

Anuj Kumar

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EDUCATION

PhD in Mechanical Engineering, Minor in Applied Mathematics | (GPA: 4.0/4.0) Aug. 2019 – Present
North Carolina State University *Raleigh, NC*

MS in Mechanical Engineering | (GPA: 4.0/4.0) en-route to PhD
North Carolina State University *Raleigh, NC*

Bachelor of Technology in Mechanical Engineering | (GPA: 8.4/10.0) July 2012 – May 2016
Indian Institute of Technology Kanpur *Kanpur, India*

TECHNICAL SKILLS

Programming Languages: Python, C/C++, Fortran, MATLAB
ML Developer Tools: JAX, TensorFlow, Git, CUDA, PETSc, VS Code, Jupyter
ML Architectures: Transformer, GNN, Autoencoder, CNN, DeepONet, PINNs
Software Packages: ANSYS Fluent, CONVERGE, Tecplot, Cantera

RESEARCH EXPERIENCE

Research Assistant, Computational Combustion and Energy Sciences Lab, NCSU Jan. 2021 – Present
React-DeepONet: An Efficient Deep Learning Chemical Kinetics Solver

- Developed an efficient and robust surrogate model for stiff chemical kinetics based on Deep Operator Networks
- Devised novel DeepONet architecture and training mechanism for robustness and physical constraints compliance
- Efficiently integrated Python based surrogate ML model with C based CFD simulation software (CONVERGE)
- Achieved speed-up of 100 for a highly complex turbulent combustion system of ECN Spray A

Turbulent Combustion Closure with Physics-Informed DeepONet *In collaboration with a lab-mate*

- Modeled physics-informed DeepONet and formulated its training mechanism in JAX
- Modified DeepONet architecture to demarcate training for turbulence and combustion and extract source terms for species
- Obtained species source terms and high-fidelity scalar values from sparse experimental observations

Reduced- Order Modeling of Turbulent Combustion *In collaboration with Sandia National Lab.*

- Low- dimensional manifold in form of Principal Components (PC) is evolved in a direct numerical simulation
- Obtained robust and accurate mapping for PC sources and transport coefficients via high-fidelity neural networks
- Achieved speed-up of 80 with high accuracy on a laboratory-scale Bunsen flame

Research Aide - PhD, Multi-Physics Computations, Argonne National Lab. May 2023 – Dec. 2023
Neural ODE Surrogate Model for Still-Chemical Kinetics

- Implemented second-order optimizer (Levenberg–Marquardt) for efficient model training and robust predictions
- Deployed physics-informed formulation for faster training and physically compliant and robust predictions
- Devised Latent Space Kinetics Identification through Neural ODE for large and complex fuels

Research Assistant, NCSU Aug. 2019 – Dec. 2020
Stability and Resolvent Analysis of Turbulent Boundary Flows

- Identified the unstable Reynolds number through eigenvalue analysis of the linearized flow operator
- Formulated reduced order dynamics through Resolvent Analysis on time averaged mean flow data
- Captured low-frequency unsteadiness and identified most-energetic turbulent eddies after flow separation in the shock-wave turbulent boundary layer interaction

Summer Research Intern, GE Aviation, General Electric India May 2015 – July 2015
Thermal Buckling in a Jet Engine Compressor Disk

- Modeled a solid disk and performed eigenbuckling analysis via Ansys, aligning results with theoretical predictions
- Predicted the compressor disk's factor of safety using the established solid disk analysis method

Suppression of the Vortex Shedding around a Square cylinder

- Numerically investigated flow around a square cylinder; discretizing Navier-Stokes equation by Marker and Cell Method
- Identified suppression region and obtained drag coefficient for various sizes of control cylinders and Reynolds numbers

PROJECTS

Linear Reduced Basis Extraction from Autoencoder

Oct. 2021 – Dec. 2021

- Identified differences in reduced-order basis and modes from linear Autoencoder and POD
- Customized hidden layers of the decoder and regularized the loss function to get same basis as POD

Reduced-Order Dynamics of Compressible Channel Flow

Oct. 2020 – Dec. 2020

- Obtained reduced order basis for the turbulent flow in form of dominant POD and DMD modes
- Identified similarities in dominant flow frequencies and structures from DMD and Resolvent analysis

