ABSTRACT BOOK

MEKANIKUM

2026

International Conference on Mechanical Engineering Advances

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FOREWORD

Welcome to the Book of Abstracts for **MEKANIKUM 2026** – International Conference on Mechanical Engineering Advances, hosted by the **Department of Mechanical Engineering, Faculty of Engineering, Universiti Malaya, Kuala Lumpur, Malaysia**. Taking place on 2–3 September 2026 in Kuala Lumpur, MEKANIKUM 2026 brings together researchers, academics, industry professionals, and students to share knowledge and explore advances under the theme **“Sustainability in Mechanical Engineering.”**

MEKANIKUM 2026 provides an interdisciplinary platform to exchange ideas, present groundbreaking developments, and foster collaboration in addressing current and emerging engineering challenges. The conference welcomes theoretical, experimental, computational, and industrial contributions that advance sustainability-driven practices across mechanical engineering and related fields.

This edition of MEKANIKUM is held in conjunction with three specialized co-located conferences: **ICSAM 2026** (2nd International Conference on Smart and Advanced Manufacturing), **NEXMAT 2026** (International Conference on Next Generation Materials), and **SSIEC 2026** (Smart and Sustainable Industrial Ecosystem Conference). Together, these interconnected events highlight the vital role of mechanical engineering in developing efficient, intelligent, resilient, and sustainable technologies across energy, materials, product design, mechatronics, artificial intelligence, and industrial systems.

The abstracts compiled in this book showcase the breadth and diversity of research presented across the MEKANIKUM 2026 platform. They represent innovative approaches, emerging technologies, and interdisciplinary solutions aimed at strengthening the connection between academia and industry.

We express our sincere appreciation to all authors, reviewers, committee members, industry partners, and participants for their invaluable contributions and commitment. This conference would not be possible without their collective expertise, efforts, and enthusiasm. We hope this Book of Abstracts serves as a valuable reference, inspiring new ideas, collaborations, and opportunities for future research. May the discussions initiated at MEKANIKUM 2026 contribute toward innovative engineering solutions and a more sustainable future.

Welcome to MEKANIKUM 2026. We wish all participants a fruitful, engaging, and inspiring conference!

Sincerely,

The Mechanical Engineering 2026 Conference Committee

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ISCAM Title

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International Conference on Smart and Advanced Manufacturing

CONFERENCE ABSTRACTS

Paper ID: ISCAM 002

Innovative DMLS-AM of Super-Duplex Stainless-Steel to Improve Its Corrosion Resistance with Excellent Mechanical and Microstructure Properties for Oil and Gas Applications

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ABSTRACT

Duplex stainless-steel (DSS) is a unique stainless-steel alloy featuring a two-phase structure, ferrite and austenite, that exhibits an excellent combination of mechanical properties and corrosion resistance. Thus, super-DSS has been applied in harsh environments and industries such as oil and gas, paper mills, chemical processing parts, heat exchangers, etc. Additive manufacturing is the next generation of manufacturing, revealing new possibilities of producing complex geometries, reducing the lead time for special spare parts, and reducing material waste. Additionally, additive manufacturing reduces machining processes, which reduces the total cost of the required component. In this research, direct metal laser sintering (DMLS) is proposed as a novel approach to additively manufacture super-DSS. The microstructure and formed phases are investigated to ensure the optimum ferrite/austenite ratio. Additionally, the mechanical properties, corrosion behaviour, and tribological properties of the prepared samples will be determined and evaluated.

Keywords: Super-duplex stainless-steel; additive manufacturing; direct metal laser sintering

Paper ID: ISCAM 003

Electro-Tribological Behavior of Laser-Cladded FeCrMoCB Coatings on AISI 52100 Bearing Steels under DC Current-Carrying Sliding Conditions

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ABSTRACT

This study explores the tribological behavior of laser-cladded coatings under both electrified and unelectrified conditions using dry and grease-lubricated environments. By employing advanced tribological testing setups, including a High-Frequency Reciprocating Rig (HFRR) integrated with a direct current (DC) power supply, the effect of electrification on wear resistance as well as friction behavior was systematically evaluated. The results revealed that electrified conditions significantly decreased the coefficient of friction (COF) and wear volume loss in comparison to unelectrified states. Between the two laser-cladded coated samples produced with various laser parameters tested, the sample S2 exhibited the best tribological performance, achieving a COF of 0.129 under dry conditions and further improved results under lubrication, indicating enhanced wear resistance due to crystalline layer formation. These findings underline the potential of electrified tribological systems for improving material durability in critical applications such as electric vehicles and other high-performance machinery. Future research is encouraged to optimize coating compositions and explore their long-term performance under variable electrical and mechanical loads.lubricated environments. By employing advanced tribological testing setups, including a High-Frequency Reciprocating Rig (HFRR) integrated with a direct current (DC) power supply, the effect of electrification on wear resistance as well as friction behavior was systematically evaluated. The results revealed that electrified conditions significantly decreased the coefficient of friction (COF) and wear volume loss in comparison to unelectrified states. Between the two laser-cladded coated samples produced with various laser parameters tested, the sample S2 exhibited the best tribological performance, achieving a COF of 0.129 under dry conditions and further improved results under lubrication, indicating enhanced wear resistance due to crystalline layer formation. These findings underline the potential of electrified tribological systems for improving material durability in critical applications such as electric vehicles and other high-performance machinery. Future research is encouraged to optimize coating compositions and explore their long-term performance under variable electrical and mechanical loads.

Keywords: Laser cladding; DC electric discharges; Fe-based amorphous coating; Tribological performance; Wear resistance; Electric vehicle applications

Paper ID: ISCAM 004

Optimization of Wax Based 3D Printing Process of Fe-based Amorphous Material using Taguchi's Method and Grey Relational Analysis

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ABSTRACT

Fe-based amorphous alloys possess exceptional properties but risk heat-induced crystallization, making low-temperature wax-based extrusion 3D printing a promising yet challenging manufacturing route due to extrusion sensitivity. In this study, a novel ternary bio-based wax binder feedstock is used and its 3D printing process is optimized to achieve consistent mass flow rate, extrusion uniformity, and dimensional stability. A hybrid Taguchi–Grey Relational Analysis (GRA) methodology was employed to systematically evaluate and optimize key extrusion parameters with minimal experimental trials. Following a Taguchi orthogonal array, GRA converted the multiple performance indicators into a single grey relational grade for simultaneous multi-criteria optimization. The multi-response analysis reveals that the most significant parameter is the material extrusion rate, which has the highest contribution to overall print stability and performance. Furthermore, the framework successfully identified the optimal processing conditions to balance all critical responses. The findings demonstrate that utilizing these optimized parameters alongside the ternary bio-based wax binder yields highly reliable and stable printability. Ultimately, this work establishes a systematic pathway for advancing the low-temperature additive manufacturing of metallic glass feedstock.

Keywords: 3D printing, Additive manufacturing, Grey relational analysis, Metallic glass, Taguchi

Paper ID: ISCAM 005

A Non-Traditional Magnetorheological Fluid Utilizing Ferrous-Based Amorphous Particles in Deep Eutectic Solvents with Enhanced Yield Stress

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ABSTRACT

Traditional magnetorheological fluids (MRFs) utilizing carbonyl iron particles (CIP) and silicone oil often face performance trade-offs between high yield stress and particle agglomeration caused by magnetic remanence. To mitigate these issues by leveraging the low remanence of metallic glasses and the tuneable interfacial chemistry of deep eutectic solvents (DESs), this study proposes a non-traditional, sustainable MRF system utilizing a ferrous amorphous alloy (Fe-Si-B) dispersed within different DESs. The magnetic properties of the amorphous alloy and resulting MRFs were characterized via VSM, and the rheological properties were obtained from a rotational rheometer and fitted into the Herschel-Bulkley model. Results indicate that while the amorphous alloy possesses a lower saturation magnetization than CIP, its significantly lower coercivity and remanence facilitate more effective magnetization/demagnetization cycles. Crucially, MRFs based on the amorphous alloy and DESs exhibited higher yield stresses compared to the amorphous alloy + silicone oil-based MRF. The ChlCl:Glyc-based MRF achieved a 25% improvement in yield stress compared to the standard CIP-silicone oil-based MRF, and a 109% improvement in yield stress compared to the amorphous alloy/silicone oil-based MRF. This enhancement in yield stress is driven by a combination of two mechanisms: the high magnetic permeability of the amorphous alloy improves its responsiveness to the magnetic field, while the hydrogen bond networks within the DES media provide strong interfacial fluid-particle interactions at the amorphous alloy's active sites that improve particle wetting and strengthen the chains formed. These findings demonstrate that the synergistic combination of amorphous alloys and DESs offers a high-performing, responsive and green alternative to traditional MRFs.

Keywords: Amorphous Alloys, Deep Eutectic Solvents (DESs), Magnetorheological Fluids (MRFs), Yield Stress

Paper ID: ISCAM 006

Pressureless Induction Sintering Route for Fe-Based Metallic Glasses Fabricated by Lithography-Based Additive Manufacturing: Densification, Amorphous Phase Retention and Mechanical Response

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ABSTRACT

Fe-based bulk metallic glasses (BMGs) are amorphous alloys formed by rapid solidification that show a unique combination of ultra-high strength, remarkable corrosion resistance and acceptable biocompatibility, owing to which they have found promising applications in dental and biomedical implants, sporting equipment, oil and gas, etc. Conventional processing methods of metallic glasses, primarily casting, require extremely high cooling rates, which restrict the producible component size to a few millimeters. Additive manufacturing (AM) has been identified as a viable alternative fabrication approach for BMGs to overcome dimensional and geometric constraints. Fusion-based techniques are challenging due to heat accumulation across successive layers, which promotes crystallization and degrades the superior properties of BMGs. In this study, a novel three-step AM technique is proposed, comprising lithography-based metal additive manufacturing (LMAM) for green part formation, thermal debinding for binder removal and pressureless induction sintering for final consolidation of FeCrMoCB BMG. It offers a faster route requiring no complex setup and provides eddy current-induced heating within the supercooled liquid region for viscous flow-driven densification without melting while preserving the amorphous structure. A systematic parametric investigation of AC power, induction frequency and sintering time is conducted to evaluate their influence on densification, mechanical strength, and amorphous content retention of induction-sintered samples. This work is expected to establish induction sintering as an effective consolidation route compared to other sinter-based AM methods of Fe-based metallic glasses, providing a quick, practical and scalable pathway to fabricate metallic glasses of complex geometry and useful dimensions beyond the critical casting size limit.

Keywords: Bulk metallic glasses, Amorphous metals, Lithography-based metal additive manufacturing, Debinding, Induction sintering

Paper ID: ISCAM 007

Spatial Electric-Field Evaluation in Multiplane Electrospinning using Symmetric Reconstruction and Mesh-Convergence Analysis

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ABSTRACT

Electric-field distribution is a key factor in multi-nozzle electrospinning because it affects jet initiation, jet stability, inter-jet interaction, and deposition uniformity. However, in numerical electrostatic simulation, the reported electric-field value can vary depending on the extraction region around the nozzle. This creates uncertainty when interpreting simulation results, especially when the entire nozzle body is assigned as the applied-voltage boundary. In addition, full simulation of a 5 × 5 multi-nozzle system requires high computational cost. This study investigates whether a reduced symmetric model with nine independent nozzle locations can reconstruct the full 25-nozzle electric-field distribution, and which extraction region provides the most reliable electric-field value for electrospinning analysis. A 5-plane and 5-nozzle electrospinning system was simulated using stationary electrostatics in COMSOL Multiphysics. Based on geometric and boundary-condition symmetry, nine independent nozzle locations were used to reconstruct the full 25-nozzle distribution through mirror symmetry. Six mesh densities, labelled Mesh A to Mesh F, were developed by refining the air domain, near-nozzle region, nozzle body, nozzle-tip distribution, and collector. The electric-field norm was extracted from the nozzle edge, tip surface, needle shaft, and nozzle surface. Mesh convergence was evaluated using relative difference against Mesh F, coefficient of variation, and repeated-measures analysis. The nozzle-edge field was highly mesh-sensitive, with a mean coefficient of variation of 24.00%, whereas the tip-surface field showed stronger convergence, with a mean coefficient of variation of 1.84%. Therefore, the nozzle tip-surface average field is recommended as the representative electric-field value, with Mesh D or Mesh E suitable for subsequent analysis.

