ORGANIZED BY
JICA Friendship Grant 2.0 &
Department of Mechanical and Aerospace Engineering

19 February 2025

One-day workshop on

Recent trends in space transportation engineering

CCE, IITH | Seminar Hall 2

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One-day workshop on

Recent trends in space transportation engineering

Invited-speaker

Hideaki Ogawa

Associate Professor
Space Systems Engineering
(Space Transportation Systems)
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Invited participants only
Limited seats (50)

For registration:
https://forms.gle/Q9U42LRfUbdihRdq9

TIMELINE	EVENTS
09.30 am – 09.45 am	Opening remarks by Prof. Ashok K Pandey
09.45 am – 10.45 am	Invited talk by Prof. Ogawa
10.45 am – 11.00 am	Tea break (Outside)
11.00 am – 11.30 am	Talk by Prof. Raja Banerjee
11.30 am – 12.00 pm	Talk by Prof. Niranjan S Ghaisas
12.00 pm – 12.30 pm	Talk by Prof. Mahesh M S
12.30 pm – 01.00 pm	Talk by Prof. Gopinath Muvvala
01.00 pm – 02.00 pm	Lunch break (Meeting Hall 10, IGH)
02.00 pm – 02.30 pm	Invited talk by Prof. Ogawa
02.30 pm – 03.00 pm	Talk by Prof. Gnanaprakash K
03.00 pm – 03.15 pm	Tea break (Outside)
03.15 pm – 03.45 pm	Talk by Prof. Sayak Banerjee
03.45 pm – 04.15 pm	Talk by Prof. Venkatasubbaiah K
04.14 pm – 04.45 pm	Talk by Prof. Sai Sidhardh
04.45 pm – 05.00 pm	Concluding remarks

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Prof. Hideaki Ogawa

Kyushu University

Physics and Optimisation of Scramjet Engines for Future Space Transportation

As space development enters a new era, demand for safe and economical access to space is rapidly growing for commercial, scientific and strategic purposes. Scramjet engines are a promising hypersonic airbreathing technology to enable efficient and flexible space transportation by eliminating the need to carry oxidisers, unlike rocket propulsion. However, scramjet flowfields are inevitably complex, involving aerodynamic and aerothermal phenomena such as shock waves, shock/boundary layer interactions and chemical reactions due to operation in extreme environments. Sequential flow processes through the intake, combustor and nozzle must complete within a very short timeframe. Developing high-performance scramjets and scramjet-powered vehicles thus requires a sophisticated methodology that allows for integral design based on accurate physical understanding. Part 1 of this lecture will present the working principles of scramjets and key physical phenomena. Part 2 will explore state-of-the-art design techniques, including multi-objective optimisation and data-driven approaches using evolutionary algorithms and machine learning for effective knowledge discovery.

Prof. Raja Banerjee

IIT Hyderabad

Effect of Flame Holding Configurations on Combustion Efficiency & Specific Impulse in a Scramjet Engine

Fuel injection and mixing in a scramjet engine is complex due to the extremely short residence time and the presence of multiple shock structures. Therefore, the flame-holding design plays an important role in the formation of a stable flame. The two most commonly used flame-holding structures used in a scramjet engine are strut-based and cavity-based structures. This work reports results from numerical simulations to study the effects of fuel injection and the subsequent combustion of gaseous fuel for strut and cavity based flame holding structures. The numerical simulations were validated with cold-flow experimental data from open literature. The reacting flow was modeled with two types of fuels: hydrogen and a mixture of methane and ethylene. Single step reactions were used in these simulations. Fuel conversion efficiency and specific impulse were used as benchmark characteristics to evaluate the performance of these two flame-holding structures.

Prof. Niranjan S. Ghaisas

IIT Hyderabad

Sub-grid scale modelling and shock-capturing issues in high-order large eddy simulation of shock-turbulence interactions

Large-eddy simulation (LES) of compressible turbulent flows must capture shocks while resolving small-scale turbulence without excessive damping—two conflicting requirements. Dissipation is needed for shock capturing, but excessive dissipation can suppress small-scale turbulence. A localized artificial diffusivity (LAD) scheme, combined with high-order central compact finite differences, has been effective in balancing these needs. However, the necessity of an explicit sub-grid scale (SGS) model remains uncertain. This study examines LES of supersonic mixing layers using three SGS models: Sigma, Anisotropic Minimum Dissipation, and Modulated Gradient. Results demonstrate that an explicit SGS model is essential for appropriate dissipation and accurate turbulence statistics. Additionally, efforts are underway to extend these simulations to complex geometries by integrating multi-block and generalized curvilinear coordinate capabilities. These advancements aim to enhance the accuracy and applicability of LES in real-world aerodynamic and propulsion problems.

Prof. Mahesh M S

IIT Hyderabad

Numerical simulation of shock interacting with bubbles/ drops

Large-eddy simulation (LES) of compressible turbulent flows is crucial for capturing shock interactions with bubbles or droplets, which occur in various scientific and technological applications. Experimental limitations hinder detailed analysis of these transient phenomena. This study employs a numerical approach to resolve compressibility effects separately for the ambient medium and the bubble or drop, accurately capturing key flow physics. A high-fidelity shock-capturing method is demonstrated for material interfaces, detailing different stages of shock interaction and bubble/droplet collapse. The model successfully simulates re-entrant jets, water hammer shocks, sheet jetting, and counter-rotating vortex formations. High-resolution temporal simulations reveal finer details of pressure build-up during sheet jetting, previously unaddressed in experiments. Additionally, energy convergence and divergence in bubble/droplet arrays under shock interactions are assessed, with implications for explosive testing, lithotripsy, and high-speed combustion. The model is further extended to study boundary effects in confined environments.

