ME Seminar

Fluid Mechanics of Endurance: From Transoceanic migratory dragonflies to Micro-Air Vehicles

Prof. Sandeeep Saha, Department of Aerospace Engineering, IIT Kharagpur, India

ABSTRACT

Nature's flyers exhibit unparalleled efficiency and resilience, performing transoceanic migrations that challenge our fundamental understanding of low-Reynolds-number aerodynamics. We will explore the intersection of biology and engineering through the lens of *Pantala flavescens*, a dragonfly capable of 14-18,000 km annual round trip across the Indian Ocean in 4 generations *i.e* the longest known insect migration. By integrating biological observation with energetic analysis that is constrained by graph theory, we uncover the mechanisms enabling such extreme endurance. We also examine the wing kinematics and aerodynamic performance of *P. flavescens* under varying wind conditions, including tailwinds and crosswinds. Utilizing experimental data and computational modeling, we probe how these insects utilize drift compensation and efficient flight in turbulent atmospheric flows. We then shift gears to highly accurate resolution of complex flow features using a novel pseudospectral method to mitigate Gibbs-Wilbraham phenomena in high-order numerical simulations, aimed to precisely capture vortical structures. A central focus is placed on "two-fluid" and "thin-film" boundary layer stability—principles derived from classical fluid mechanics that may provide insight into the dragonfly's highly efficient flight. We present findings on how wing surface morphology and kinematics influence lift-to-drag ratios at Reynolds numbers where conventional airfoil theory fails. Beyond biological inquiry, we propose novel concepts for the next generation of Micro-Air Vehicles (MAVs). By fusing insights from insect migration networks with dart-shaped projectile aerodynamics, we propose innovative design paradigms for autonomous systems capable of long-range, energy-efficient flight. The talk concludes by highlighting how the synergy between integrative biology and aerospace engineering can solve persistent challenges in low-speed aerodynamics.

ABOUT THE SPEAKER

Dr Sandeep Saha is an Associate Professor in the Department of Aerospace Engineering, IIT Kharagpur. He obtained his bachelors and masters degrees in Mechanical Engineering from IIT Kharagpur. He completed his PhD in Mechanical Engineering from Imperial College London. He thereafter worked as a Marie-Curie Experienced Researcher, CNRS (Laboratoire FAST), Orsay, France. Thereafter he worked as an Aerodynamics Engineer, ALSTOM Power (now GE), Rugby, UK; then as Research Scientist (Fluids), Schlumberger Gould Research, Cambridge, UK; and then as Academic Staff member, Mechanical Engineering, University of Duisburg-Essen, Germany (in collaboration with SIEMENS AG). He has worked on a range of problems in fluid mechanics and in recent years has focused on Low Reynolds number Aerodynamics ranging a broad spectrum of problems like insect flight, extraterrestrial flight, respiratory flows and waste heat recovery and sports aerodynamics.

11th March 2026, 11.00 AM, AR Auditorium, Department of Mechanical Engineering, IISc