Keywords: Multi-plane electrospinning; Electric field; Mesh independence; Symmetry reconstruction; COMSOL; Nozzle tip; Finite element simulation

Paper ID: ISCAM 008

Microstructure and Chloride Stress Corrosion Cracking Resistance of Direct Hot-Rolled Recycled AA6063-T4 for Refinery Instrument Tubings

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ABSTRACT

The recycling of aluminum machining chips into refinery-service sheet requires reliable corrosion assessment against conventional materials used in chloride-bearing environments. This study investigates the microstructure and chloride stress corrosion cracking (Cl-SCC) susceptibility of AA6063-T4 sheet produced by direct hot rolling (DHR) of compacted machining chips and compares its performance with conventional wrought AA6063-T4 and sensitized 316L stainless steel. A central composite design and response surface methodology were used to evaluate the effects of rolling temperature and cumulative thickness reduction. AA6063-T4 chips with thicknesses of 0.5–2.0 mm were cold compacted at 200 kN and processed by seven-pass DHR at the optimum condition of 520 °C and 80% cumulative thickness reduction. The microstructure was characterized using optical microscopy, field emission scanning electron microscopy, and transmission electron microscopy. Chloride SCC was evaluated according to ASTM G129 using slow strain rate testing in 3.5 wt% NaCl at a strain rate of $1 \times 10^{-6}\ s^{-1}$ and -200 mV versus Ag/AgCl. The DHR-AA6063-T4 exhibited a mean grain diameter of 22 ± 2 µm, compared with 68 ± 8 µm for conventional AA6063-T4, representing 3.1-fold grain refinement ($p < 0.0001$). Its precipitate-free-zone width was reduced from 187 ± 24 to 42 ± 6 nm, while the fine intragranular Mg-Si precipitate density increased by 5–10 times. The DHR-AA6063-T4 showed a Cl-SCC susceptibility index of 12.6 ± 1.9%, compared with 42.4 ± 3.5% for conventional AA6063-T4 and 28.3 ± 3.2% for sensitized 316L, corresponding to reductions of 70% and 45%, respectively. These findings demonstrate that DHR processing substantially improves the microstructural characteristics and chloride SCC resistance of recycled AA6063-T4 chips, supporting its potential as a sustainable alternative to sensitized 316L stainless steel for instrument tubing in chloride bearing refinery service.

Keywords: Direct hot rolling (DHR); AA6063-T4 Aluminum alloy; Chloride stress corrosion cracking (Cl-SCC); Solid-state recycling; Refinery instrument tubing.

Paper ID: ISCAM 009

Gallium Nitride Thin Films Prepared by MOCVD Epitaxial Technology for High-Performance Radiation Detectors

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ABSTRACT

The need for reliable and efficient radiation detectors for particle physics, space technologies, nuclear power plants, medicine, and homeland security applications is growing rapidly. The requirements set for radiation detectors are complex, from excellent efficiency and energy resolution to extreme radiation tolerance. Among numerous candidates, semiconductor radiation detectors offer various advantages due to their outstanding material properties. Due to the wider bandgap than Si (1.12 eV) and the recent progress in material fabrication, wide-bandgap (WBG) semiconductors are becoming a new driving force for radiation detection. Gallium nitride (GaN), a third-generation wide-bandgap semiconductor material (bandgap width of 3.4 eV), possesses excellent physical and chemical properties, including high breakdown field strength (3.3 MV/cm), high radiation hardness, high thermal conductivity, and excellent chemical stability. These properties make it an ideal candidate material for high-performance radiation detectors. Metal-Organic Chemical Vapor Deposition (MOCVD) enables precise control over film composition and the growth of complex structures, making it suitable for preparing high-quality GaN thin films. The purpose is to use MOCVD to deposit high-quality gallium nitride thin films with low dislocation density on silicon substrates and bulk gallium nitride substrates, design different vertical structures, and produce high-performance radiation detectors.

Keywords: Gallium nitride; MOCVD; Radiation detector; Thin film deposition; Wide-bandgap semiconductor

Paper ID: ISCAM 011

Machining Performance of Modified Malaysian Tropical Wood for High-Value Application Material

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ABSTRACT

Wood modification has become an important approach for enhancing the physical, mechanical, and durability properties of wood, to make it useful in high-value engineering applications. However, previous studies have focused on improving wood performance through modification. Limited attention has been given to the effects of these modifications on machining behaviour, particularly for Malaysian tropical wood species. Understanding the relationship between wood modification and machinability is important because machining quality directly influences manufacturing efficiency, surface finish, dimensional accuracy, and the quality of finished wood products. This paper discusses the influence of wood cell wall modification on machining performance by examining the changes in wood structure and their potential effects during cutting. It is proposed that controlled modification alters the mechanical characteristics and microstructure of wood, which affects material removal mechanisms, surface integrity, machining defects, cutting forces, and tool wear. Peripheral milling is the primary machining process due to its widespread use in wood industrial applications. Wood modification is expected to play a significant role in determining machining performance, where moderate modification may improve surface quality and machining stability, while excessive modification may increase brittleness, resulting in an increase of machining defects and accelerated tool wear. The expected outcome of this study is to provide a better understanding of how wood modification influences machinability and to identify suitable modification conditions that balance enhanced material properties with efficient machining performance. The findings are expected to support the development of high-performance Malaysian tropical wood products with improved manufacturability and greater industrial application.

Keywords: Malaysia tropical wood; Modification wood; Machining

Paper ID: ISCAM 013

Catalytic Infrared Curing of Thermosetting Powder Coatings: Curing Mechanism, Quality Prediction, and Optimization Control

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ABSTRACT

Curing is a critical stage that determines both the coating quality and the production economics of thermosetting powder coatings. Conventional hot-air curing suffers from low efficiency and high energy consumption, whereas catalytic infrared (CIR) curing can efficiently and cleanly convert the chemical energy of fuel into infrared radiant energy, showing great potential for rapid curing. However, the quantitative relationship between the CIR curing parameters and the coating quality remains unclear, and its rapid curing mechanism, process description models, and optimization control strategies have yet to be established. To this end, this study systematically investigates the performance evaluation, curing mechanism, quality prediction, and optimization control of CIR-cured coatings, using a polyester/triglycidyl isocyanurate powder coating and two epoxy/polyester hybrid powder coatings—one epoxy-dominant and one polyester-dominant. First, three curing methods—hot-air oven (HTO), electric infrared (EIR), and CIR—were compared under identical coatings and operating conditions. Owing to the good match between the radiation spectrum and the absorption characteristics of the coatings, EIR and CIR were able to heat the coatings to the curing temperature within 120 s, achieving good mechanical properties in a short time. In contrast, HTO yielded the highest final mechanical properties due to its slow heating stage, while exhibiting slower deterioration in surface gloss and color difference. These results reveal distinct curing mechanisms and strategic requirements among the three methods. Second, the effects of curing time, curing distance, and gas flow rate on the adhesion, hardness, impact resistance, gloss, and color difference of the coatings were systematically examined. The curing distance was found to play a dominant role in most quality indicators through its influence on the radiant energy density. On this basis, a coating quality dataset was constructed, and several machine learning models were compared. Tabular Prior-data Fitted Network was ultimately selected to establish a high-accuracy prediction model for small samples, which was then coupled with non-dominated sorting genetic algorithm II multi-objective optimization and technique for order of preference by similarity to ideal solution to obtain the optimal curing parameters. Experimental validation showed that the average relative errors of the five quality indicators for the three coatings were all below 10%. Compared with the manufacturer-recommended hot-air curing process, the optimized CIR curing reduced the curing time by 47–77% while achieving superior adhesion (4.06–4.34 MPa) and impact resistance (85–90 cm). Future work will focus on developing a three-dimensional coupled heat-transfer and curing kinetics numerical model of the CIR curing process and achieving real-time optimization and control. This study provides a systematic theoretical basis and engineering reference for the efficient and rational application of CIR curing technology in the field of thermosetting powder coatings.

Keywords: Thermosetting powder coatings; Catalytic infrared curing; Curing mechanism; Coating quality prediction; Optimization control

Paper ID: ISCAM 014

A Data-Driven Framework for the Identification and Evaluation of Human–Robot Collaboration Parameters in End-of-Life Vehicle Disassembly

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ABSTRACT

The disassembly of end-of-life vehicles involves complex, variable, and physically demanding activities that may benefit from effective human–robot collaboration. However, the implementation of human–robot collaboration in vehicle disassembly requires a clear understanding of the parameters that influence the suitability and organisation of collaborative tasks. This study aims to develop a data-driven framework for identifying and evaluating human–robot collaboration parameters within the end-of-life vehicle disassembly context. The study parameters derived from the initial phase of the research were converted into a structured quantitative survey and evaluated by respondents with relevant knowledge and experience. The survey-based analysis examined the perceived relevance and importance of the identified parameters for supporting human–robot collaboration decisions. The findings resulted in a consolidated and prioritised set of parameters representing the principal considerations for human–robot collaboration in end-of-life vehicle disassembly. The quantitative assessment also provided evidence regarding the relative importance of the identified parameters and their potential application in subsequent task assessment and decision-making processes. The proposed framework provides a systematic foundation for structuring human–robot collaboration requirements before the development of task-allocation models or robotic systems. This study contributes to the early-stage development of human-centred and data-informed collaborative disassembly systems for improving the sustainability, safety, and efficiency of end-of-life vehicle processing.

Keywords: Human–robot collaboration; End-of-life vehicles; Automotive disassembly; Parameter identification; Survey-based analysis

Paper ID: ISCAM 015

Statistical Characterization of Bubble Size Distribution in a Venturi Bubble Generator Under Varying Flow Conditions and Air Inlet Diameters

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ABSTRACT

Efficient gas-liquid mass transfer is essential for improving the performance of aeration systems used in aquaculture, wastewater treatment, and other environmental applications. Although Venturi bubble generators have been widely investigated for microbubble production, previous studies have primarily focused on representative bubble diameters or oxygen transfer performance, while comprehensive statistical characterization of bubble populations under varying air inlet diameters remains limited. This study experimentally investigates the effects of air inlet diameter on bubble size distribution in a Venturi bubble generator under different water and air flow rates. Two air inlet diameters (1.0 and 1.5 mm) were evaluated at water flow rates of 60-100 LPM and air flow rates of 1 and 2 LPM. High-speed visualization combined with ImageJ-based digital image analysis was employed to determine equivalent bubble diameters. The novelty of this work lies in integrating probability density functions, cumulative distribution functions, and lognormal distribution fitting to comprehensively characterize bubble populations. The results showed that increasing the water flow rate enhanced turbulent shear, resulting in smaller bubbles with narrower and more uniform size distributions. Conversely, increasing the air flow rate promoted bubble coalescence, producing broader distributions with a higher proportion of coarse bubbles. Under identical operating conditions, the 1.0 mm air inlet consistently generated finer and more uniformly distributed bubbles than the 1.5 mm air inlet due to its higher air injection velocity and stronger gas-liquid interaction within the Venturi throat. The lognormal model accurately described the experimental bubble size distributions, while probability density functions and cumulative distribution functions analyses effectively quantified the influence of operating parameters on bubble characteristics. These findings demonstrate that optimizing the air inlet diameter and operating conditions is an effective strategy for controlling bubble size distribution and improving the performance of Venturi-based aeration systems.

Keywords: Microbubble generation; High-speed visualization; Probability density function; Lognormal distribution; Gas-liquid mass transfer

Paper ID: ISCAM 016

Influence of Mechanical and Thermal Forming Histories on Hydrogen Embrittlement (HE) Resistance of Deep-Drawn SUS304 Cups

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ABSTRACT

Delayed hydrogen-induced cracking frequently initiates from the top edges of deep-drawn SUS304 metastable austenitic stainless-steel cups due to the synergistic interplay of strain-induced α'-martensite, internal hydrogen, and residual tensile hoop stresses. This study compares the HE resistance of ironed and annealed crack-free cups via electrochemical charging. To isolate failure mechanisms from top-edge geometric vulnerabilities, a "lifted cup" configuration is implemented by positioning the specimen rims slightly above the electrolyte surface. The experimental results demonstrate that longitudinal cracks initiate exclusively along the outer sidewall surface just below the electrolyte line; however, through-thickness crack propagation is effectively suppressed by the compressive residual hoop stresses acting on the inner cup surface. For the 27% ironed cups, the incubation time required for the initial crack to appear ranges between 2.0 - 2.5 h. This duration increases 2.0- to 2.5-fold when the mean ironing ratio is elevated from 27% to 33%. Conversely, the HE resistance of the cups annealed at 300°C is approximately five times greater than that of the 27% ironed specimens, yielding a crack-free duration of 10 – 12 h, which can be further extended up to 16 h by increasing the annealing temperature to 400°C. Mechanistically, while the ironing process effectively reduces and homogenizes the residual hoop stresses, it simultaneously increases the volume fraction of brittle α'-martensite via severe sidewall thinning strains. In contrast, post-forming annealing uniformly relaxes the entire residual hoop stress profile without accumulating additional plastic strain. Consequently, the lower martensitic content enables the annealed cups to exhibit superior HE resistance.

Keywords: Hydrogen embrittlement crack; Delayed cracking; Hydrogen charging; SUS304 Stainless steel; Deep drawing

Paper ID: ISCAM 017

Characterisation of Direct Laser Writing Parameters for the Development of a Pegda-Based Flexible Glucose Biosensor

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ABSTRACT

Flexible hydrogel-based optical biosensors require precise and reproducible microfabrication to achieve reliable sensing performance. This study characterises green-light direct laser writing (DLW) parameters for a poly(ethylene glycol) diacrylate (PEGDA)-based hydrogel formulation intended for flexible optical glucose biosensors. Compared with trial-and-error optimisation, the proposed approach combines experimentally calibrated multiphysics modelling with process-window prediction, enabling optimisation of fabrication parameters while reducing experimental iterations. A 515 nm femtosecond laser system was modelled in COMSOL Multiphysics using the measured sample-plane laser power, a moving Gaussian beam, Beer–Lambert optical attenuation and absorbed-dose accumulation. The absorbed-dose threshold was treated as an operational calibration parameter and validated against post-development microscopy, yielding an optimal threshold of $D_{(crit)} = 1 \times 10^9$ J m^{-3} for process-map visualisation. The calibrated power–scan speed map predicted that cured feature width increased with laser power and decreased with scan speed. At 15% laser power, the predicted feature width decreased from 7.74 μm at 10 μm s^{-1} to 0.15 μm at 250 μm s^{-1}. Thermal simulations predicted a maximum temperature increase of 2–9 K, confirming that photochemical dose accumulation, rather than thermal effects, governs the polymerisation process. Preliminary glucose measurements over the physiologically relevant range of 2–20 mM demonstrated concentration-dependent hydrogel swelling, with the raw swelling ratio exhibiting a strong linear response (R^2 = 0.9973). These results establish a calibrated fabrication framework that links DLW process optimisation with hydrogel sensing behaviour, providing a more predictive and reproducible route towards the development of flexible optical glucose biosensors for interstitial fluid monitoring.

