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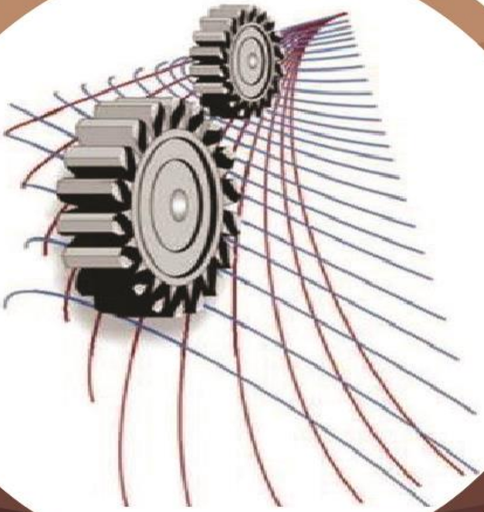

ICME 2025
ABSTRACTS

Department of Mechanical Engineering
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Abstracts
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International Conference on Mechanical Engineering 2025
(ICME 2025) 17-18 December, 2025, Dhaka, Bangladesh

Paper ID: K-01

Biomechanics Link Between Mind and Body

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ABSTRACT
For centuries, the relation between mind and body has intrigued philosophers and 118scientists. How body affects the mind, and mind affects the body? Since mid-19th century, scientists searched for the "mind" in the anatomy of brain, just as they explored the "body" with Da Vinci's artistic renditions of muscles. Muscles are considered as contractile force actuators, and neurons as information processors. Here, we will discuss our findings, revealed by a novel MEMS sensor, that neurons are also contractile, both *in vivo* and *in vitro.* This contractility leads to tension in axons, a long cable-like structure that connects neurons with each other. We measure the magnitude and time evolution of tension in axons using specially designed MEMS force sensors. We then correlate the tension with neuronal function (firing pattern). We find that without this tension neurons cannot function. Furthermore, we have preliminary evidence of increased neuronal contractility with physical exercise, revealing the first possible link between mind and body. Understanding the critical role of neuron mechanics on neuron function may lead to new therapies against mental diseases including anxiety, depression, dementia, and Alzheimer's disease.

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Paper ID: K-02

Advancing Biomass-Based Materials Toward Sustainable High-Performance Composites

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ABSTRACT

The urgent global demand for sustainable materials has driven the replacement of conventional petroleum-based plastics and metals with environmentally benign alternatives across high-performance sectors. Natural Fiber Reinforced Composites (NFRCs), fabricated from readily available lignocellulosic resources such as jute, flax, and hemp, are increasingly recognized as a promising class of sustainable materials due to their low density, cost-effectiveness, and intrinsic biodegradability [1]. Despite these advantages, widespread industrial adoption has been limited by inherent material challenges, notably poor fire resistance and high hydrophilicity, which compromise dimensional stability and mechanical integrity in humid or outdoor environments. Additionally, traditional industrial additives and flame retardants often rely on toxic compounds that diminish both eco-friendliness and structural performance [2]. This study addresses these challenges through a multi-pronged approach. Fully biobased chitosan- and starch-based matrices were developed as sustainable NFRC platforms. For high-performance polymer matrices, including polypropylene, vinyl ester, and epoxy, biobased additives derived from agricultural waste such as pinecone, chitosan, grass, eggshell, and rice husk were incorporated to enhance mechanical and flame-retardant performance. To overcome the common issue of fiber hydrophobicity and potential mechanical degradation when using flame-retardant additives, a novel plant-based liquid fiber treatment was developed. This treatment imparted robust fire resistance and improved water repellency to natural fibers without compromising, and in some cases enhancing, their mechanical properties. Additionally, hybrid fiber reinforced composites were systematically studied. These hybrid systems demonstrated the versatility of the developed materials, achieving a balance of mechanical strength, flame retardancy, and water resistance across diverse fiber-matrix combinations, highlighting their potential for high-performance applications. Beyond fire safety, this work also demonstrates the development of self-healing NFRCs capable of autonomously repairing minor mechanical damage, as well as transparent wood composites that combine optical clarity with high strength and thermal stability [3]. These advancements highlight the potential of biomass-based materials to meet diverse functional requirements, offering lightweight, durable, and environmentally friendly alternatives to conventional materials.

