18th National Frontiers of Engineering (NatFoE) & IMP 2024
under the aegis of
ANRF (SERB)-INAE Conclaves on Atmanirbhar Technologies Engineering Secured Future

The 18th Symposium on National Frontiers of Engineering (NatFoE), a flagship event organized by the Indian National Academy of Engineering (INAE) since 2006, aims to inspire young engineers (aged approximately 27-45) from industries, universities, and R&D labs to present cutting-edge research in various engineering fields. The 18th NatFoE-24 symposium was hosted by the Indian National Academy of Engineering (INAE) in collaboration with the National Institute of Technology Warangal, under the auspices of the ANRF (SERB) - INAE Conclave on Atmanirbhar Technologies for Engineering a Secured Future, held on November 15-16, 2024.

This annual event was attended by numerous young researchers from academic institutions, R&D laboratories, and industries. The symposium's inaugural function took place at the Ambedkar Learning Centre at NIT Warangal, with notable dignitaries including Prof. Indranil Manna President, INAE, Prof. Sivaji Chakravorti, Vice President, INAE, Prof. Bidyadhar Subudhi, Director, NIT Warangal, and Prof. Shirish H Sonawane, Dean of Research and Development, NIT Warangal gracing the occasion.

In line with the country's mission on Atmanirbhar Technologies under four themes were decided for the symposium as mentioned below:

- Additive Manufacturing and Automation
- Smart Grid: Power Electronic Converters, Control and Protection
- Green Hydrogen and Storage Technologies
- Quantum Computing, Artificial Intelligence, and Machine Learning

Based on the aforesaid themes, four sessions were conducted as follows:

Session 1: Additive Manufacturing and Automation
Coordinators: Prof. Adepu Kumar, Prof. Ravi Kumar and Prof. Shivraman

Plenary Talk: **Human-Centric Manufacturing and Industry 5.0**

Prof. S K Pal highlighted the transformative potential of Artificial Intelligence (AI) and automation in manufacturing, with a focus on Industry 5.0's human-centric approach. Unlike Industry 4.0, which emphasizes digitization and automation, Industry 5.0 fosters collaboration between humans and intelligent machines, ensuring that human creativity, problem-solving, and emotional intelligence remain central to the process.

AI and automation optimize manufacturing by improving efficiency, enhancing quality, reducing costs, and driving innovation. AI handles repetitive tasks, allowing humans to focus on more complex, creative work. However, the human element remains crucial for addressing challenges that require emotional intelligence and judgment. Prof. Pal also stressed the importance of sustainability in manufacturing, advocating for the integration of green technologies, alternative energy, and scalable automation. This approach can help small-scale industries reduce costs, enhance energy efficiency, and contribute to a greener future.

Cybersecurity risks related to AI and automation were another concern. As industries become more interconnected, robust cybersecurity measures are essential to protect data and operational safety.Looking to the future, Prof. Pal discussed the potential of 6G networks and the Internet of Things (IoT) in enabling real-time communication and self-optimizing factories. Tactile IoT systems will enhance precision and safety, making manufacturing smarter, more efficient, and safer.

Dr. Gururaj T (ARCI): **Additive Manufacturing by Laser Powder Bed Fusion**

Dr. Gururaj discussed key advancements in material development for Additive Manufacturing (AM) using Laser Powder Bed Fusion (L-PBF) technology. He emphasized the importance of alloy chemistry modification to optimize material properties for efficient 3D printing and the role of spherical powders in improving flowability and consistency, which enhances print quality and reduces defects.

He also highlighted the integration of conformal cooling channels in AM, which improve heat dissipation and extend the lifespan of manufacturing dies. Additionally, Dr. Gururaj stressed the benefits of topology optimization for designing lightweight structures, reducing material usage while maintaining structural integrity. Looking to the future, he outlined the development of new alloy powders, including non-weldable materials, and the potential of Artificial Intelligence (AI) and Machine Learning (ML) to optimize AM process parameters in real-time, enhancing precision and efficiency. He also emphasized improving powder flowability by refining powder sphericity and eliminating satellite particles to ensure consistent and reliable printing.

In conclusion, Dr. Gururaj's insights pointed to a future where advancements in materials, AI-driven optimization, and refined powder characteristics will revolutionize Additive Manufacturing, benefiting industries like aerospace, automotive, and healthcare.