Keywords: EGDA hydrogel; APBA; direct laser writing; COMSOL Multiphysics; glucose sensing; process optimisation.

Paper ID: ISCAM 018

Grain Refinement of Wire Arc Additive Manufactured Duplex Stainless Steel through TiN Inoculation

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ABSTRACT

Wire arc additive manufacturing (WAAM) offers a cost-effective and high-deposition-rate route for the fabrication of near-net-shape duplex stainless steel (DSS) components. However, the directional heat extraction, repeated thermal cycling and slow cooling rates that are intrinsic to WAAM frequently produce coarse columnar δ-ferrite grains, an imbalance of the ferrite-to-austenite (α/γ) phase ratio and a pronounced crystallographic texture, all of which degrade ductility, fatigue life and localised corrosion resistance. In the present work, titanium nitride (TiN) was introduced as an interlayer inoculant during WAAM of ER2209 DSS to assess its capability for grain refinement and phase-balance control. A thin TiN slurry prepared in ethanol was deposited between successive weld passes such that approximately 3 wt% of TiN was retained in the melt, and a second wall produced under identical process parameters but without inoculant served as the baseline. The microstructure, inclusion population and mechanical performance of the two walls were compared using optical microscopy, scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM–EDS), Vickers microhardness and uniaxial tensile testing. TiN inoculation produced a clear suppression of epitaxial columnar growth and a more equiaxed δ-ferrite morphology, accompanied by a reduction in the size and number density of inclusions and a change in their chemistry from a Fe–Cr–Ni system to a N-bearing Fe–Cr–Ni–N system. The average microhardness rose from 260.25 HV_2 to 271.46 HV_2 (+4.3%) and the ultimate tensile strength from 725.0 $N \cdot mm^{-2}$ to 763.2 $N \cdot mm^{-2}$ (+5.3%). The improvements are interpreted in terms of heterogeneous nucleation on TiN particles, solute-induced growth restriction by liberated Ti and N, and Hall–Petch strengthening. The results demonstrate that interlayer TiN inoculation is a practical and effective microstructural-control strategy for WAAMed duplex stainless steels.

Keywords: Wire arc additive manufacturing; Duplex stainless steel; Inoculation; Titanium nitride; Grain refinement

Paper ID: ISCAM 020

Metal Additive Manufacturing Research in Malaysia: A Bibliometric Review

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ABSTRACT

Metal additive manufacturing (AM) is listed as a priority technology in Malaysia's New Industrial Master Plan 2030, yet the country's research position in this field has never been described systematically. This paper reviews the Malaysian metal AM research landscape using bibliometric data from Scopus and SciVal for the period 2000–2025. Publication records were retrieved using a defined keyword and affiliation query and analysed for annual output, dominant process technologies and materials, leading institutions and authors, and international collaboration patterns. Malaysian output is then compared with that of Singapore, Thailand and Indonesia to provide regional context. The review concludes that Malaysian metal AM research is still concentrated in a small number of groups and provides a baseline for planning national research priorities and capability development.

Keywords: Metal additive manufacturing; Bibliometric analysis; Scopus; Malaysia; Research trends

Paper ID: ISCAM 021

Mechanical Integrity Assessment of Shell-and-Tube Heat Exchangers Considering Baffle Cut Configuration Using Finite Element and Analytical Methods

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ABSTRACT

Shell-and-tube heat exchangers are crucial in many industrial settings, especially where safety and reliability are paramount, like in processes involving high pressure and temperature. This study examines how the design of baffle cuts affects the mechanical performance of a shell-and-tube heat exchanger. The study uses a combined approach, combining finite element analysis with analytical methods. The three-dimensional model was created using Autodesk Inventor and then analyzed using SimScale. This process allowed for the creation of a detailed mesh, which included about 24.3 million cells. We tested seven different baffle cut variations, with percentages ranging from 17.5% to 32.5%. We did this under both internal pressure loading (0.36 MPa on the shell side and 0.23 MPa on the tube side) and the effects of gravity. The data indicates a substantial increase in the maximum von Mises stress within the tube region, escalating from 91.8 MPa to 176.7 MPa, representing an approximate 92.5% rise, as the baffle cut is enlarged. This observation suggests an augmentation in the structural load imposed by the flow. Conversely, the stress experienced by the shell remains relatively constant, fluctuating between 83 and 85 MPa, thereby demonstrating minimal sensitivity to alterations in the baffle configuration. The behavior of the baffle components is non-linear; specifically, at a 22.5% baffle cut, the peak stress reaches 194.9 MPa. Consequently, localized flow–structure interactions are evident. Displacement analysis shows that the tube's deformation gradually increases from 0.495×10^{-3} m to 0.517×10^{-3} m. In contrast, the baffle's deformation decreases by about 26%. Therefore, larger baffle cuts help improve fluid flow. The findings indicate a significant trade-off between a structure's load-bearing capacity and its deflection characteristics. While enlarging the baffle cut enhances flow efficiency, it simultaneously increases stress concentrations in critical components, such as tubes. These observations provide useful insights into design principles. They underscore the necessity of considering both stress and deformation when optimizing baffle designs in heat exchanger systems, which is crucial for ensuring mechanical integrity and operational safety.

Keywords: Baffle cut, Mechanical integrity, Finite element analysis

Paper ID: ISCAM 022

Effect of Additives on Wollastonite-Based Filaments for Fused Filament Fabrication

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ABSTRACT

The growing demand for advanced ceramic components with complex geometries has increased interest in Fused Filament Fabrication (FFF) as a cost-effective additive manufacturing alternative to conventional ceramic processing methods. Wollastonite ($CaSiO_3$), a bioactive calcium silicate ceramic, is particularly valued for its versatile applications in biomedical and engineering fields. However, achieving high ceramic loading in FFF feedstocks typically compromises melt flowability, processability, and filament flexibility, making successful extrusion difficult without modifying the polymer binder system. To address this issue, this study investigates the effect of binder additives, specifically polyethylene glycol (PEG), palm stearin (PS), and polyvinyl alcohol (PVA) on the rheology and extrusion behaviour of polylactic acid (PLA) based wollastonite feedstocks. The Critical Powder Volume Percentage (CPVP) was determined using a Brabender Internal Mixer, leading to the preparation of five distinct formulations containing 64 vol.% wollastonite with varying binder compositions. Capillary rheometric conducted at 200°C revealed that all formulations exhibited pseudoplastic (shear-thinning) behaviour, with flow behaviour index (n) values ranging from 0.660 to 0.875, confirming improved flowability under increasing shear rates. Apparent viscosities ranged from approximately 20 to 70 Pa·s within shear rates of 370 to 5000 s^{-1}, placing them well within the ideal processability window for filament extrusion. The specific combination of additives significantly impacted particle and polymer interactions and melt mobility shows the 75PLA/20PEG/5PS system exhibited the highest viscosity, whereas the addition of PVA in the 65PLA/15PEG/5PS/15PVA formulation produced the lowest viscosity. Based on these rheological profiles, the tailored additive formulations are expected to yield superior extrusion stability, uniform filament diameter, and enhanced structural integrity during printing. Ultimately, this work demonstrates that judicious additive selection provides precise control over feedstock rheology, establishing a vital foundation for optimizing subsequent FFF printing, debinding, and sintering processes.

Keywords: Binder additives; Fused filament fabrication; Rheological properties; Wollastonite

Paper ID: ISCAM 023

Multimodal Warning Signals as Cognitive Support in Automated Driving: A Review of Situation-Aware Adaptation Mechanisms

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ABSTRACT

As conditionally automated driving advances, drivers increasingly shift from continuous control to supervisory monitoring, creating risks of attentional disengagement, reduced situation awareness, and abrupt workload increases during transitions of control. This review systematically searched and screened studies on multimodal warnings in automated driving and applied hierarchical classification and narrative synthesis to examine modality functions, cross-modal synergy and interference, and situation-aware adaptation mechanisms. Evidence indicates that visual displays are suited to communicating hazard sources and system states, auditory signals support rapid attentional capture and urgency perception, and haptic warnings provide a distinctive contribution to action preparation because they do not require sustained visual attention, are less vulnerable to acoustic masking, and can encode spatial and temporal cues through bodily interfaces. However, additional modalities do not inherently improve performance; temporal misalignment, redundant information, and competing demands may reduce effectiveness. An evidence-informed framework is therefore proposed that integrates external-risk assessment, driver-state estimation, modality-function allocation, and dynamic presentation control to support safer, more interpretable, and adaptive takeover interfaces.

Keywords: Conditionally automated driving; Takeover request; Multimodal warning; Haptic feedback; Situation awareness

Paper ID: ISCAM 024

Machine-Learning Based Predictive Maintenance for Semiconductor Probe Card Failure Prediction Using Wear and Operational Behaviour Features

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ABSTRACT

Probe cards play a critical role in semiconductor wafer testing, where degradation directly affects test accuracy, manufacturing yield, product quality, and equipment productivity. Current maintenance practices primarily rely on threshold-based indicators such as the lower 10^{th} percentile (P10) probe height or fixed maintenance schedules. However, these indicators provide only a simplified representation of probe health and fail to capture wear variability across the probe population, potentially resulting in undetected degradation and unexpected failures. This research proposes a wear-distribution-based predictive maintenance (PdM) framework for semiconductor probe cards. Probe degradation was investigated using probe-height distribution analysis, operational-use variables, and historical failure records collected from industrial production environments. Degradation-aware features representing wear severity, wear variability, degradation stability, and degradation progression were engineered to provide a multidimensional representation of probe health. These features were subsequently integrated with ensemble machine-learning models for failure prediction. Results demonstrated that failure cards consistently exhibited lower values across the probe-height distribution than non-failure cards, indicating that degradation affects the entire probe population rather than only the lower-tail probes represented by conventional P10 monitoring. Feature sensitivity analysis further showed that wear-distribution characteristics were the most influential feature category, contributing between 31.6% and 34.6% of total model sensitivity. This framework consistently outperformed conventional P10-based monitoring, achieving F1-scores of 0.393, 0.593, and 0.618 for 7-day, 14-day, and 30-day failure prediction horizons, respectively. These findings demonstrate that wear-distribution-based degradation modelling provides a more comprehensive representation of probe-card health and offers significant potential for intelligent predictive maintenance and proactive maintenance decision-making in semiconductor manufacturing.

Keywords: Condition monitoring; Degradation modelling; Feature engineering; Failure prognostics; Ensemble learning

Performance Comparison of Yolo Models in Detecting and Classifying Defects in Gayo Arabica Green Coffee Beans

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ABSTRACT

This study evaluates YOLO-based object detection models for identifying and classifying defects in Gayo Arabica green coffee beans. It addresses the limitations of manual inspection, which is time-consuming, subjective, and inconsistent. Three models were compared: YOLOv5m, Custom-YOLOv8m integrated with the Convolutional Block Attention Module (CBAM), and YOLOv11m, with particular emphasis on comparing Custom-YOLOv8m-CBAM and YOLOv11m. The dataset contained 8,132 annotated images generated from 3,400 original images through augmentation. It covered one normal class and five defect classes: broken, insect-damaged, black, faded, and sour beans. Each model was trained for 100 epochs and evaluated using precision, recall, F1-score, mean Average Precision (mAP), confusion matrices, and qualitative visual analysis. YOLOv11m achieved the highest recall of 0.903 and mAP of 0.940, demonstrating superior detection capability. YOLOv5m obtained the highest precision of 0.932 and F1-score of 0.900. Custom-YOLOv8m-CBAM showed the most balanced and stable performance, supported by smoother loss curves, consistent F1-confidence patterns, and reliable visual predictions. Compared with YOLOv11m, it demonstrated stronger stability and generalization under varying conditions. Therefore, although YOLOv11m achieved the best peak performance, Custom-YOLOv8m-CBAM offers a more reliable solution for practical automated coffee quality inspection. The findings also underscore the importance of localized datasets for robust agricultural object detection applications.