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Paper ID: K-03

Advances in Traumatic Brain Injury Risk Prediction And Prevention

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ABSTRACT

Head and neck injuries, including traumatic brain injuries (TBI), are among the leading causes of disability and death worldwide, affecting millions of individuals in motor vehicle accidents, sports, and military settings [1–5]. The first segment of this study introduces a musculoskeletal head–neck model [4] developed to investigate the effects of impact location, severity, and neck strength on head and neck injury parameters. Various impact severities, characterized by linear and rotational acceleration profiles, were analyzed. The second segment presents a neural network–based optimization framework for designing lighter yet highly energy-absorptive structures to effectively mitigate acceleration during impact [6–8]. Finally, the study discusses the limitations and challenges of current approaches to TBI prediction and prevention, and outlines directions for future research.

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Paper ID: K-04

Development of a Design Standard for E-Rickshaws in Bangladesh

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ABSTRACT
Electric motor and battery-powered three-wheelers, commonly known as Easybikes, have currently been termed as “Low Speed E-Rickshaws” by the local government division of Bangladesh. These vehicles have gained widespread popularity especially in rural areas since their first introduction in 2006. These vehicles are used in huge numbers (estimated 2-3 million) vastly spreading electric mobility in Bangladesh. They are creating millions of jobs, supporting livelihoods and reducing the effective need of imported diesel fuel and resulting emissions. The Easybike fleet is contributing hugely to the economy of the country. Although with zero tailpipe emission and high economic benefits, these low-cost vehicles face significant challenges regarding passenger and vehicle safety, inefficient batteries, improper charging practices, and issues relating to manufacturing quality. Unfortunately still there is no central regulatory authority overseeing their configurations, numbers to be registered, technical specifications and production quality. This research at BUET, funded by Bangladesh Energy and Power Research Council (BEPRC) aimed to propose a design standard for manufacturing these E-Rickshaws in Bangladesh. Based on this specified guideline government of Bangladesh is currently developing a registration process for introducing such type-approved E-Rickshaw models produced by local industry.
An initial technical assessment, involving - road survey, manufacturing plant visits and stakeholder meetings, was carried out to assess the in-use designs, vehicle usage and their performance. The survey assessed feedback from drivers, passengers, vehicle owners, manufacturers, component importers, and associated regulating authorities. The various existing vehicle configurations throughout the country were studied and road tests of a number of selected vehicle models were carried out to evaluate their performance. Through these surveys some key limitations were identified in the existing configurations, and 16 technical modifications were proposed to improve the vehicle and passenger safety as well as their functionality. However all desired changes and some electrical conversion efficiency issues could not be addressed under the proposed design standard due to the limitation regarding increase of production cost of the vehicle, which the market may not support at this stage. Major Easybike manufacturers, component importers and regulating authorities were consulted at various stages of developing this design standard.
A standardized E-Rickshaw model was developed and fabricated with a built-in speed limit of 30 km/h. The E-Rickshaw had two passengers and driver configuration, fitted with four half-doors with locking facility. The physical dimensions, weight, tyre size, acceleration, turning and braking performance were designed as per the proposed guideline specification. The ground coverage of the vehicle (1.1 × 2.5 m) was kept very similar to that occupied by a pedal driven rickshaws considering inner city use. The vehicle width was limited so that two such vehicles could pass across each other in typical narrow rural roads. The turning radius of the prototype was 2.4m which could ensure to take full u-turns in roads with 5m widths and delicate maneuvering within congested charging stations. The vehicle produced was tested in the laboratory using a chassis dynamometer and on road as well. The chassis structure was

physically tested for bending and twisting strength limits. Using the current production technique the mostly locally produced body parts could be quickly assembled to fabricate a full vehicle. The strength of body material, coating thickness and paint quality were tested. Light, horn and wind shield safety features as well as the water wading capability of the IP67 specified motor drive and its harnesses were tested with the vehicle sufficiently immersed in a water tank. The prototype developed weighed 394 kg (including batteries) which could reach a maximum limiting speed of 30 km/h within 16 sec from rest and capable of easily climbing 7°(12%) gradient at full load capacity of 250kg using the drive system powered by a 1.2 kW-48V PMSM motor. The hydraulic brakes used could bring the vehicle from top speed to rest within 7.2 meters on a road. The current prototype was fitted with four 12V Pb-Acid batteries each of 140 Ah capacity which took about 8 hours to get fully charged using single phase AC charger consuming 6.7 kWh of electricity. It was capable to run for about 65 km at full capacity on a single charge yielding an electrical mileage of 9.7 km/Unit of electricity. The motor was capable of producing regenerative braking but it was found not be very effective in recharging the batteries. Front and rear suspension springs and dampers were specified to reduce vibration and comfort of the ride. The vehicle was fitted with a new design of weather protection that can provide protection of the passengers as well as the driver under all weather conditions of Bangladesh.

