

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.