Keywords: Gayo arabica coffee, Defect detection, YOLOv5, YOLOv8-CBAM, YOLOv11, Deep learning, Computer vision

Paper ID: ISCAM 026

Detection Transformers for Road Damage Detection: A Comparative Benchmark of DETR Variants Across Heterogeneous Datasets

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ABSTRACT

This study presents a comparative evaluation of Detection Transformer (DETR) based object detection models for automated road damage detection, aiming to explore their potential to replace conventional detection pipelines that rely on handcrafted anchors and complex postprocessing. DETR-based models offer an end-to-end detection approach that leverages global context understanding and eliminates the need for manually designed components, which is particularly beneficial for handling the diverse shapes and scales of road surface defects. We evaluate five models: CoDeTr Swin, RT-DETR, RT-DETRv3, UAV-DETR, and a convolutional baseline model, OBC-YOLOv8. Our contributions include a focused review of DETR-based methods for road damage detection, performance evaluation using mean average precision on diverse datasets, and fine-tuning of selected models to assess their adaptability and generalizations. Among the models, CoDeTr Swin consistently achieved the best results, reaching 87 percent MAP at IoU threshold 0.50 and 60 percent at 0.50 to 0.90 on the China test set, and maintaining top scores of 95 and 75 percent respectively on the Aceh test set. RT-DETRv3 offered competitive accuracy while reducing computational overhead by using a hybrid encoder. Although significantly lighter, OBC-YOLOv8 demonstrated strong MAP@50 performance, making it suitable for resource-constrained deployments. Dense supervision was a key contributor to improved accuracy and convergence speed, particularly for CoDeTr Swin and RT-DETRv3. The observed differences in performance across datasets also highlight the influence of image acquisition methods and damage characteristics. These findings demonstrate that DETR-based models hold strong potential for road damage detection by combining architectural simplicity, contextual awareness, and reliable accuracy.

Keywords: Road damage detection; Deep learning; Detection transformer, DETR

NEXMAT

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CONFERENCE ABSTRACTS

Paper ID: NEXMAT 001

Cellulose Nanocrystal-Based Composite Films Enabling Passive Daytime Radiative Cooling Under Real-World Conditions

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ABSTRACT

Passive daytime radiative cooling (PDRC) is a promising approach for reducing cooling energy consumption by reflecting solar radiation and emitting thermal energy through the atmospheric transparency window. However, the development of sustainable, low-cost, and scalable PDRC materials remains a challenge. In this study, a bio-based composite film composed of cellulose nanocrystals (CNCs), titanium dioxide (TiO_2), and polyvinyl alcohol (PVA) was fabricated using a water-based process for PDRC applications. The incorporation of CNCs and TiO_2 enhanced light scattering and thermal radiation management, resulting in an average solar reflectivity of 63% (across the 0.2-2.5 μm wavelength region) and a thermal emissivity exceeding 95% within the 8-13 μm atmospheric window. The high emissivity enabled efficient radiative heat dissipation, while the renewable CNC component improved the sustainability of the composite film. Remarkably, the fabricated film exhibits notable passive cooling effects in outdoor conditions: a 6.8°C reduction drop on exposed sunlight compared to the air temperature without external energy input. These findings demonstrate the potential of CNC-based composite films as sustainable PDRC materials and provide a pathway toward environmentally friendly cooling technologies for building and packaging applications.

Keywords: composite film; daytime cooling; cellulose nanocrystal; emissivity; reflectance

Paper ID: NEXMAT 002

Design and Structural Performance of Auxetic Core Peek Sternal Implants Under Physiological Loading

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ABSTRACT

Total sternal reconstruction after cancer resection or severe chest trauma remains a major clinical challenge. Titanium implants cause stiffness mismatch and stress shielding, while PEEK reduces this mismatch but still lacks the internal architecture to absorb dynamic loads from coughing or blunt impact. Current additively manufactured designs also lack engineered internal architecture for stress redistribution and energy absorption, a gap this study addresses. This study aims to design and evaluate auxetic-core PEEK sternal implants with improved stress distribution, stiffness, and specific energy absorption (SEA) relative to a solid PEEK baseline. Three topologies, Double Arrowhead (DAH), Re-entrant Star Hybrid (RSH), and Re-entrant Chiral Hybrid (RCH), were fabricated in PLA and tested at three scaling ratios to validate a finite element model against experimental results. The validated model was then applied to a full-scale PEEK sternum under a 2 kPa coughing pressure. FEA validation reached a maximum stiffness error of 12.71%. RSH showed the highest stiffness and SEA among isolated structures, while DAH showed the strongest auxetic response. All three topologies absorbed two to three times more energy per unit mass than a conventional honeycomb control. At implant scale, all nine configurations kept safety factors above 5. RCH gave the lowest peak stress, better stiffness retention, and SEA close to the solid baseline despite a 33.6% mass reduction, while DAH gave the highest SEA gain but the lowest stiffness retention. These results confirm that auxetic PEEK cores are mechanically feasible for sternal reconstruction, with RCH recommended for further development.

Keywords: auxetic metamaterial, sternal implant, PEEK, finite element analysis, energy absorption

Paper ID: NEXMAT 003

Process Parameter Optimization and Forming Quality Analysis of LPBF-Fabricated Y-Modified Al–Mg–Si Alloy

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ABSTRACT

Laser Powder Bed Fusion (LPBF) technology offers broad application prospects for the fabrication of complex aluminum alloy components. However, Al-Mg-Si series aluminum alloys are susceptible to defects such as lack-of-fusion pores, gas pores, and cracks during the LPBF process, which compromise the relative density and mechanical properties of the fabricated parts. In this study, Y-modified Al-Mg-Si alloy powder was employed as the raw material, and samples were fabricated via LPBF. Orthogonal experiments were designed with laser power (200, 220, and 240 W) and scanning speed (600, 800, 1000, and 1200 mm/s) as the main variables to systematically investigate the effects of process parameters on defect morphology, porosity, grain structure, and microhardness. The results demonstrate that increasing the laser power from 200 W to 240 W significantly improved the densification of the samples and remarkably reduced large lack-of-fusion defects and crack-like defects. Under the same laser power, the porosity initially decreased and subsequently increased with increasing scanning speed. The optimal comprehensive forming quality was achieved at a laser power of 240 W and a scanning speed of 800 mm/s, yielding a minimum porosity of 0.349%. The alloy microstructure was dominated by fine equiaxed grains with an average grain size of 4.63 μm, accompanied by low texture intensity and a randomized grain orientation distribution. The corresponding microhardness reached 75.02 $HV_{0.5}$. This study provides an experimental basis for the process optimization of Y-modified Al-Mg-Si alloy via LPBF and for subsequent performance enhancement.

Keywords: additive manufacturing; Al–Mg–Si alloy; grain structure; laser powder bed fusion (LPBF); porosity; Y modification

Paper ID: NEXMAT 004

Nanofluids for Enhancement of Heat Exchange Efficiency in a Closed-Conduit Flow using Bio-Based Carbon Nanotube Nanofluids: Experimental and Numerical Analyses

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ABSTRACT

Heat exchangers facilitate the transmission of thermal energy between various fluids, and the system's efficiency is largely dependent on the heat transfer fluid. While traditional fluids have been used, the recent studies focus on developing nanofluids containing suspended nanoparticles to further enhance heat transfer properties. In this study a bio-based, carbon-structured nanofluid was synthesized by environmentally friendly means and characterized for its potential to improve heat exchanger performance. Clove-functioanlized multi walled carbon nanotube (CMWCNT) nanofluids functionalized with clove were prepared at 0.025, 0.05, and 0.1 wt.% concentrations. Their thermophysical characteristics, such as density, thermal conductivity, and viscosity, as well as their dispersibility in the base fluid were evaluated. The nanofluids were tested in a square pipe flow heat transfer configuration under constant heat flux. The 0.1 wt.% CMWCNT nanofluid showed the largest increases in density (0.13%), viscosity (5.19%), and thermal conductivity (7.12%) at 30°C. The heat transfer coefficient and Nusselt number increased in tandem with the increasing flow rate, indicating an improvement in heat transfer performance when compared with the performance of pure water. The 0.1 wt.% CMWCNT nanofluid showed the Nusselt number 32.52% greater than that of water at the maximum flow rate of 8 L/min. However, the frictional pressure loss, which is undesirable, also increased. At 0.1 wt.% concentration, the nanofluid had a 15.94% higher frictional pressure loss at the lowest flow rate compared to that of water. In conclusion, CMWCNT nanofluids showed the potential to enhance heat exchanger efficiency, though the associated augmented pressure loss occurred should be addressed in design considerations.

Keywords: Synthesis; nanofluid; functionalization; multiwall nanotubes; heat exchanger; heat energy

Paper ID: NEXMAT 005

Heavy Metal Mitigation in Vegetable Oils and Oilseed Processing: Current Removal Strategies, Analytical Evidence, and Future Perspectives

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ABSTRACT

There is a growing concern regarding heavy metal contamination in vegetable oils, which could affect food safety, oxidative stability, product quality, and regulatory compliance. Metals such as lead, cadmium, arsenic, chromium, nickel, copper, and iron may contaminate oils through soil, irrigation water, agrochemicals, oilseed processing, refining equipment, storage, and packaging materials. Although some metal-associated impurities may be removed by conventional refining operations such as degumming, neutralization, bleaching, and deodorization, these operations are not specifically designed for the selective removal of heavy metals and may result in oil loss, micronutrient degradation, wastewater generation, and increased processing costs. The present review critically evaluates recent developments in heavy metal removal and mitigation strategies for vegetable oils, focusing on studies published during 2020–2026. The potential of integrated strategies for oilseed extraction and current methods such as adsorptive bleaching, activated clay, and carbon treatments are assessed for their removal efficiencies, retention of oil quality, scalability, applicability to food-grade applications, and environmental impact. A distinction is made between analytical extraction methods and practical industrial decontamination technologies. The available literature suggests that adsorption-based and integrated extraction approaches may offer promising routes for reducing metal concentrations. However, evidence remains limited for multimetal removal, process-scale validation, adsorbent regeneration, mass-balance analysis, and long-term oil stability. Future research should focus on food-compatible adsorbents, continuous processing systems, validated multielement monitoring, techno-economic assessment, and life cycle analysis. In conclusion, heavy metal removal from vegetable oils is an emerging research field that requires further systematic studies to establish safe, efficient, and industrially feasible mitigation strategies.

Keywords: Heavy metals; Vegetable oils; Edible oil refining; Adsorption; Bleaching earth; Food safety

Paper ID: NEXMAT 006

Europium-Doped Calcium Silicate for Biomedical Applications: A Comprehensive Review

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ABSTRACT

This review examines the synthesis and characterization of europium-doped calcium silicate biomaterials, highlighting their exceptional bioactivity and biocompatibility (Chen et al., 2024). Furthermore, the inclusion of europium ions imparts unique luminescent properties that enable real-time monitoring of material degradation and integration into the physiological environment (Bai et al., 2022). By leveraging these photoluminescent characteristics, researchers can precisely track the metabolic release of silicate and calcium ions, which are essential for stimulating osteogenic differentiation and enhancing bone regenerative potential (Kuo et al., 2025). The integration of rare-earth elements into the calcium silicate matrix not only enhances the material's imaging capabilities but also potentially modulates local immune responses and antibacterial activity, thereby overcoming traditional limitations in complex hard-tissue repair (Zhao et al., 2023; Zhu et al., 2024). Beyond their imaging utility, these doped scaffolds significantly improve the mechanical integrity and chemical stability of the host-implant interface, mirroring the structural reinforcement observed in other advanced silicate-based bioactive systems (Yang et al., 2024, p. 59). Moreover, the incorporation of lanthanide dopants enables fine-tuning of surface energy and topographical features, which are critical parameters for optimizing cellular adhesion and subsequent proliferation of osteoblastic lineages (Zhao et al., 2021). Consequently, the synergistic effect of the dopant and the calcium silicate matrix fosters a microenvironment conducive to mineral deposition, effectively accelerating the regeneration of critical-sized bone defects (Liu et al., 2021; Shan et al., 2023).

Keywords: Biomaterials; Osteogenic; Bioactivity; Biocompatibility; Lanthanides

Paper ID: NEXMAT 007

Where Battery-Free Indoor IoT Nodes Stay Powered, a Viability Model Anchored to Multi-Year Measured Indoor Harvest Energies

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ABSTRACT

Battery-free indoor sensor nodes are commonly specified by their photovoltaic technology and its efficiency, yet whether a deployed node stays powered depends on the entire chain from room to workload. This model-driven computational study quantifies beginning-of-life viability using an availability model anchored to measured daily harvest energies from six real indoor positions spanning 16.3 to 720.8 mJ cm^{-2} day^{-1}. Availability was computed over one year for a 4 cm^2 node with measured converter efficiency applied, across sleep currents of 1 to 10 µA, harvest multipliers to 2.0 times, a measured amorphous-silicon panel, storage leakage of 0 to 2 µA, and reporting rates of 6 to 3600 times per hour. Over the tested ranges, position and controller standby current are comparable first-order variables; a two-way variance decomposition attributes 43.9 percent of the grid variance to position and 35.4 percent to sleep current with no leakage, and position dominates at 80.4 against 9.8 percent at 2 µA leakage. The hallway position is non-viable in every tested cell. Sleep current moves the viable positions from five of six at 1 µA to zero of six at 5 µA and above at the nominal off-state draw; either 1 µA of leakage or realistic multi-day and seasonal trace structure reduces the count at 1 µA to three. Technology is a lower-order variable yet decisive at the margins, raising one office from 0.08 to 0.93 availability at 2 µA. For low-duty-cycle nodes in the studied envelope, position survey and controller selection must both precede photovoltaic technology choice.