Mr. Ankith Sahu, (Objectify Technologies Pvt Ltd): **Qualification and Standards in Additive Manufacturing (AM), especially for aerospace and aviation applications**

Mr. Ankit Sahu highlighted the critical role of process and material qualification in metal Additive Manufacturing (AM), especially for aerospace and aviation applications. He discussed strategies for design planning, ensuring regulatory compliance, and adhering to industry standards such as AWS D20, with a focus on dimensional tolerances, acceptance criteria, and Non-Destructive Testing (NDT) qualifications.

Mr. Sahu emphasized the importance of integrating online defect monitoring during the Laser Powder Bed Fusion (L-PBF) deposition process and process validation to enhance reliability and maintain high-quality manufacturing standards. He also outlined future efforts to advance regulatory compliance, improve defect detection methods, and refine manufacturing practices, all aimed at supporting the development of advanced components for aerospace and unmanned aerial vehicles.

Prof. Poonam Sundriyal (IIT KGP): **3D Printing for Energy Devices**

Prof. Poonam Sundriyal explored the innovative application of 3D printing technology in the development of flexible, wearable supercapacitors integrated with energy-harvesting components. These supercapacitors are designed to efficiently store and deliver energy while being able to withstand mechanical stress, making them ideal for wearable electronics. The integration of energy-harvesting components enables these supercapacitors to generate power from external sources such as motion or environmental factors, providing a sustainable and self-sufficient energy solution. Prof. Sundriyal highlighted the promising performance of these devices in real-world conditions, where flexibility and durability are critical, especially in applications involving continuous wear or movement.

Looking to the future, Prof. Sundriyal emphasized the importance of advancing the technology behind cell-powered electronics. By incorporating higher-energy harvesting components and enhancing the durability of the supercapacitors, these devices can become more robust, capable of functioning reliably even under continuous deformation. This innovation will be crucial for the development of practical, sustainable, and energy-efficient solutions for a wide range of applications, from wearable health monitoring systems to flexible electronics in various industries. Prof. Sundriyal's research aims to not only push the boundaries of energy storage technology but also contribute to the creation of more environmentally friendly, self-powered devices that can meet the growing demand for efficient and sustainable electronic solutions.

Session 2: Smart Grid: Power Electronic Converters, Control and Protection

Coordinators: Prof. Ram Krishan and Prof. V. T. Somasekhar

The plenary session titled "Smart Electric Grids: Power Management, Control, and Protection Challenges" under theme 2 was presented by Prof. S. C. Srivastava from IIT Kanpur, a pioneer in power system advancements. Prof. Srivastava provided an enlightening overview of the history of smart grids and detailed the microgrid system, highlighting cutting-edge technologies for power management. Elucidating the operational challenges encountered while operating the microgrid initiated by IIT Kanpur, he presented a real-time case study on renewable energy–integrated microgrid operations. Furthermore, during the interactive session, he explained the concept of net-zero emissions and the progress made in this cutting-edge research area. He opined that smart grids with extensive renewable energy integration pave the way to the herculean task of meeting the ever-growing electricity demand in the future.

As part of the smart grid theme, three invited lectures were delivered by young researchers from IIT Delhi, IIT Kharagpur, and IIT Bhubaneswar. Dr. Yashasvi Bansal, Assistant Professor in the Department of Electrical Engineering at IIT Delhi, gave an insightful presentation on the "Transformative Role of PMUs for Monitoring and Protection in Smart Grids." She highlighted the crucial role of Phasor Measurement Units (PMUs) in real-time monitoring, protection, and control of smart grid systems, emphasizing their effectiveness in enhancing the reliability and stability of power grids.

The next lecture was presented by Dr. P. Deepak Reddy, Assistant Professor at IIT Kharagpur, who focused on the "Operation and Control of Microgrid Systems." He shared his cutting-edge research on microgrid systems, discussing the various operational modes and control strategies that ensure efficient and reliable integration of renewable energy sources. In the final session, Dr. Chandrashekhar Perumalla from IIT Bhubaneswar provided valuable insights into wireless power transfer and the challenges involved in electric vehicle (EV) charging. He emphasized the importance of developing robust EV charging infrastructure to support India's ambitious net-zero emission targets, underscoring the critical role of innovative technologies in achieving a sustainable future.

Key Takeaways:

- **Integration of Renewables**: Transitioning to smart grids with renewable energy is inevitable for a sustainable future but requires innovative management strategies and new technologies.
- **Real-Time Monitoring**: PMUs and other real-time monitoring devices are essential to maintain grid stability and manage complex, dynamic systems.