The E-Rickshaw along with the measured performance results were exhibited and presented to stakeholders since early 2023. The research team had many meetings with policy making administration at various phase to convince them regarding the safety issues and the potential of such a vehicle. A three-phase strategy was proposed to related government agencies at the middle of 2023 for the registration of standardized vehicles – (i) An initial phase of transformation for inclusion of the vast number of in-use Easybikes through formal registration process after going through proposed modifications; (ii) Type approval of new standardized models that will come fresh out of the production line of enlisted factories with an economic life of about five years; and (iii) New design standards of 3-wheeler and 4-wheeler low speed EVs for near future implementation. The low speed category and a number of features detailed in this proposal have already been incorporated in the “Electric Vehicle Registration Rules 2023” implemented by BRTA. The local government department of the government has taken the initiative of registration of such standardized new production of 3-weheelers termed as “Low Speed E-Rickshaws”. The local government ministry has already approved the proposed technical specification guideline in early 2025 and is now in the process of implementation of the registration program initially at Dhaka metropolitan city through DNCC and DSCC. The ministry also has plans to expand the program to other city corporations, district towns and small municipalities throughout the country. The industry has been very enthusiastic to embrace the standardization. Eight local manufacturing industries have already developed standardized E-Rickshaw prototypes which have passed through their evaluation procedure tested out by BUET, achieving the specific technical requirements. This element of standardized mode of electric transportation is also being incorporated in the “Electric Vehicle Manufacturing Policy” by the ministry of industries and “Electric Vehicle Charging Policy” by SREDA. Hence, despite numerous challenges the proposal of registration of standardized low speed 3-wheeler E-Rickshaws is gradually gaining ground. Finally if implemented this process can create an encouraging example where a research outcome from academia makes its place in national level policy and manufacturing standard for the local industry, affecting livelihoods of millions in Bangladesh.

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Paper ID: K-05

Investigating Nanoparticle-Polymer Interaction at The Atomic Scale in Nanocomposites

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ABSTRACT
The synthesis of polymer nanocomposites by reinforcing nanoparticles into a polymer matrix is a well-established field, and the last few decades have produced an enormous amount of data showing impressive property enhancements. However, a critical gap remains: the fundamental science driving this improvement has not been fully elucidated. The origin of these enhancements is clearly the particle-polymer interaction at the atomic scale, governed by two primary factors: 1) Interfacial Forces: The specific chemical interactions between the nanoparticle surface and the polymer chains (e.g., Van der Waals forces, ionic/electrostatic forces, π-π stacking, covalent, and hydrogen bonding). The nature of these forces is dependent on the chemical composition of both the nanoparticle and the polymer architecture. 2) Polymer Chain Conformation and Dynamics: How the presence of the nanoparticle surface alters the polymer chain's movement and arrangement (dynamics and conformity). This directly influences bulk material properties such as glass transition temperature, crystallinity, storage and loss modulus, cross-linking density, and stress transfer. The following discussion, using examples of silica nanoparticle-reinforced nanocomposites, will further explain the role of these two atomic-level factors.