Keywords: Indoor photovoltaics; Battery-free IoT; Energy harvesting; Availability; Supercapacitor

Paper ID: NEXMAT 008

Optimizing Workability in Waste-Derived Cementitious Blends: A Response Surface Study of Rice Husk Ash-Snail Shell Ash Concrete

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ABSTRACT

Ordinary Portland cement (OPC) production remains a major contributor to global anthropogenic CO_2 emissions, motivating the search for sustainable partial cement replacements. This study applies Response Surface Methodology (RSM) to model and optimize the workability of concrete incorporating Rice Husk Ash (RHA) and Snail Shell Ash (SSA) as a combined supplementary cementitious material. Eleven RSM-generated mixes, with RHA varied from 5-15% and SSA from 15-25% by weight of cement, plus a control mix, were proportioned and evaluated using the slump test. A linear regression model relating slump to RHA and SSA content was developed and validated through analysis of variance (ANOVA), yielding a statistically significant model ($p < 0.0001$) with a coefficient of determination (R^2) of 0.9148. Slump decreased consistently with increasing RHA and SSA content, from 50 mm for the control mix to as low as 20 mm. Numerical optimization identified 9.96% RHA and 23.40% SSA as the combination that best balances workability retention, predicting a 31.20 mm slump at 50% desirability. The model offers a practical, statistically validated basis for proportioning RHA-SSA blended concrete.

Keywords: Response surface methodology; Rice husk ash; Slump; Snail shell ash; Sustainable concrete

Paper ID: NEXMAT 009

Geometry Optimisation and Process Characterisation for Shear-Mode Testing of Sintered Copper Nanoparticle Interconnects: A Finite Element and Microstructural Study

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ABSTRACT

Sintered copper (Cu) nanoparticles offer a cost-effective, electrochemically stable alternative to silver-based interconnects in power electronics, but shear-mode mechanical characterisation of thin sintered Cu joints remains underdeveloped relative to tensile-mode and bulk-material studies, limiting the constitutive data available for finite element (FE)-based reliability assessment. For specimen design, eight lap-shear joint geometries- the traditional single-lap joint (SLJ), tapered, stepped, and rounded SLJ variants, and micro-shear specimen (MSS) designs- were evaluated by FE analysis using stress concentration factor (Kt), von Mises stress, deformation, and a Load Transfer Uniformity Index (LTUI). A Modified Micro Shear Specimen (MMSS), incorporating dual R0.50 mm sweep fillets and a 45° chamfer, achieved the lowest Kt of all configurations (2.59 vs. 15.09 for the SLJ baseline, an 83.8% reduction), a 96.4% deformation reduction relative to the SLJ, and a threefold improvement in LTUI over the standard MSS. The MMSS was fabricated and validated by stereo and optical microscopy, confirming fillet/chamfer fidelity and a defect-free three-layer joint architecture, establishing it as the specimen for subsequent shear testing. In parallel, preliminary process characterisation compared nano-micro-Cu paste sintered with and without curing agent. SEM showed that paste containing curing agent produces a cohesive but metallurgically incomplete metal-polymer composite, while paste without curing agent yields a fully metallic, porous network offering greater scope for optimisation of sintering parameters; this system was selected for further development. An initial tensile comparison indicated that formic acid addition reduced joint strength and strain-to-failure, consistent with a binder-outgassing porosity mechanism rather than reduced crosslink density.

Keywords: Sintered copper nanoparticles, Micro shear specimen design, Stress concentration factor (Kt), Finite element analysis, Copper paste sintering process

Paper ID: NEXMAT 010

Towards a User-friendly Python Interface for FEniCSx-FUS

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ABSTRACT

Accessible software interfaces are important for facilitating the use and development of scientific computing applications. FEniCSx-FUS is an open-source finite element solver for acoustic wave simulations, with its computational components implemented in C++. However, using a compiled C++ interface may increase the effort required to configure simulations and develop new applications. In this presentation, the development of a Python-based interface for FEniCSx-FUS is discussed. The interface is implemented using nanobind and closely follows the structure of the existing C++ interface. It allows users to construct and run simulations in Python using FEniCSx meshes, facet tags, material properties and acoustic source parameters while retaining the underlying C++ solver implementation. A representative acoustic wave propagation problem is considered to demonstrate the developed interface. Preliminary numerical results show that the problem can be successfully configured and executed through Python. Overall, this development provides a more accessible and extensible interface for FEniCSx-FUS, facilitating its use in computational acoustics research.

Keywords: Acoustic; Finite element method; Python API

Paper ID: NEXMAT 012

M³A-REE: Enhanced Characterization of Matrix Masking Effects in Boron-Rich Rare Earth Materials Using Interpretable Machine Learning

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ABSTRACT

Characterizing rare earth elements (REEs) embedded in light-element matrices using energy-dispersive spectroscopy (EDS) is challenging due to the matrix-dominated compositional effects. In heterogeneous multiphase materials, localised REE enrichment is often underestimated, therefore limiting the interpretation of elemental distribution and phase segregation behaviour. Despite the widespread use of scanning electron microscopy (SEM), EDS, and X-ray diffraction (XRD) to evaluate matrix masking, quantitative frameworks remain scarce. We propose an M³A-REE (Matrix Masking Multivariate Analysis for Rare Earth Evaluation) framework that combines comparative EDS analysis, quantitative metrics, and interpretable unsupervised machine learning. A mMulti-phase, boron-rich, crystalline rare-earth composite containing five target REEs (Nd, La, Y, Sm, and Ce) was investigated. As a result, two dimensionless metrics, the Matrix Masking Index (MMI) and Matrix Suppression Factor (MSF), are developed to isolate matrix interference by comparing full-spectrum and filtered REE EDS analyses. Results show considerable differences in REE suppression behaviour; yttrium exhibited the strongest masking effect, achieving MMI values up to 19.08× and MSF values above 94%, while neodymium and lanthanum showed MSF values between 86% and 90%. Interpretable unsupervised machine learning, including Principal Component Analysis (PCA) and hierarchical clustering, was applied to five experimentally characterised compositional regions to distinguish matrix-dominated and REE-enriched domains. The first principal component explained 97.9% of the total variance. Our proposed M³A-REE framework provides a quick, low-impact methodology for characterizing localised enrichment and establishes a proof-of-concept for future AI-assisted multi-phase materials characterization.

Keywords: Rare earth elements; Matrix masking; Interpretable machine learning; Energy-dispersive spectroscopy; Materials characterization

Paper ID: NEXMAT 013

A Bibliometric Analysis of Bimetallic Catalysts for Hydrogen Production through Ammonia Decomposition

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ABSTRACT

Ammonia decomposition is gaining attention as a route for COx-free hydrogen delivery, yet research on bimetallic catalysts remains fragmented across catalyst systems and collaboration networks. This study analysed 111 English-language articles and reviews from 2010–2025, selected from 239 Web of Science Core Collection records, using bibliometrics, VOSviewer mapping, and JCR indicators. The dataset received 5,519 citations. Publication output rose from 11 papers in 2010–2015 to 34 in 2016–2020 and 66 in 2021–2025; annual output increased from 8 papers in 2023 to 17 in 2024 and 29 in 2025. China contributed 51 papers (45.95%), while the United States recorded the highest impact at 137.6 citations per paper. The International Journal of Hydrogen Energy led with 19 papers and 903 citations, whereas Applied Catalysis B: Environment and Energy averaged 104 citations per paper. Temporal mapping showed a shift from kinetics in 2010–2015 to nanoparticles and bimetallic catalyst design in 2016–2020. During 2021–2025, Ni and Ru became the leading themes, with 16 occurrences and total link strength 144, and 11 occurrences and total link strength 89, respectively, alongside density-functional theory and advanced material architectures. Only 23 papers (20.72%) involved international co-authorship, and 16 of 22 collaborating countries contributed to no more than two international papers. The findings indicate rapid growth around Ni/Ru systems and mechanism-guided design, but continued concentration and limited international participation. Future studies should prioritize harmonized reporting, long-duration testing, operando identification of active phases, and reactor–catalyst co-design for non-noble systems.

Keywords: Ammonia cracking; Hydrogen generation; Bimetallic catalysts; Bibliometric analysis; VOSviewer

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Paper ID: SSIEC01

Practices, Drivers and Challenges in Eco-Design Adoption in Malaysia's Plastic Manufacturing Industry

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ABSTRACT

The Malaysian plastic manufacturing industry, while a significant economic contributor valued at approximately USD 4.04 billion, faces severe environmental challenges including substantial marine pollution and suboptimal recycling rates resulting in an estimated USD 1.1 billion annual loss in potential material value. This paper investigates the adoption of eco-design practices among ISO 14001-certified plastic manufacturers in Malaysia, exploring eco-design practices and two important influencing factors: the drivers and challenges influencing eco-design implementation in the Malaysian plastic industry. A qualitative methodology was employed, using purposive sampling to conduct semi-structured interviews with Environmental Management Representatives (EMRs) from five certified plastic manufacturing firms. Data were analysed through Inductive Content Analysis (ICA). Findings reveal that material selection, product recyclability, and energy efficiency design are the most consistently adopted eco-design components, while Life Cycle Analysis and packaging efficiency remain nascent. Customer pressure and regulatory mandates emerged as the dominant drivers while key challenges include high implementation costs and a pervasive knowledge-behaviour gap, supplier-related constraints, regulatory governance gaps, and inadequate post-consumer recycling infrastructure. This paper provides stakeholder-driven insights to advance eco-design adoption and support Malaysia's transition toward industrial sustainability.

Keywords: Eco-design; Sustainability; Environmental impacts: Sustainable development

Paper ID: SSIEC02

Evaluating Customer Readiness for Artificial Intelligence Adoption in Physical Retail Stores Across Malaysia

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ABSTRACT

As Artificial Intelligence (AI) is taking a critical role in enhancing customer engagement and retail operations efficiency, the evaluation of impact on customer attitudes and readiness to adopt these technologies is important. Presently, AI integration is widely used for enhancing business operations and customer satisfaction across various industries. This paper aims to examine the impact of retail customers' prior experience, perceived risks, and self-assessment to manage AI technologies on customer readiness to adopt AI in physical retail stores within Malaysia. This paper also evaluates technology literacy and technology simplicity as moderating roles. Quantitative design with structured questionnaire survey was conducted with 280 Malaysian retail customers and the data was analyzed using SPSS and SmartPLS. Study results show that prior experience and self-assessment positively affect AI use readiness and perceived risks negatively influence it. These relationships are moderated by both technological literacy and technological simplicity. Behavioural and technological factors into AI adoption research were integrated. Existing Technology Acceptance Model (TAM) was extended to include technological moderators in a physical retail context. Retail AI developers should enhance customer familiarity with proper digital literacy, supported by simplified AI interfaces.

Keywords: Artificial intelligence adoption; Customer readiness; Physical retail stores; Technology literacy; Structural equation modelling

Paper ID: SSIEC03

Design and Development of a Solar-Assisted Dryer for Organic Waste Treatment in Waste-to-Energy Plant

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ABSTRACT

To address the inefficiency of waste-to-energy plants caused by the high moisture content of municipal solid waste (MSW), this study evaluates a sustainable solar-assisted dryer utilizing a solar air collector as a pre-treatment alternative to fossil-fuel-powered thermal dryers. Using a two-phased approach of numerical Finite Element Analysis simulations via SolidWorks and physical experimental trials, the research optimized the dryer's design for maximum moisture reduction. Simulations under ideal Malaysian weather conditions identified black-painted aluminum as the optimal base material due to its superior thermal absorptivity (0.95), achieving internal base temperatures exceeding 85°C. Subsequent physical testing with simulated organic waste compared three configurations over five-hour daily operational windows: a direct solar dryer, an un-finned solar air collector, and a finned solar air collector. The experimental results complimented the simulations, revealing that the solar air collector incorporated with fins was the most effective setup, increasing overall drying efficiency by 10% compared to standard models. This optimized configuration successfully reduces MSW moisture content, thereby enhancing its theoretical calorific value. The improved calorific value paves the way for more efficient waste-to-energy conversion that makes utilizing a solar air collector as pre-treatment a more viable alternative compared to industrial dryers running on fossil fuels.

Keywords: Solar dryer; Waste-to-Energy; Thermal performance; Moisture reduction; Calorific value

Paper ID: SSIEC04

Comparative Evaluation of Waste Vegetable Oil-Derived Biodiesel and Green Diesel Via Hydrogen-Free Catalytic Deoxygenation

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ABSTRACT

The increasing demand for sustainable transportation fuels and the environmental impacts of fossil diesel have encouraged the development of renewable diesel alternatives from waste-derived feedstocks. Waste vegetable oil, obtained from used cooking oil sources, is a promising low-cost feedstock for producing biodiesel and green diesel. Although biodiesel produced through transesterification is widely used as a renewable diesel substitute, its application is limited by relatively lower heating value, oxidation stability concerns, and partial compatibility with existing diesel infrastructure. Green diesel has gained attention due to its hydrocarbon composition and diesel-like fuel characteristics, but further investigation is required to develop simple and cost-effective production routes using waste-derived feedstocks. Therefore, this study compares waste vegetable oil-derived biodiesel and green diesel produced through low-power microwave-assisted transesterification and hydrogen-free catalytic deoxygenation, respectively. Biodiesel was synthesized using a 9:1 methanol-to-oil molar ratio, 1.5 wt.% KOH catalyst loading, and 10 min reaction time. Green diesel was produced using 5 wt.% Ni/Al_2O_3 catalyst at 350°C under a nitrogen atmosphere. The fuels were characterized based on density, kinematic viscosity, flash point, oxidation stability, higher heating value, copper strip corrosion, and GC-MS analysis. The green diesel showed favorable fuel properties over biodiesel. Overall, waste vegetable oil demonstrates strong potential as a sustainable feedstock for renewable diesel fuel production, while hydrogen-free catalytic deoxygenation offers a promising route for producing green diesel from waste oil.