- **Microgrid Flexibility**: Microgrids provide modular, adaptable solutions for modern grids, but require complex control strategies for seamless integration.
- **Investment in EV Infrastructure**: Scaling up EV charging infrastructure which includes wireless charging, is the key to evolving sustainable solutions in the arena of transportation.

These sessions collectively emphasized that the future of smart grids relies on technological innovation, renewable integration, infrastructure development, and effective administration to meet environmental and energy objectives.

Session 3: Green Hydrogen and Storage Technologies
Coordinators: Prof. P. V. Suresh and Prof. K. Manohar

The second day of NatFoE 2024, held on 17th November 2024, featured an engaging session on Green Hydrogen and Storage Technologies. The theme conveners extended a warm welcome to the speakers, guests, participants, and students, setting the stage for an important discussion at the intersection of innovation, sustainability, and national progress.

As the world faces the dual challenges of climate change and energy security, green hydrogen stands out as a promising solution. It is a clean, versatile energy carrier with the potential to revolutionize industries, transportation, and power generation. Simultaneously, advancements in energy storage technologies are essential for unlocking the full potential of renewable energy, ensuring stability, reliability, and scalability. Together, green hydrogen and storage technologies form the foundation of a sustainable energy future, both globally and in India.

The session began with a plenary lecture by Prof. S. Basu from IIT Delhi, a leading expert in electrochemical systems. His insightful talk, titled *Electrochemical Engines for Energy Storage and Conversion to Achieve Net Zero Carbon Emission*, provided a thorough overview of hydrogen's transformative potential as an energy carrier. Prof. Basu emphasized the critical advancements needed to make hydrogen and fuel cell technologies both sustainable and economically viable. He also highlighted the development of a membrane-less alkaline micro-electrolyser, a promising innovation that could significantly improve the efficiency and cost-effectiveness of hydrogen production.

This was followed by three invited lectures that further enriched the discussion:

- Dr. Vijay Radhakrishnan from Reliance India Limited, Mumbai, delivered an insightful overview of Sodium-ion batteries as a sustainable alternative to Lithium-ion batteries. He elaborated on the engineering challenges and commercialization pathways essential for advancing this technology.

- Dr. Sujit Pillai from MNRE presented updates on government policies supporting the green hydrogen mission. His talk on the *Indian National Green Hydrogen Mission* and advancements in electrolyzer technologies (PEM, AEM, SOEC, and alkaline electrolyzers) provided a roadmap for scaling up green hydrogen production in India.

- Dr. Sreedevi Varam from NIT Warangal shared cutting-edge research on on-demand hydrogen generation using novel aluminum composite materials. She explored aluminum's exceptional energy density and the role of metal activators and additives in addressing challenges in hydrogen storage and transportation, showcasing its transformative potential for clean energy systems.

These talks offered a comprehensive overview of the latest advancements, challenges, and opportunities in green hydrogen and storage technologies. Each lecture was followed by engaging

audience interactions, with insightful questions and constructive suggestions that enriched the collaborative spirit of the session. The session concluded with a heartfelt thank you to INAE for providing this invaluable platform to exchange ideas, inspire innovation, and foster collaborations that will drive progress toward our net-zero aspirations.

Session 4: Quantum Computing and AI ML
Coordinators: Prof. P. Radhakrishna, Prof. Manish Kumar Bajpai and Prof. U. Venkanna

Five talks on state-of-the-art technologies were organized as a part of second day of NaTFoE 2024. The main frontiers of each talk are listed below:

- Quantum Technologies in the National Quantum Mission: The National Quantum Mission (NQM) has created four technology verticals in quantum computing, communication, sensing and metrology, and materials and devices. These four verticals aim to translate quantum science into applicable technologies that benefit Indian industry and society. The main challenges discussed were Scaling Quantum Systems, efficient Quantum Algorithms, Quantum Materials and Hardware, Quantum Networking and Communication, Error Mitigation and Noise Management, and Standardization and Accessibility.

- Importance of Remote Photoplethysmography in AI: Remote photoplethysmography (rPPG) is a contactless technology that estimates physiological parameters such as heart rate, respiratory rate, and blood oxygen saturation using video-based analysis. Coupled with AI, rPPG has become a transformative tool across various domains, emphasizing its significance in modern healthcare, wellness, and beyond. The critical points discussed are AI integration with contactless health monitoring, development of AI algorithms for robust signal interpretation, leveraging federated learning for privacy-preserving data analysis, and Integration of rPPG into interoperable AI-powered health systems.