Development of an FVM solver for Euler equations on unstructured grids Feb. 2020 – Apr. 2020

- Developed a compressible Euler equation solver in Fortran for 2D unstructured meshes
- Evaluated Fluxes using the Van Leer flux vector splitting and reconstruction-evolution (MUSCL) methods
- Validated the solver for subsonic, transonic and supersonic flows past a circular cylinder, NACA0012 airfoil and circular bump

INVITED TALKS AND CONFERENCE PRESENTATIONS

- 1. The Crunch Group, Brown University**(Invited Talk) Feb. 2024
Efficient and Physically Consistent Surrogate Modeling of Chemical Kinetics Using Deep Operator Networks
- 2. NeurIPS 2023, Machine Learning and the Physical Sciences** Dec. 2023
Physics - Informed Machine Learning for Reduced Space Chemical Kinetics
- 3. Multi-Physics Computations, Argonne National Lab.** Dec. 2023
Development of a Neural ODE-based Scientific Machine Learning Framework Towards Acceleration of Combustion CFD Simulations
- 4. 76th Annual Meeting of the APS Division of Fluid Dynamics** Nov. 2023
A Framework for Combustion Chemistry Acceleration with DeepONets
- 5. The 13th U.S. National Combustion Meeting** Mar. 2023
Acceleration of Stiff Chemistry Integration with DeepONets
- 6. Multi-Physics Computations, Argonne National Lab.**(Invited Talk) Mar. 2023
Combustion Simulation Acceleration via Principal Component (PC) Transport and Deep Operator Networks (DeepONets)
- 7. 76th Annual Meeting of the APS Division of Fluid Dynamics** Nov. 2022
Acceleration of Turbulent Combustion Simulation through Principal Components Transport and Machine Learning
- 8. 18th International conference on Numerical Combustion** May. 2022
Reduced Order Modeling of Turbulent Combustion via Principal Component Transport

LEADERSHIP

Vice-President, MAE Graduate Student Association

2022 – 2023

- Led the organization of key social and professional departmental events, enhancing community engagement
- Chaired weekly GSA committee meetings, ensuring leadership continuity and decision-making efficacy

Manager, Mechanical Division of Sinter Plant, Tata Steel India

July 2017 – July 2019

- Efficiently managed planned shutdowns and breakdowns, minimizing operational disruptions
- Formulated and executed annual budgets, optimizing inventory management and cost efficiency
- Led and developed a team of 25 junior engineers, enhancing team performance and skillset

National Cadet Corps Cadet, 2 UP Composite Technical Regiment

July. 2012 – May. 2013

- Actively engaged in adventurous activities including parasailing and target shooting, and contributed to awareness rallies

- [1] **Anuj Kumar** and Tarek Echekki. Combustion chemistry acceleration with deepnets. *Fuel*, 365:131212, 2024.
- [2] Ki Sung Jung, **Anuj Kumar**, Tarek Echekki, and Jacqueline H. Chen. On the application of principal component transport for compression ignition of lean fuel/air mixtures under engine relevant conditions. *Combustion and Flame*, 260:113204, 2024.
- [3] **Anuj Kumar** and Tarek Echekki. Physics - informed machine learning for reduced space chemical kinetics. 2023. NeurIPS 2023 Workshop: Machine Learning and the Physical Sciences.
- [4] Tadbhagya Kumar, **Anuj Kumar**, and Pinaki Pal. A physics-constrained neuralode approach for robust learning of stiff chemical kinetics. 2023. NeurIPS 2023 Workshop: Machine Learning and the Physical Sciences.
- [5] **Anuj Kumar**, Martin Rieth, Opeoluwa Owoyele, Jacqueline H. Chen, and Tarek Echekki. Acceleration of turbulent combustion dns via principal component transport. *Combustion and Flame*, 255:112903, 2023.
- [6] **Anuj Kumar** and Tarek Echekki. A Framework for Combustion Chemistry Acceleration with DeepONets. *arXiv preprint arXiv:2304.12188*, 2023.