Keywords: Biodiesel; Green diesel; Waste vegetable oil; Catalytic deoxygenation

Paper ID: SSIEC05

Experimental Characterization of Liquid Film Thickness during Direct Contact Condensation in High-Energy Steam–Water Flow

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ABSTRACT

This study experimentally investigates the effect of direct contact condensation (DCC) in a high-energy steam-water flow on liquid film thickness in a vertical upward two-phase flow channel. Measurements were performed using the Constant Electric Current Method (CECM), which enables simultaneous determination of liquid film thickness and void fraction under dynamic flow conditions. The experimental facility consisted of a 600 kg/h capacity boiler that generated both saturated and superheated steam. The steam was introduced into an industrial scaled vertical water flow channel with an inner diameter of 40-mm and a height of 6-m. A series of CECM sensors, comprising an anode, cathode, and voltage fluctuation detector, were installed at 50-mm intervals along selected axial positions (L/D) of the test section. The sensors were connected to a National Instruments (NI) data acquisition system for real-time monitoring and data recording. The flow conditions were varied by changing the combinations of liquid and gas superficial velocities (j_L and j_G), expressed in terms of the slip ratio (j_G/j_L). The experimental results demonstrate that, at a constant liquid superficial velocity, the liquid film thickness decreases with increasing steam superficial velocity as the flow progresses upward. This behavior is attributed to intensified bubble coalescence, which promotes the formation of larger bubbles, followed by transitions to slug and annular flow regimes. Consequently, the liquid film becomes progressively thinner with increasing axial distance due to the combined effects of bubble growth, condensation, buoyancy, and gravitational forces. In contrast, at lower steam superficial velocities, bubble coalescence is less pronounced, resulting in minimal flow regime transition and relatively uniform liquid film thickness along the channel. These findings indicate that liquid film thickness is strongly influenced by both the axial measurement location and the superficial velocities of the gas and liquid phases, providing valuable insight into the hydrodynamic behavior of DCC in vertical steam-water two-phase flows.

Keywords: Direct contact condensation, Steam-water, Two-phase flow, Film thickness, Constant current sensor

Paper ID: SSIEC06

Design and Evaluation of Automated Bidet Nozzle Geometry with CFD-Based New Nozzle Channel Optimization

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ABSTRACT

Smart toilet cleaning performance depends strongly on nozzle geometry, which governs the conversion of inlet pressure into a stable cleaning jet. This study evaluates automated bidet nozzle performance through experimental analysis of first-generation (G1) and second-generation (G2) nozzles, together with a Computational Fluid Dynamics (CFD) investigation of a third-generation (G3) single-nozzle channel design. G1 and G2 were tested at 30, 35, and 40 psi under front and rear nozzle positions and target-plate angles of 0°, 15°, and 20°. High-speed imaging, ImageJ cleaning-area measurement, optical-flow velocity estimation, flow/pressure monitoring, and CFD with the Volume of Fluid (VOF) model were employed to analyse spray dynamics. G2 demonstrated significant improvements over G1, reducing response time by 19.42% (front) and 30.35% (rear). At 40 psi and the 0° rear condition, G2 achieved an effective cleaning area of 154.9 cm² compared with 107.2 cm² for G1. Jet velocity increased to 11.35 m/s for G2, while dynamic pressure reached 66 kPa, approximately 55% higher than G1. CFD results agreed with experimental trends. The proposed G3 CFD model further improved energy conversion efficiency, reduced pressure loss, and enhanced velocity uniformity, supporting sustainable and efficient smart toilet design.

Keywords: Energy efficiency; Jet stability; Spray dynamics; Sustainable sanitation systems; Volume of Fluid (VOF)

Paper ID: SSIEC07

A Multi-Reflective-Mirror-Based Autonomous Robotic System for Railway Track Defect Inspection

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ABSTRACT

This paper presents an autonomous robotic system for railway track inspection to comprehensively detect rail defects caused by frictional wear and daily transportation damage. An autonomous inspection robot is proposed based on a multi-reflective-mirror design and a multi-sensor fusion framework. By utilizing the optical reflection characteristics of multiple mirrors, the system can capture the vulnerable areas of the rail using only a single camera and several strategically placed mirrors. Experimental results demonstrate that the proposed system achieves robust performance in both laboratory testing and real-world application scenarios. In addition, the local normalization-based image processing method and fuzzy-logic-based decision provides high detection accuracy and precision in visual computer processing procedure. The proposed system satisfies the practical requirements of autonomous railway track defect detection and shows strong potential for real-world railway maintenance applications.

Keywords: Rail surface defect detection; Mirror reflection; Local normalization; Fuzzy logic.

Paper ID: SSIEC08

Toward a Culturally-Responsive IR 4.0 Sustainability Readiness Index: Framework and Application Development

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ABSTRACT

Industrial Revolution 4.0 (IR 4.0) readiness assessment has predominantly focused on technological and operational dimensions, often overlooking the role of cultural values in shaping sustainability-oriented adoption. This study proposes a two-phase framework for developing an application that measures and prioritizes IR 4.0 sustainability readiness while explicitly accounting for cultural influences. In the first phase, Structural Equation Modelling – Partial Least Squares (SEM-PLS) is employed to test the relationships between cultural value dimensions and key sustainability readiness factors. In the second phase, these weights are integrated into a mobile/web-based application in which users provide contextual ratings for each readiness factor. The application computes a new composite weight by multiplying the SEM-derived weight with the user rating, generating a relative ranking that reflects both empirical cultural influence and user perception. These ranking forms the basis of a readiness index, allowing organizations to identify priority areas and develop targeted, culturally-informed strategies for IR 4.0 implementation. The proposed framework is validated through industry testing and iterative refinement based on user feedback. By embedding cultural considerations as a quantifiable component of readiness assessment, this study contributes a novel, practice-oriented tool that bridges theoretical cultural analysis with actionable decision support, offering both academic and industry stakeholders a more contextually relevant approach to sustainability-driven IR 4.0 adoption.

Keywords: Industry 4.0; Cultural values; Malaysia; Sustainability; Structural equation modeling

Paper ID: SSIEC09

Designing an IoT-Enabled Lightweight Digital Twin APP Prototype for Sustainable Agri-Product Systems

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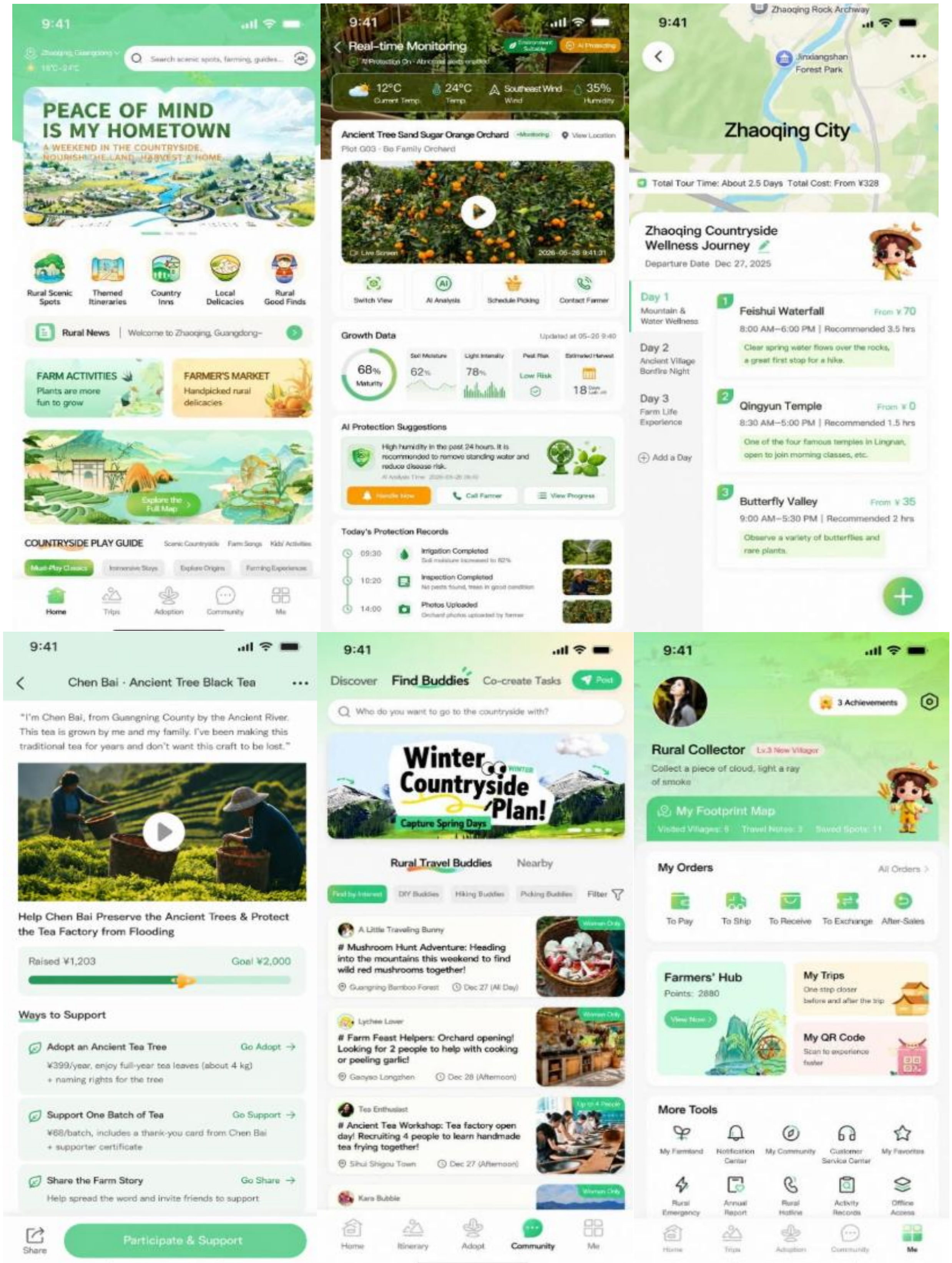
ABSTRACT

Sustainable agri-product systems require greater transparency, traceability, and user participation to bridge the trust gap between rural producers and urban consumers. However, many existing agri-product platforms remain transaction-oriented, offering limited visibility into farming environments, crop growth, and product circulation processes. To address this problem, this study proposes an IoT-enabled lightweight digital twin app prototype for sustainable agri-product systems. Using a prototype-based design research approach, the study developed a high-fidelity mobile app prototype integrating product adoption, virtual farm representation, real-time environmental monitoring, product source traceability, marketplace circulation, and user participation functions. The prototype translates selected agricultural data, including temperature, humidity, wind direction, soil moisture, light intensity, crop maturity, pest risk, and harvest prediction, into user-facing visual interfaces. A preliminary user evaluation was conducted with 15 ordinary users using a five-point Likert-scale questionnaire. The results showed positive user perceptions across five dimensions: transparency received the highest score ($M = 4.43$, $SD = 0.50$), followed by trust ($M = 4.40$, $SD = 0.50$), sustainability perception ($M = 4.27$, $SD = 0.58$), usability ($M = 4.13$, $SD = 0.51$), and engagement ($M = 4.07$, $SD = 0.64$). These findings suggest that IoT data visualization and lightweight digital twin representation can enhance users' understanding of agricultural production, strengthen perceived credibility, and support sustainable consumption. The study contributes a user-centred design practice for applying lightweight digital twin concepts to sustainable agri-product service systems.

Keywords: Lightweight digital twin; IoT data visualization; APP prototype; Sustainable agri-product systems; User experience design.

Partial interface prototype demonstrations:



Paper ID: SSIEC10

Design of an Intelligent Medical Accompaniment Service System Based on the Double Diamond Model

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ABSTRACT

This study proposes an artificial intelligence–enabled intelligent medical accompaniment service system (AI-AcomMed) based on the Double Diamond Model to address fragmented healthcare journeys, difficulties in accessing medical information, waiting-related anxiety, and the digital divide experienced by patients. Following the Double Diamond design framework, user needs were explored through shadowing observations, semi-structured interviews, and user experience journey maps. By integrating large language models and related AI technologies, an intelligent medical accompaniment system was developed to support the entire healthcare journey, including pre-consultation guidance, in-consultation navigation and accompaniment, waiting-time companionship, and post-consultation medical report interpretation. The System Usability Scale (SUS) was employed to evaluate system usability and user acceptance. The system achieved a mean SUS score within the "good" usability range, significantly exceeding the average benchmark for digital health applications. The findings indicate high levels of usability and user satisfaction. In particular, the system demonstrated strong capabilities in waiting-time companionship, proactive navigation, and medical report interpretation, providing both human-centered care and emotional support throughout the healthcare process. The Double Diamond Model offers a user-centered design paradigm for intelligent healthcare service innovation. Through proactive companionship and emotionally responsive interactions, the AI-AcomMed system enhances patients' sense of security, trust, and engagement, facilitating the transformation of digital healthcare from a function-oriented tool into a companion-oriented service ecosystem.