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Paper ID: K-06

Inverse Heat Transfer Problems in Thermal Ablation

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ABSTRACT

During the reentry of space vehicles, the extreme temperatures encountered by their thermal shields surpass the capabilities of conventional temperature sensors for direct measurement. Consequently, temperature sensors are positioned beneath the surface of these hot shields for temperature monitoring, and an inverse analysis is performed to estimate the thermal ablation for appropriate tile design. Unfortunately, inverse heat transfer problems are inherently ill-posed since they lack a unique solution and are highly susceptible to measurement noise. As a result, solving these problems requires identifying unknown parameters or functions that produce an acceptable value for the objective function. Recent advances in machine learning, particularly deep learning, have revolutionized the field by providing data-driven approaches to inverse problems. Hence, a physics-informed neural network (PINN) that combines losses from both data and physics of the problem is a promising technique for inverse problems in thermal ablation, including the prediction of unsteady heat flux. However, traditional physics-informed machine learning algorithms, such as PINN, struggle with predicting heat flux in thermal ablation problems due to moving boundary conditions and a lack of temperature data in the inaccessible domain near the moving ablation boundary. This study presents a hybrid approach, using an artificial neural network for the accessible domain and a physics-based numerical technique for the inaccessible domain to solve the inverse heat transfer problem in thermal ablation. For the forward problem, a physics-based numerical model is developed to obtain the temperature distribution in the unsteady advection-diffusion problem for both charred and non-charred ablations, considering simultaneous mass and heat transfer from the ablative boundaries. Owing to the change in the length of the computational domain due to the moving boundary, the Landau coordinate is used to remap the new grids each time. The temperatures at the sensor locations are obtained from the quadratic interpolation of the numerical solution at the remapped grid points, which are used for training our machine learning algorithm. Our results indicate that this hybrid methodology significantly outperforms traditional physics-informed machine learning techniques, achieving excellent accuracy in predicting the temperature profiles and heat fluxes under complex conditions for both constant and variable heat fluxes and properties.

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Invited Talks

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Paper ID: I-01

Materials State Assessment of Fiber-Reinforced Polymer Composites and Bonded Joints: State of The Art and Emerging Material-As-Sensor Techniques

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ABSTRACT

Fiber reinforced polymer composites and adhesively bonded joints are widely used in aerospace, energy, automotive, and defense applications because of their high specific strength, corrosion resistance, and broad design flexibility. As their use expands and replaces traditional metallic components, the need for reliable material state-based assessment methods has grown. These methods must follow the degradation of raw materials such as prepregs, monitor the evolution of material state during manufacturing through in situ measurements, detect defects introduced during processing, track internal damage under mechanical and thermal loads, evaluate long term environmental effects such as moisture uptake and determine the quality of adhesively bonded joint in assembled structures. A broad suite of non-destructive testing and evaluation (NDT&E), and structural health monitoring (SHM) techniques, including ultrasonics, X-ray computed tomography, thermography, guided waves, digital image correlation (DIC), acoustic emission, and optical fiber sensors, supports these needs. Although these methods have demonstrated strong capability, many exhibit limited sensitivity to subtle changes in the polymer matrix, cannot reliably capture the onset of micro scale damage, and often struggle to detect early signs of matrix degradation, interphase deterioration, or distributed micro cracking that do not produce clear geometric or surface level signatures. To address this gap, researchers are investigating methods that can sense the intrinsic condition of the material. Broadband dielectric spectroscopy [1] shows significant promise because the dielectric response is strongly influenced by polymer chemistry, moisture content, molecular mobility, and micro cracking within the matrix and the interphase [2]. Measurements collected across a broad frequency range allow the material to function as its own sensing element. This enables assessment of raw materials, monitoring of cure progression during manufacturing [3], evaluation of adhesive bond quality, and tracking of environmental degradation [4], while also informing decisions related to reuse or recycling at the end of service life[5].This work presents a concise overview of current NDE and SHM monitoring approaches for composite structures and bonded joints and highlights the potential of broadband dielectric spectroscopy to provide continuous, sensitive, and material state specific information.

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Paper ID: I-02

Additive Manufacturing of Multifunctional Wood Structures

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ABSTRACT

For millennia, natural wood has served as a foundational material for buildings, furniture, and architectural structures. Wood is typically shaped through subtractive manufacturing techniques, which generate substantial waste and inefficiency. [1]. Therefore, additive manufacturing of wood presents a sustainable opportunity to minimize and valorize wood waste. In this work, we explore this vision through direct ink writing (DIW) of natural wood components. First, we demonstrate an additive-free, water-based ink composed of lignin and cellulose, the primary building blocks of wood, that enables the 3D printing of architecturally designed wooden structures [2], [3]. The printed structures after post-processing closely resemble the visual, textural, olfactory, and anisotropic mechanical properties of natural wood. Next, we extend this approach to address the critical challenge of wood flammability [4], [5]: by incorporating a natural fire retardant derived from nuts and seeds, phytic acid (PA), into our original wood ink. Eventually, we achieve intrinsically fire-resistant and self-extinguishing 3D-printed wood that meets the highest safety standards, surpassing the properties of natural wood.

