21(2): 9-17.
- P.K. Pavalavanni, K.-S. Kim, S. Oh, J.-Y. Choi (2015). Numerical Comparison of Hydrogen-Air Reaction Mechanisms for Unsteady Shock-Induced Combustion Applications. Journal of Mechanical Science and Technology, 29(3): 893-898.

Manuscripts in Preparation

- P.K. Pavalavanni, et al. (2026). Development of a Bi-Fidelity Neural Network Surrogate Framework and Its Application to Feed-Forward Control of Multi-Fuel Energy-Assisted Compression Ignition Engines.
- P.K. Pavalavanni, et al. (2026). Layered Multi-Input Neural Networks for Cross-Dimensional Data Assimilation and High-Dimensional Engine Control Testing. In progress.

International Conferences (Recent and Relevant)

- P.K. Pavalavanni, et al. (2026). A Feature-Focused Neural Network Based Bi-Fidelity Surrogate Model for Combustion Prediction in Aerial Internal Combustion Engines. AIAA SciTech 2026.
- Sai Ranjeet Narayanan, P.K. Pavalavanni, et al. (2026). Numerical Modeling of Spark Ignition in Aerial Internal Combustion Engines Using Low Cetane Number Sustainable Aviation Fuels. AIAA SciTech 2026.
- Praise Noah Johnson, P.K. Pavalavanni, et al. (2026). Modeling of Plasma Ignition of Low Cetane Fuels in an Aerial Internal Combustion Engine. AIAA SciTech 2026.
- P.K. Pavalavanni, et al. (2025). Bi-Fidelity Neural Network Model for Multi-Fuel Capable Internal Combustion Engines. AIAA SciTech 2025.
- P.K. Pavalavanni, et al. (2024). Numerical Modeling of Energy Assisted Compression Ignition Engines for Aerial Operations. AIAA SciTech 2024.
- S. Raghunath, P. Sathiah, P.K. Pavalavanni (2022). Progress in CFD Simulation of Deflagration Using PDRFOAM. HAZARDS32 Conference.
- P.K. Pavalavanni, J. Ryu, J.-Y. Choi (2021). Dynamic Mode Decomposition Analysis of the Detonation Cell-Bifurcation Process. AIAA Propulsion and Energy Forum.
- P.K. Pavalavanni, et al. (2019). Modal Decomposition Analysis of Fuel-Air Mixing in a Supersonic Combustor with a Cavity. AIAA Forum.