Keywords: Double diamond model; Intelligent healthcare; Medical accompaniment service; Service design; Artificial intelligence

Paper ID: SSIEC11

Design Strategies for Age-Friendly Park Facility Products in Malaysia

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ABSTRACT

Global population ageing is accelerating, and Malaysia is approaching the transition toward an ageing society. Urban parks play an important role in supporting older adults' outdoor activities and health promotion. Public facility products in urban parks should support older adults' safety, accessibility, comfort, and long-term use. However, existing park facilities in Malaysia remain insufficient in addressing older adults' needs. This paper aims to present design strategies for designing park facilities that meet older adults' needs. These design strategies of older adults for designing park facilities were developed on field investigation. The findings identified multiple facility-related problems affecting older adults, including insufficient facilities, ageing and damaged infrastructure, and poor accessibility, particularly in resting and exercise facilities. Field investigations further confirmed the specific forms of these facility-related issues. Based on these findings, ergonomics-based design strategies were proposed to improve the renewal and sustainable use of age-friendly facilities. This paper provides practical design strategies for product designers in designing age-friendly facilities for older adults. The proposed strategies aim to enhance older adults' safety, accessibility, and comfort within urban green spaces, thereby supporting age-friendly park renewal and park facility design in response to the ageing of Malaysia's population.

Keywords: Older adults; Age-friendly; Facility products; Ergonomics; Design strategies

Paper ID: SSIEC12

A Preliminary System Dynamics-Based Recovery Model for Spent Coffee Grounds Recycling in a Sustainable Industrial Ecosystem

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ABSTRACT

Spent coffee grounds (SCG) are continuously generated by coffee shop operations and have been widely recognised as a recoverable resource for biofuels, bio-oil, activated carbon, compost, materials and consumer products. Existing studies have demonstrated diverse technical pathways for SCG valorisation. However, technical feasibility does not ensure sustained recycling in real operational contexts. In practice, SCG recovery depends on the alignment of material characteristics, coffee shop routines, collection reliability, processing cost, stakeholder coordination and downstream value. Current research remains limited in explaining why technically feasible SCG recycling pathways often struggle to become stable recovery systems. In particular, the interactions among operational burden, feedstock stability, business incentives, market viability and policy support are still insufficiently understood. To address this gap, this paper proposes a preliminary system dynamics-based recovery model for SCG recycling in coffee shop ecosystems. The model is developed from SCG valorisation literature, coffee shop operational observations, preliminary stakeholder insights and illustrative cost-market reasoning. It conceptualises key feedback mechanisms shaping the transition from technical feasibility to real-world operational viability. Rather than offering a validated predictive simulation, the model serves as an initial explanatory framework to guide future empirical research, including stakeholder interviews, field observation and possible stock-and-flow modelling. This paper contributes by positioning SCG recycling as a sustainable industrial ecosystem problem that requires coordinated recovery conditions, viable infrastructure and downstream value creation.

Keywords: Spent coffee grounds; coffee shop ecosystem; circular economy; system dynamics; recovery models

Paper ID: SSIEC13

AI-assisted Design Innovation Based on Cultural Gene Theory: A Case Study of Yiwulü Mountain Manchu Papercut

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ABSTRACT

Current research on cultural heritage faces numerous challenges, including damage caused by natural and human factors, a break in the succession of inheritors, and a growing disconnection from modern life. It is imperative to adopt emerging technologies to support both the protection and innovation of cultural heritage. In this work, the cultural gene theory was integrated with AI, taking the Yiwulü Mountain Manchu Papercut (YMMP) as an example. The research is mainly divided into two stages, The first stage is AI-assisted cultural gene collection. Through ChatGPT, the cultural gene of YMMP was collected followed by the establishment of a culture gene database. And the second stage is AI-assisted cultural gene translation. The dominant genes were used as design references, while the recessive genes served as design norms. Midjourney was used to generate innovative papercut that align with traditional styles. Finally, the 5-level Likert Scale was used to measure the satisfaction and style similarity between the papercut generated by AI and the papercut made by expert of YMMP. The result proves that participants prefer the papercut generated by AI and the traditional style is simulated well by AI. An approach to enable a full-process proactive AI-assisted protection and innovation of cultural heritage is served.

Keywords: Cultural gene; AI; Design innovation

Paper ID: SSIEC14

Thermal Performance Assessment of High Reflectance Roof Coatings Using Building Energy Modelling

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ABSTRACT

Roof solar heat gain is a practical cooling problem in Malaysia because many low-rise buildings receive strong year-round solar exposure while relying on air-conditioning. This study evaluates a high-reflectance, high-emissivity roof coating for concrete and zinc roofing using an experimental-simulation workflow. Outdoor roof-specimen measurements were used to validate OpenStudio/EnergyPlus models with a site specific hybrid (EnergyPlus Weather) file. Coating properties were entered by converting solar reflectance to solar absorptance, $\alpha_{solar} = 1 - SR$, and using thermal emittance as the long-wave emissivity input. The validated input method was then applied to a simplified Rumah Hijau whole-building model with four scenarios: bare concrete, painted concrete, bare zinc and painted zinc. For the 1 September–31 October simulation period, painted concrete reduced total HVAC electricity from 1055.56 to 772.22 kWh, while painted zinc reduced it from 1041.67 to 805.56 kWh. These reductions correspond to HVAC elec tricity savings of 26.8% and 22.7%, respectively. With an assumed coating cost of RM1000 and a tariff of RM0.5068/kWh, simple payback was estimated at 1.16 years for concrete and 1.40 years for zinc. The results indicate useful cooling-energy reduction under fixed model assumptions but should not be interpreted as direct electricity-bill predictions.

Keywords: Cool roof; High-reflectance coating; EnergyPlus/OpenStudio; Roof temperature validation; Malaysia

Paper ID: SSIEC15

Growth Responses of *Chlorella* and *Navicula* to Supplemental CO_2 Feed and Irradiance

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ABSTRACT

Microalgal cultivation can support biological carbon utilization, but growth depends on both carbon delivery and irradiance. This exploratory study screened supplemental CO_2 feed and white-light irradiance for *Chlorella* sp. and *Navicula* sp. during 14-day batch cultivation in 500 mL Erlenmeyer photobioreactors with 350 mL working volume. Two independent one-factor-at-a-time experiments were performed. In the carbon-feed screen, all flasks received ambient air and were supplied with 0, 150, or 300 mL min^{-1} of additional CO_2. In the irradiance screen, cultures received ambient air only at 100, 150, or 200 µmol photons m^{-2} s^{-1}. Growth was tracked on Days 1, 7, and 14 by hemocytometer cell counts and optical density at 680 nm (OD_{680}). At Day 14, 150 mL min^{-1} produced the highest values within both species: 73.6 × 10^{4} cells mL^{-1} and OD_{680} 0.689 for *Chlorella* sp., and 107.7 × 10^{4} cells mL^{-1} and OD_{680} 0.868 for *Navicula* sp. The 200 µmol photons m^{-2} s^{-1} treatment also produced the highest irradiance-screen values for both species. Because each treatment used one biological flask, the findings are descriptive and identify best-performing tested settings rather than statistically confirmed optima. The results support replicated factorial validation with direct carbon-balance measurements.

Keywords: Microalgae; Supplemental CO_2; Irradiance; *Chlorella* sp.; *Navicula* sp.

Paper ID: SSIEC16

Development of a Machine Learning-Based Task Classification Model for Optimizing Human–Robot Collaboration in End-of-Life Vehicle (ELV) Disassembly

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ABSTRACT

Efficient End-of-Life Vehicle (ELV) disassembly is vital for the circular economy, yet manual processes remain slow and hazardous. While Human-Robot Collaboration (HRC) offers a solution, current systems lack the real-time perception required to maintain safety boundaries mandated by ISO/TS 15066. This research develops a machine learning framework for real-time task classification using a Lean Perception architecture that prioritizes computational efficiency by replacing high-latency visual tracking with purely kinematic data. Utilizing a multi-node network of three Inertial Measurement Units (IMUs) equipped with onboard Kalman filters, spatial data was captured for five core disassembly tasks: unscrewing, unbolting, opening the hood, uncapping, and lifting. Evaluation of temporal segmentation revealed that a 2.0-second Fixed-Size Overlapping Sliding Window (FOSW) optimally captured macro-kinematic upper-arm translations, resolving fine-motor confusion. A 100-tree Random Forest ensemble was selected for final deployment, achieving 89.1% classification accuracy. The model was chosen for its lightweight O(1) computational complexity, enabling the sub-second inference speeds necessary for industrial safety. Integration into a live UDP dashboard demonstrated the system's ability to provide continuous task-state updates with algorithmic prediction smoothing and a confidence-based safety threshold to prioritize functional safety. This work establishes a robust, low-latency perception module that bridges the gap between theoretical HRC and practical, intelligent ELV recycling workstations

Keywords: Human-robot collaboration (HRC); End-of-life vehicles (ELV); Machine learning; Task classification; Inertial measurement units (IMU)

Paper ID: SSIEC17

Human-Factor Effects and Parameter Configuration of Haptic Takeover Warnings under True and False Alarms in Level 3 Conditional Automated Driving

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ABSTRACT

Level 3 conditional automated driving requires drivers to resume vehicle control promptly when the system approaches its operational limits. Takeover warnings therefore need to facilitate effective responses to genuine hazards while avoiding unnecessary actions induced by false alarms. This research uses a sequential two-stage experimental design to investigate the human-factor effects of integrated haptic takeover-warning configurations and their key physical–temporal parameters. Stage 1 used a 2 × 2 within-subject design with 56 participants to compare the behavioural and subjective effects of two integrated haptic configurations under true alarm and false alarm conditions, yielding 3,360 formal trials. The results showed that the model-estimated braking response time was approximately 14.4% lower for Mode B under true alarm. Under false alarm, false braking increased from 4.3% to 7.9%, and the trial-level model indicated that the odds of false braking in Mode B were approximately 1.90 times higher than in Mode A. Mode B was also associated with higher perceived urgency, perceived intensity, and discomfort, indicating a clear trade-off between response efficiency and false-alarm tolerance across the two haptic configurations. Stage 2 used a 2 × 2 frequency × envelope within-subject factorial manipulation, with waveform and maximum presentation duration held constant, to compare four parameter configurations. The same 56 participants completed 4,032 formal trials, and formal analyses of the parameter effects are currently underway. Overall, the research establishes a sequential empirical structure that progresses from integrated configuration evaluation to parameter-level factorial analysis, providing a basis for developing haptic takeover-warning configuration and calibration strategies that jointly consider response efficiency, false-alarm tolerance, and user experience in Level 3 automated driving.

Keywords: Level 3 automated driving; Haptic warning; Takeover request; False alarm; Braking response time; Parameter configuration

Paper ID: SSIEC18

Characterization and Thermal Decomposition Performance of Ammonium Perchlorate Incorporated with Carbohydrate Binders in Solid Rocket Propellants

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ABSTRACT

One of the main goals in modern solid rocket propellant research is to produce clean, environmentally friendly combustion that complies with insensitive munitions standards. The combustion of composite solid rocket propellants made of ammonium perchlorate (AP), hydroxyl-terminated polybutadiene (HTPB), and aluminum produces a high volume of chlorine gas and dense smoke particles, which is harmful and obstructs the vision of armed forces. To reduce smoke production, HTPB is being replaced with sugar alcohols, which serve as biodegradable fuels. This solid propellant was characterized using FTIR, XRD, CHNS analysis, DSC, and TGA. Additionally, the smoke intensity and solid residue from solid propellant combustion were characterized. The reaction kinetics were studied using TGA under iso-conversional conditions, and the effects of the metal additive on solid propellant were compared. To estimate kinetic parameters during high-temperature decomposition, thermal analysis experiments were conducted at four heating rates using the Ozawa and Kissinger methods. The results indicate that combining AP and sorbitol with ferric oxide synergistically reduces the energy activation to 122.47 kJ/mol compared to AP/sorbitol alone. Conversely, the addition of magnesium increases the activation energy to 156.68 kJ/mol. Overall, ferric oxide acts synergistically in both formulations by lowering the energy calculated activation through both the Ozawa and Kissinger methods. Furthermore, results from the combustion of solid propellants demonstrate that using sorbitol as a solid fuel significantly reduces smoke opacity compared to HTPB. Further tests using starch, a natural polymer, supported these findings.

Keywords: Sorbitol; Ammonium perchlorate; Solid propellant; Thermal decomposition; Activation energy

Paper ID: SSIEC19

Coupled Aero-Hydrodynamic Modelling and Stability Analysis of a Multi-Source Floating Renewable Energy Harvester

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ABSTRACT

Multi-source floating renewable energy harvesters integrating wind, wave, and solar technologies offer high offshore power density but face severe dynamic stability challenges in harsh marine environments. Predicting the platform's behavior - particularly for those supporting hybrid vertical-axis wind turbines (VAWTs) - is computationally prohibitive using fully coupled computational fluid dynamics (CFD) and highly inaccurate using decoupled linear methods. This study presents a novel, reduced-order, partially coupled aero-hydrodynamic simulation framework to efficiently evaluate a 6-Degree-of-Freedom hybrid Darrieus-Savonius VAWT platform. The platform's hydrodynamic parameters (mass, damping, and stiffness) were rigorously calibrated from high-fidelity ANSYS AQWA diffraction analyses using system identification techniques. Time-varying aerodynamic thrust and torque were computed using the Double Multiple Stream Tube and Chauvin pressure-drag models under IEC Kaimal turbulent wind fields and then integrated into the time-domain equations of motion. Simulations reveal that while the canonical platform remains highly stable at a rated wind speed of 6 m/s, it exhibits capsize vulnerability - with roll and pitch exceeding 45° - under extreme 20 m/s offshore storm conditions. Through parametric design exploration, we demonstrate that a combined stability variant utilizing deep ballast and expanded pontoon waterplane area effectively limits maximum rotational offsets to under 6°. Ultimately, this computationally efficient framework captures critical nonlinear aero-hydrodynamic interactions, enabling rapid feasibility assessments and structural optimization for next-generation sustainable offshore energy infrastructure.