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Paper ID: I-03

Design and Performance Evaluation of Hybrid Electric Powertrain, Power and Propulsion Systems (HEPPPS) For Unmanned Aerial Vehicles (UAVS)

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ABSTRACT
Conventional and fixed-wing aircraft for uncrewed/unmanned aerial vehicles (UAVs) have become a vital asset in modern military operations, providing significant advantages in surveillance, reconnaissance, and tactical support [1]. UAVs offer real-time intelligence, surveillance, and reconnaissance (ISR) capabilities, eliminating the risk to human lives and enabling continuous monitoring of enemy movements, terrain, and infrastructure [2, 3]. Recently, there has been a growing demand for eco-friendly and carbon-neutral commercial airlines in the aerospace and aviation industries [4]. According to NASA, commercial airlines are estimated to account for 12% of all carbon emissions [5, 6]. The US government plans to decrease carbon emissions by 40% by 2050 [7]. While commercial airlines aim to achieve carbon-neutral emissions, tactical and military UAVs are more focused on stealth signatures. The propulsion and aircraft configuration are highly coupled during the design cycle [8, 9]. With the propulsion as the leading component of the system, the aircraft configuration design follows through iterative processes [10-13]. It is a complicated, iterative, and highly lengthy process to find an optimal or near-optimal condition considering all aspects above. This paper aims to provide a detailed analysis of the information and suggest design criteria that outperform the baseline aircraft while enhancing modality, performance, and radar signatures. Furthermore, this study suggests precise aerodynamic performance evaluation and design criteria considering the actual flight path, operations, and propulsion for the transitional "conversion" methodological development. This paper makes a significant contribution to the design domain analysis and flow for existing UAVs, particularly in the context of transitioning from internal combustion engines (ICEs) to electrified or hybrid propulsion systems. We first evaluate the performance of the baseline UAV's range and endurance. Then, we calculate the same metrics when hybrid or electric batteries are adopted on the same baseline model. As a result, performance deficiency guides us in establishing design criteria to match or compensate for the deficiency, as shown in Fig. 4. The MQ-1C Gray Eagle UAV, used by the US Army, was selected as the baseline aircraft, featuring a diesel-based engine and a propeller located at the rear of the vehicle. It has a range of 2,500 nautical miles and about 25 hours of flight time. The first new propulsion system is electric power battery packs. As a thruster, the same propeller of the MQ-1C Gray Eagle is considered, as shown in Table 1 and Figure 1. Due to their significantly lower energy density compared to diesel engines, battery-driven propulsion systems achieve approximately 1/10 of the baseline in both flight distance and endurance. Although the performance of alternative power systems surpasses that of the current model, their significance lies in their extremely low thermal signatures and high stealth capabilities. Results demonstrate that batteries offer zero carbon emissions but incur a trade-off in flight endurance and range, which may be justified for strategic missions requiring sustainable fuel alternatives, as illustrated in Figs. 2 and 3. The second propulsion system is a hybrid electric power and propulsion system, combining a turbogenerator (TG) with multiple electric ducted fans (EDFs). The results show that a selected model of EDF and a single TG match the performance of the baseline model. This implies that the need for design criteria to match

performance can suggest new configurations for future tactical and more mission-oriented vehicle designs. The performance comparison table highlights the trade-offs in transitioning from conventional diesel propulsion to electric and hybrid alternatives. The conventional Gray Eagle, powered by a Thielert 165 HP engine, achieves a superior endurance of over 25 hours and a range exceeding 2,500 nautical miles, driven by a high energy density of 12,600 kWh/kg. In contrast, the battery-only electric variant, though benefiting from higher energy conversion efficiency (80–85%), suffers from significantly lower endurance (3.61 hours) and range (288 N-mile) due to the limited energy density (400 kWh/kg) of current battery technologies. All configurations maintain consistent aerodynamic lift and drag characteristics, with a cruise speed of 92 mph and a maximum takeoff weight (MTOW) of approximately 1,634 kg. While electric and hybrid systems promise silent operation, lower emissions, and reduced fuel costs, their endurance and range limitations underscore the need for advancements in energy storage technology to match the operational capabilities of conventional systems.