Prof. Gopinath Muvvala
IIT Hyderabad

Overcoming Challenges in Large Area Metal Additive Manufacturing: From System Design to Material Integrity

This invited talk delves into the complexities of large-area metal additive manufacturing (AM), emphasizing the critical aspects of system design and material integrity. The process presents significant challenges, including thermal distortion, residual stress accumulation, porosity, and anisotropy, all of which can severely impact part quality and structural performance. Addressing these concerns requires a multidisciplinary approach involving real-time process monitoring, advanced computational modeling, and optimized processing conditions. The talk will explore innovative strategies to mitigate these challenges, such as adaptive control systems, in-situ defect detection, tailored thermal management techniques, and material selection methodologies to enhance reliability. Additionally, the role of machine learning and data-driven approaches in predicting and preventing defects will be discussed. By integrating robust process controls and material engineering principles, the goal is to improve the efficiency, repeatability, and scalability of large-area metal AM, paving the way for widespread industrial adoption.

Prof. Gnanaprakash K
IIT Hyderabad

Combustion characteristics of composite solid propellants for underwater, microscale and rocket propulsion applications

Modern composite solid propellants (CSPs) are formulated with various additives to enhance rocket propulsion performance based on specific applications. Hydro-reactive solid propellants (HRPs) are particularly suited for underwater propulsion, while pyroelectric solid propellants (PSPs) require external electric power to sustain combustion. Recently, CSPs with metal hydride additives like lithium aluminum hydride ($LiAlH_4$) and lithium boron hydride ($LiBH_4$) have gained interest due to their high energy content and combustion efficiency. This study explores the development of these propellants using experimental techniques to understand their combustion characteristics. The impact of blended metal particles (Al/Mg) on HRPs for water-breathing propulsion systems is analyzed. Additionally, the burning behavior of PSPs with perchlorate- and nitrate-based oxidizers and various metal fuels is examined. The metal hydride additives role in CSP combustion is assessed for optimized advanced propulsion applications.

Prof. Sayak Banerjee
IIT Hyderabad

Optimization of Endothermic Fuels for Hypersonic Engines

Hypersonic scramjet engines experience extreme heat loads that threaten engine wall integrity, while design constraints often prevent the use of coolants. A promising solution is utilizing endothermic cracking of liquid hydrocarbon fuels by passing them through wall microchannels to absorb heat. However, these fuels exhibit significant chemical and physical ignition delays, making combustion under scramjet conditions challenging. This talk explores strategies to optimize fuels and additives that enhance endothermic cooling while improving combustion performance. Key challenges include tailoring fuel compositions for efficient heat absorption and rapid ignition, ensuring compatibility with high-speed flow environments, and mitigating coke formation in microchannels. Additionally, advancements in catalysis, fuel blending, and alternative high-energy-density fuels are examined. The discussion will highlight recent experimental and computational studies aimed at improving fuel reactivity, optimizing heat sink capability, and integrating advanced fuel formulations into scramjet propulsion systems for enhanced thermal management and overall performance.

Prof. Venkatasubbaiah K
IIT Hyderabad

Numerical Investigation of combustion-induced unstart in SCRAMJET Isolator

Combustion-induced unstart remains a challenge in hypersonic vehicles. This study investigates unstart phenomena in a SCRAMJET isolator-combustor of constant cross-sectional area by replicating combustion-induced unstart through downstream heat addition. Increased temperature and pressure in the combustor simulate realistic boundary conditions for the upstream isolator. Simulations are performed using the density-based solver rhoCentralFoam in OpenFOAM, with turbulence modeled using Menter's k-ω shear stress transport model. Shock-boundary layer interactions (SBLI) due to heat addition manifest as a shock train. A parametric study explores the effects of inlet Mach number and heat flux. Results indicate that back-pressure from heat addition and interactions between subsonic separation bubbles are primary causes of unstart. Higher inlet Mach numbers promote separation bubble formation, while increased heat flux accelerates unstart. The methodology is validated against experimental data from the literature, providing insights into scramjet stability and design optimization. Future work will focus on mitigating unstart through active flow control strategies.

Prof. Sai Sidhardh

IIT Hyderabad

Fastening schemes for ultra-high temperature applications in hypersonic vehicle structures

Hypersonic flight presents extreme challenges for structural materials due to intense aerodynamic heating and high mechanical loads. Carbon fiber-reinforced silicon carbide (C-SiC) composites offer a promising solution with their high-temperature resistance and structural integrity. Additionally, a Thermal Protection System (TPS) is essential to shield the primary structure from extreme temperatures on the surface. An appropriate design for the fastening scheme is essential to accommodate complex thermo-mechanical response while presenting resistance to external mechanical loads. Suitable designs that can distribute thermal stress effectively reduce the risk of local hot spots, thereby enhancing structural integrity. This talk will explore the novel design methodologies for passively cooled fastening schemes under ultra-high temperatures, incorporating appropriate fasteners and insulating. Our findings are expected to provide valuable insights into the design and suitability of different fastening mechanisms for extreme temperature applications and strategies to enhance their reliability and longevity.

CO-ORDINATOR

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