- Quantum Simulators and Accelerators: Harnessing PARAM for Quantum Computing Acceleration: Quantum simulators and accelerators are crucial in advancing quantum computing, offering the capability to model quantum systems and execute quantum algorithms faster. PARAM, India’s Indigenous supercomputing series, plays a vital role in fostering the development of quantum computing acceleration. By integrating quantum simulators and accelerators into its architecture, PARAM can lead India's efforts in quantum research, supporting applications in science, engineering, and beyond. This synergy positions PARAM as a cornerstone in the quantum computing revolution.

- Symbiotic Relationship Between Artificial Intelligence and Computing Systems Design: There is a symbiotic relationship between artificial intelligence, primarily machine learning and deep learning, and computing systems design, emphasizing how they have come to influence the progress of each other. Traditionally, we believe in providing more computing power to the ever-increasing complex ML/DL models. The symbiotic relationship between AI and computing systems design reshapes the technological landscape. This interplay drives innovation in AI applications and enhances computing platforms, paving the way for more intelligent, efficient, and sustainable systems. By harnessing this synergy, industries can address emerging challenges in energy, scalability, and real-world AI deployment.

- AI Infrastructure: Optimizing LLM Inference for Efficiency and Scalability: Large Language Models (LLMs) are revolutionizing AI applications with their unprecedented language understanding and generation capabilities. However, training and deploying these models at scale can be computationally expensive and resource-intensive. To unlock the

full potential of LLMs, it is crucial to optimize their inference process. Optimizing LLM inference for efficiency and scalability is at the frontier of AI infrastructure development. Through innovations in model compression, hardware acceleration, memory optimization, and scalable frameworks, the field is moving toward sustainable, real-time, and accessible LLM deployment. These advancements enable broader adoption of LLMs and ensure their role in shaping transformative applications across industries.

Around 70 faculty and researchers from various engineering institutions participated in the two-day program. 28 posters were presented during the event and in addition a National Level Competition, Innovations in manufacturing practices was dovetailed with the 18th National Frontiers of Engineering (NatFoE-24) Symposium on the second day where students across India presented their innovative ideas.

Innovation in Manufacturing Practices:

The *Innovation in Manufacturing Processes (IMP) – 2024*, organized by INAE in collaboration with the National Institute of Technology Warangal under the aegis of the ANRF (SERB) - INAE Conclave on *Atmanirbhar Technologies- Engineering Secured Future*, took place on November 16, 2024. This event brought together a diverse group of participants, including undergraduate and postgraduate (Master's students) as well as start-ups, all presenting innovative ideas and projects related to advancements in the manufacturing sector.

A total of 24 teams participated, pitching their cutting-edge ideas and demonstrating how they could revolutionize manufacturing processes. The event highlighted a broad spectrum of topics, from new manufacturing techniques to sustainability innovations, all aimed at driving progress within the industry.

At the conclusion of the event, cash awards were presented by eminent guests in three distinct categories, recognizing the most outstanding projects. In addition, certificates were distributed to the best poster presentations across four themes, further encouraging participants to engage in deep research and innovative thinking. The event not only provided valuable exposure to the participants but also fostered collaborations, ideas exchange, and inspiration, contributing to the larger goal of fostering an Atmanirbhar (self-reliant) manufacturing ecosystem in India.

Highlights:

- Over 28 posters were presented at the symposium, each reviewed by Prof. Sivaji, Prof. Subudhi, and an evaluation committee for each theme. Best poster certificates were awarded to the top presentations.
- The event featured 18 plenary and keynote talks, with a focus on diversity in the topics covered.
- A total of 67 participants from across the country attended the two-day symposium, with 64 participants from IMP presenting their ideas.
- 24 innovative ideas were pitched in the IMP session, out of the 67 submitted.
- Prof. Manna and Prof. Sivaji engaged with the IMP participants, offering valuable insights and feedback while also reviewing the prototypes.
- An MoU was signed between NIT Warangal and Agastya Hydrogen, marking a significant step in advancing collaboration in hydrogen technologies.

Participants, especially students, expressed that the symposium provided an excellent learning opportunity. They were highly motivated and inspired by the posters and exhibits showcased during IMP, which fueled their enthusiasm for innovation and research in the manufacturing sector.