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Paper ID: I-04

Additive Manufacturing of Composites: Prospects, Challenges and Future Roadmap

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ABSTRACT
Additive manufacturing (AM) of polymeric composites will be presented, highlighting its potentials, challenges, and current research directions. AM of composites is challenging due to issues related to high void contents, microcracks, weak through-thickness properties, and long cure cycles. The design of a new nozzle geometry, annealing and functionalization of fibers in the Fused deposition method (FDM) of AM will be evaluated to reduce void contents and improve the performance of thermoplastic composites. Cure kinetics of Frontal polymerization (FP), a self-sustaining, energy-efficient fast curing technique driven by the exothermic nature of polymerization reactions, will be investigated as a prospective route for AM of thermoset composites. A comprehensive experimental and numerical study of AM relating to structural composites with limitations and prospects will be outlined in this presentation.

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Applied Mechanics

Paper ID: 192

Molecular Dynamics Study of Grain Size Effects on High-Temperature Nanoindentation of Nanocrystalline Titanium

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ABSTRACT
Molecular dynamics (MD) is used to investigate the nanoindentation behavior of polycrystalline titanium (Ti), with a specific focus on the effect of grain size and phase transformation at elevated temperature. Motivated by the lack of existing nanoscale mechanical analyses of nanocrystalline Ti under indentation loading, the work employs high-fidelity MD simulations to evaluate the influence of grain refinement on mechanical response and α-to-β phase transformation behavior. Nanocrystalline Ti samples are generated using the Voronoi tessellation method with varying grain numbers (NG = 5 – 25), corresponding to grain sizes ranging from 7.25 nm to 4.24 nm. A constant value of spherical indenter is used to simulate nanoindentation at a controlled velocity. Results show that finer grain systems initially resist indentation due to dense grain boundary networks. As indentation proceeds, these systems exhibit lower resistance during plastic deformation stages, evidencing the inverse Hall-Petch (IHP) effect. Coarser grains, in contrast, show dislocation-driven plasticity, requiring higher stress and producing greater peak forces. The α-to-β (HCP-to-BCC) phase transformation is observed to be grain-size dependent, occurring more prominently in finer grains under higher indentation loads. Furthermore, stress analysis reveals localized shear in coarse grains, while finer grains demonstrate a more uniform stress distribution. This study not only characterizes grain size-dependent mechanical behavior in nanocrystalline Ti but also establishes a foundation for future research to further explore nanoscale deformation physics.

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Paper ID: 204

Effects of Stone-Wales Defects in Mechanical Performance of CNT-POM Nanocomposites: A Reactive Force Field MD Study

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ABSTRACT

Polymer-based carbon nanotube (CNT) composites are excellent choice for usage in aerospace and automotive structures, electronics and energy storage devices, and biomedical components. Addition of CNTs makes the composites stronger, stiffer, and durable. Polyoxymethylene (POM) is a favorable choice for polymer matrix because of its robustness, dimensional stability, and wear resistance. The high performance of CNT reinforced polymer composites is susceptible to defects within CNTs, especially Stone - Wales (SW) defects. SW defects are topological faults that are caused by the rotation of carbon-carbon bonds in the CNT structure. Defected CNTs have lower strength, and the polymer-CNT interactions are also hampered, resulting in inferior performance of the composites. This study uses molecular dynamics (MD) simulations to investigate the mechanical performance of CNT-POM nanocomposites for different volume percentages of CNTs with varied quantity of SW defects. The Young's modulus (YM) and Ultimate Tensile Strength (UTS) decrease with increasing number of SW defects. The maximum reduction in YM and UTS is found to be 11.8% and 37%, respectively for pristine to 4 SW defected CNT-POM composites. The YM and UTS increase by a maximum of 43% and 50%, respectively as the volume fractions of CNTs increase from 11.03% to 14.90%. This study provides mechanical deterioration data induced by defects in the CNT and facilitates the design of high strength, high stiffness nanocomposites.