Keywords: Multi-source renewable energy platform; Vertical axis wind turbine; Aero-hydrodynamic coupling; Reduced-order modelling; 6-DOF dynamic response

Paper ID: SSIEC20

Effect of BHT Antioxidant on the Thermo-Oxidative Stability and Tribological Performance of Waste Cooking Oil-Derived TMP Ester Biolubricant

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ABSTRACT

Waste cooking oil (WCO) valorisation as a sustainable feedstock for biolubricant production supports waste reduction goals and the development of biodegradable and non-toxic alternatives to petroleum-based lubricants. However, WCO biolubricants often show poor oxidative stability, which limits practical applications. The chemical modification strategies and incorporation of antioxidants are required to enhance the performances and extend biolubricants' shelf life. This study investigates the relationship between thermo-oxidative degradation and wear progression in a WCO-derived trimethylolpropane (TMP) ester biolubricant formulated with and without butylated hydroxytoluene (BHT). The samples were subjected to accelerated thermo-oxidative ageing based on ASTM D4636 principles at 120°C for up to 72 h under controlled airflow in the presence of a metal catalyst. Degradation was evaluated through acid value, kinematic viscosity, carbonyl index, oxidation induction period, tribological performance by four-ball tester and worn surface analysis by SEM-EDX. The results show that BHT prolonged the oxidation induction period and suppressed the ageing-induced increases in acid value, carbonyl index and kinematic viscosity. The antioxidant-containing biolubricant also exhibited less severe wear and reduced surface damage after ageing compared to that of additive-free biolubricant. Oxidation indicators correlated with the tribological deterioration, indicating that the buildup of degradation products and viscosity growth were associated with poorer lubricant performance and increased wear. These findings demonstrate that controlling thermo-oxidative degradation is vital for maintaining the physicochemical and tribological performance of WCO-derived TMP ester biolubricant.

Keywords: Waste cooking oil; Thermo-oxidative ageing; Oxidation stability; Antioxidant additive; Tribological performance

Paper ID: SSIEC21

Decarbonization Strategies for Electric Vehicle Batteries Production

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ABSTRACT

The rapid growth of electric vehicles (EVs) has led to a sharp increase in demand for lithium-ion batteries (LIBs), raising environmental concerns, particularly regarding greenhouse gas (GHG) emissions during production. This study conducts a cradle-to-grave Life Cycle Assessment (LCA) on three battery chemistries, Lithium Iron Phosphate (LFP), Lithium Nickel Cobalt Aluminum (NCA), and Lithium Nickel Manganese Cobalt (NCM), evaluating emissions across material extraction, manufacturing, transportation, use, and end-of-life (EOL) treatment. Results show that material and manufacturing stages together account for up to 90% of total emissions. Under a reuse and recycled material scenario, the total GHG emissions, indicated in CO2 equivalents (CO_2-eq), over a 10-year lifetime are estimated at 55.13 kg CO_2-eq/kWh for LFP, 64.64 kg CO_2eq/kWh for NCA, and 66.53 kg CO_2-eq/kWh for NCM811, reflecting up to 40% reduction compared to production using virgin materials. Key decarbonization strategies identified include the use of recycled content, integration of renewable energy, and energy-efficient manufacturing techniques such as dry electrode coating and localized dry rooms. Incorporating circular economy practices such as reuse and remanufacturing further enhances emission reductions, offering actionable insights for a more sustainable EV battery value chain.

Keywords: Electric vehicles, Lithium-ion batteries, Life cycle assessment, Decarbonization

Paper ID: SSIEC22

Operational Readiness of Small and Medium Enterprise (SME) Automotive Workshops in Implementing Recovery Activities for Second-Life Electric Vehicle (EV) Batteries

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ABSTRACT

The transition to the use of electric vehicles (EVs) has now become a primary agenda for achieving environmental sustainability. However, this transition requires the preparation of a good support service ecosystem, especially those involving local Small and Medium Enterprise (SME) workshops. Although workshop operators are interested in EVs, their level of readiness is still hindered by various critical operational issues. Therefore, this study aims to assess the readiness level of SME workshop operators in adapting to EV maintenance technology and second-life battery recovery. Additionally, this study aims to identify the main barriers and develop a framework to support the upgrading process of the involved workshops. Hence, 30 SME workshop operators have been involved in this study as the primary respondents. Subsequently, Qualitative Comparative Analysis (QCA) was applied to determine the primary causal combinations influencing their readiness status. The results of the QCA analysis found that the simultaneous combination of a lack of skills, lack of facilities, and lack of finances (~KM*~FS*~KW) is the root cause explaining 96.3% of the workshops' unreadiness. This barrier is supported by the operators' feedback, which ranked the issue of financial capital as the most critical obstacle at 90%. Furthermore, the findings also indicate an information delivery problem, as 86.7% of operators were unaware of government assistance initiatives. In conclusion, although awareness regarding EV safety already exists, weaknesses in terms of financial and technical skills still make it difficult for SME workshops to initiate these services. Hence, this study proposes a framework involving funding assistance from the government, technology transfer by the industry, and the enhancement of mechanic training through TVET programs.

Keywords: Electric vehicles; EV Batteries; Recovery process; SME Workshop; QCA

Paper ID: SSIEC23

Material Screening of Reusable High-Temperature Masking Systems for HVOF-Based Aerospace Repair Processes

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ABSTRACT

High Velocity Oxy-Fuel (HVOF) thermal spray processes require effective masking systems to protect non-target surfaces from overspray deposition, thermal loading and abrasive particle impact. Conventional masking approaches are based on the adhesive-type masking. Although adhesive-based masking systems are effective, they generate recurring consumable costs and prolonged masking time due to their single-use nature, motivating the development of reusable masking solutions. The development of reusable masking systems requires materials capable of maintaining dimensional stability and structural integrity under combined thermal and kinetic loading conditions. This study presents a preliminary material screening methodology developed to evaluate candidate materials for reusable masking applications in HVOF environments. Seven materials comprising conventional engineering polymers, elastomers, ceramic-based materials and additively manufactured materials were assessed under representative HVOF exposure conditions. The findings demonstrate that material selection for reusable HVOF masking systems cannot rely solely on published service temperature ratings. Materials exhibiting excellent nominal thermal resistance may still fail under the combined influences of particle impact, thermal cycling and deposition accumulation. The study further demonstrates the effectiveness of coupon-based material screening as a practical down-selection methodology for identifying promising candidates prior to more complex geometry-specific durability evaluations. Based on the screening results, two materials were identified as the most suitable candidates for further development and validation.

Keywords: HVOF thermal spray; Reusable masking systems; Aerospace repair; High-temperature polymers; Material screening

Paper ID: SSIEC24

Investigation of Ergonomic Challenges Associated with Dental Visual Aids and Work-Related Musculoskeletal Disorders Among Dentists

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ABSTRACT

Work-Related Musculoskeletal Disorders (WMSDs) are highly prevalent among dental professionals due to prolonged static posture, repetitive movements, and awkward working positions during clinical procedures. Despite the increasing use of dental visual aids such as magnification loupes and dental microscopes, limited studies have compared their ergonomic impact on operator posture and musculoskeletal risk. This study aims to investigate the ergonomic challenges associated with different dental visual systems, including naked eye practice, loupes, and microscopes. Task analysis was conducted to evaluate clinical workflow, visual demand, postural demand, and ergonomic risk during dental procedures. Failure Mode and Effects Analysis (FMEA) was also applied to identify and prioritize critical ergonomic risk factors associated with visual accessibility during clinical tasks. The findings showed that naked eye practice was associated with greater neck flexion, trunk flexion, awkward posture, and higher musculoskeletal risk. The use of loupes improved visual access and reduced excessive head tilt, while microscope-assisted procedures demonstrated better upright posture and reduced neck strain. However, prolonged static posture remained a concern across all visual systems.
The study concludes that dental visual systems significantly influence operator posture and ergonomic risk. The findings highlight the importance of ergonomic assessment and may support future improvements in occupational health and ergonomic practices in dentistry.

Keywords: Ergonomics, Dentistry, WMSDs, Dental visual aids, Task analysis, FMEA

Paper ID: SSIEC25

Bio-Inspired Lattice Topologies in Spherical Sports Equipment: Experimental Evaluation of Energy Dissipation in Additively Manufactured Sepak Takraw Balls

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ABSTRACT

The high-velocity impacts inherent in sepak takraw expose athletes to significant repetitive forces, particularly during heading maneuvers. Traditional manufacturing methods, such as injection-molded polypropylene and rattan weaving, offer limited structural flexibility to optimize internal stiffness for targeted energy dissipation. This study investigates the integration of bio-inspired, topology-optimized lattice structures (e.g., Voronoi and hexagonal configurations) within the shell of sepak takraw balls to enhance impact attenuation. To establish a rigorous performance baseline, dynamic kinematic parameters - specifically the coefficient of restitution - were first empirically derived from a conventional Sepak Takraw ball via standardized physical drop-test experiments. Subsequently, physical prototypes of the novel lattice configurations were fabricated via fused deposition modeling and subjected to identical drop-testing protocols. Experimental results demonstrate that the conventional ball exhibits a baseline coefficient of restitution of 0.673, whereas the additively manufactured prototypes achieved tailored coefficient of restitution values ranging from 0.725 to 0.772. These findings confirm that altering the internal lattice topology directly modulates energy absorption capabilities while maintaining dimensional deviations strictly below 15% to meet international sizing regulations. Ultimately, this study establishes a scalable, empirical framework for engineering additively manufactured sports equipment tailored to specific biomechanical injury thresholds, laying the essential groundwork for future computational modeling.

Keywords: Additive manufacturing; Lattice structures; Energy dissipation; Sports engineering; Material efficiency

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Sustainable Infrastructure for Outdoor Sports: CFD-Driven Airflow Control and Cost Feasibility in Airbadminton Arenas

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ABSTRACT

Outdoor sports like AirBadminton are highly vulnerable to wind-induced shuttlecock drift, which compromises gameplay fairness and safety. Designing sustainable, cost-effective infrastructure to control these environmental challenges remains a critical engineering gap. This study presents a comprehensive 3D computational fluid dynamics (CFD) analysis to optimize the aerodynamic and economic performance of semi-enclosed AirBadminton arenas. Utilizing the realizable k-epsilon turbulence model across varying wind profiles, the impact of roof geometries, wind barriers, and corner billboard placements on internal airflow was evaluated. The results indicate that the proposed modular arena achieves an approximate 70% reduction in internal wind speed, successfully attenuating the Badminton World Federation's 3.33 m/s external velocity limit to an ideal 0.2 m/s within the central playing zone. Furthermore, integrating corner billboards significantly disrupts flow separation and minimizes turbulent vortex formation, though this shielding effect inherently alters the aerodynamic load distribution on the perimeter structures. A corresponding feasibility analysis demonstrates that utilizing lightweight, modular materials - such as aluminum trusses and sandwich panels - yields a total construction cost of approximately RM 553,300 (USD 140,076) for a 300-spectator facility. This CFD-driven approach successfully balances aerodynamic control, structural integrity, and economic viability, offering a validated, sustainable blueprint for developing high-performance outdoor sports infrastructure globally.

Keywords: Computational fluid dynamics (CFD); Sustainable sports infrastructure; Aerodynamic wind attenuation; Techno-economic feasibility; AirBadminton

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Fostering Inclusivity in Adaptive Sports: Design and Preliminary Validation of an Embedded Aiming Prototype for Visually Impaired Archers

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ABSTRACT

Adaptive archery for visually impaired athletes traditionally relies on cumbersome, tripod-based mechanical tactile sights that restrict mobility and limit independent training. In alignment with the United Nations Sustainable Development Goals (SDG 10 and SDG 11) to reduce inequalities and foster inclusive community sports facilities in Malaysia, this preliminary study presents the design and early validation of a portable, sensor-based aim-assist prototype. The system architecture replaces static mechanical constraints with a digital interface, integrating an ESP32 microcontroller, an ADXL345 inertial measurement unit for pitch and roll tracking, and a time-of-flight laser sensor for spatial target alignment. The hardware is enclosed in an impact-resistant, 3D-printed PETG housing designed to withstand bow recoil. Preliminary laboratory and field testing at 1-meter and 5-meter ranges evaluated the system's threshold gating and latency. Benchmarking demonstrated a highly responsive mean signal propagation delay of 16.70 ms, which successfully mitigates disruptive over-correction loops by operating well below the human biomechanical perception threshold. During 5-meter trials, the aim-assist module enabled a 100% target hit rate, achieving high precision with a core cluster spread of 4.5 cm and an extreme spread of 14.2 cm. However, a systematic grouping offset of 8 cm was observed, highlighting ongoing data validation challenges related to a 0.9° mechanical sensor misalignment and variations in archer release biomechanics. These initial findings validate the proof of concept for empowering adaptive athletes through digital sensing, while clearly delineating the calibration improvements required for future field deployment.

Keywords: Assistive mechatronics; Inclusive product design; Sensor-based aiming; Adaptive archery; Inertial measurement unit