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Numerical Analysis of the Oblique Impact Perforation Response of a Flat-Nosed Projectile

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ABSTRACT

This study numerically investigates the oblique impact perforation response of a 26.3 mm Al 6061-T651 plate impacted by a non-deformable flat-nosed projectile. Using ABAQUS/Explicit with a Johnson-Cook elasto-viscoplastic model, we study impact angles of 90°, 70°, 50°, and 30° with a 20 mm projectile (200 gm, 35 mm length). A refined 0.8 mm mesh is applied in the impact zone. Validation against benchmark data establishes credible residual velocity trends. Results show classical shear-plugging for the flat nose across all angles. The ballistic limit increases markedly with obliquity (218.75 m/s at 90° to 367.5 m/s at 30°). At a fixed impact speed, the residual velocity decreases from 90° to 30° as the effective penetration path lengthens, which intensifies shear-plugging, sliding friction, and membrane stretching. Energy absorption rises with obliquity, consistent with the longer effective penetration path and tangential work. The study clarifies how obliquity amplifies shear-dominated plugging for flat impacts on thick aluminum and provides design-relevant metrics for protective structures.

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Paper ID: 425

Enhancing Mechanical Characteristics of Aluminium Wrapped Iron Slag Core Structure

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ABSTRACT

This study investigates the development and mechanical evaluation of aluminium channels filled with electric-arc-furnace (EAF) iron slag as an innovative composite structural material. The objective is to utilize iron-slag, an industrial by-product, to enhance strength and stiffness of lightweight aluminium sections while promoting environmental sustainability. Specimens were fabricated by filling rectangular hollow aluminium channels with molten iron slag under controlled cooling to avoid thermal damage. Flexural behaviour was examined through ASTM E290 three-point bending tests, while compressive performance was measured following ASTM D3410 compression tests. Results show substantial improvements compared to unfilled channels: flexural stress increased from 52 MPa to 136–139 MPa and compressive stress enhanced from 29 MPa to 100–116 MPa. These gains are attributed to the infill's ability to restrain local buckling, increase section modulus and distribute loads more uniformly. The findings demonstrate a cost-effective route to produce high-performance aluminium composite members from industrial waste with significant economic and environmental benefits.

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Bio Engineering

Paper ID: 100

Computational analysis of the effects of left ventricular remodeling observed in heart failure with preserved and reduced ejection fraction

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ABSTRACT
Understanding the implications of left ventricular remodeling is essential in elucidating the underlying pathophysiology of heart failure with preserved and reduced ejection fraction (HFpEF and HFrEF). LV remodeling phenotypes such as concentric remodeling (CR), concentric hypertrophy (CH), and eccentric hypertrophy type I and II (EH-I and EH-II) have been investigated previously using idealized, symmetric LV geometries, which overlook the natural asymmetry in wall thickness and curvature observed in vivo. In this study, a subject-specific asymmetric LV geometry was reconstructed from computed tomography (CT) imaging of a healthy subject. Finite element (FE) simulations were carried out to evaluate the hemodynamic and myocardial strain responses of the remodeled geometries relative to the healthy LV. The asymmetric FE model reproduced overall pressure-volume (PV) loop trends consistent with published articles but revealed deviations in stroke volume (SV) and global longitudinal strain (E_ll). All remodeling cases produced ejection fraction (EF) values >50%, aligning with HFpEF clinical ranges, although this contradicted the conventional association of eccentric hypertrophy with reduced EF. EH-I induced the largest SV increase, while CR exhibited elevated EDP and reduced E_ll which fall within the clinical range of HFpEF. This approach enhances physiological realism in computational modeling and offers a framework for personalized assessment of remodeling phenotypes, potentially guiding patient-specific treatment strategies.

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Computational Simulation of Nanoparticle Behavior Using Artificial Neural Networks

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ABSTRACT
Nanotechnology and computer modeling have come together to create new ways to explore targeted drug management and diagnostic devices in the human vascular system. This simulation uses Artificial Neural Networks (ANNs) to model the behavior of nanoparticles in hemodynamic contexts. ANNs can predict how nanoparticles will move, spread out, and group together in different blood flow situations since they can represent complex nonlinear systems. The simulation includes physical elements such as blood viscosity, wall shear stress (WSS), oscillatory shear index (OSI), relative residence time (RRT) and the characteristics of nanoparticles. The ANN was trained on a dataset obtained via numerical modeling to precisely predict the movements of nanoparticles. The findings indicate that the ANN model yields precise and computationally efficient predictions in contrast to conventional numerical simulations. This technology paves the way for personalized nanomedicine in the future, enabling real-time forecasting and control of nanoparticle usage, thereby enhancing treatment safety and success.

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Identification of MGMT Methylation in Glioblastoma Using MR Imaging and Machine Learning with Explainability

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ABSTRACT

Glioblastoma brain cancer poses a significant clinical challenge due to its aggressive behavior and poor prognosis with minimal survival. The O(6)-Methylguanine-DNA Methyltransferase (MGMT) gene plays a critical role in repairing DNA damage in cancer cells, thereby creating therapeutic resistance. Methylation of the MGMT promoter region sensitizes cancer cells to alkylating agents for damage. Therefore, MGMT gene methylation status is considered a prognostic biomarker in clinical practices. However, the molecular diagnostics of MGMT promoter methylation status are invasive and time-consuming. MR imaging has the potential to non-invasively identify the methylation status. Nevertheless, selecting significant image biomarkers from particular tumor regions and specific MR imaging types for better prediction outcomes is still challenging. This study attempts to analyze and identify the significant radiomics features of three tumor regions from different MR imaging for MGMT methylation identification. A substantial number of features have been selected using the feature selection method and are used in machine learning approaches. SHAP (SHapley Additive exPlanations) explainable model is used to interpret the machine learning model output based on the features. The results demonstrate that radiomic features derived from Dynamic Susceptibility Contrast (DSC) imaging - specifically the ap-rCBV and PSR derivatives features from the enhanced tumor (ET) region have higher significance. Also with ML, selected features of DSC imaging outperformed other MRI types in predicting MGMT methylation status. These findings provide valuable insights to practitioners for the optimal selection of tumor sub-regional features and imaging types for MGMT methylation prediction non-invasively.

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AutoDrip: A Cost-Efficient Fluid Management System

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ABSTRACT
Dengue fever is a major health concern in subtropical regions, where severe cases require precise intravenous (IV) fluid therapy to prevent life-threatening complications. In resource-limited settings, manual drip regulation is error-prone due to staff shortages and inadequate monitoring. AutoDrip, an automated gravity-driven fluid management system, is presented to calculate the required flow rate (RFR) and regulate the clinical flow rate (CFR) for dengue patients. The device combines a stepper motor–driven flow controller, a non-contact infrared (IR) drop sensor, and a binary search–based feedback algorithm. System performance was evaluated under dengue IV therapy protocols. The RFR calculation achieved 100% accuracy, drop count accuracy averaged 98.3%, and CFR regulation reached 99.3% accuracy, stabilizing within 7-9 iterations. These results demonstrate that precise and reliable infusion control can be achieved with a low-cost device, making AutoDrip a practical solution to enhance patient safety and reduce clinical workload during dengue outbreaks.

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Feasibility of Body Weight Supported Treadmill Rehabilitation for Early Stroke Recovery in Bangladesh: A Pilot Case Study

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ABSTRACT
Stroke often results in long-term motor impairments, with gait dysfunction being one of the most disabling consequences. In resource-limited settings such as Bangladesh, access to advanced rehabilitation technologies is limited by high costs and infrastructure constraints. This study aimed to evaluate the feasibility and preliminary effectiveness of a locally-fabricated, low-cost Body Weight Supported Treadmill (BWST) system for early stroke rehabilitation. A single male participant in the subacute phase of stroke recovery completed a 15-session BWST intervention over five weeks alongside routine physiotherapy. Training was performed using a low-cost, locally fabricated BWST system suited for resource-limited settings. Clinical outcomes (Berg Balance Scale and Timed Up and Go test) and spatiotemporal gait parameters were assessed before and after the intervention. Gait symmetry and variability were evaluated using Symmetry Index (SI%) and Coefficient of Variation (CV%). Improvements were observed in balance, mobility, and gait performance, with bilateral increases in step length, stride length, velocity, and cadence. Enhanced symmetry was reflected in reduced SI%, while lower CV% indicated improved gait consistency. No adverse effects were observed. This pilot study demonstrated the feasibility and potential effectiveness of a lowcost BWST system for early stroke rehabilitation in resource-limited settings.

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Evaluation of innovative backsheets for optimizing the performance and lightness of photovoltaic panels: a three-dimensional analysis

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ABSTRACT
The choice of backsheet material directly influences the thermal and electrical performance and weight of photovoltaic (PV) panels. The objective of this study is to evaluate the influence of different backsheet materials on the thermal and electrical performance and weight of PV panels in order to propose optimal solutions for residential and commercial applications. Four backsheets were analyzed: Tedlar, Aluminum (Al), TPU+MXene, and PDMS+BN. A three-dimensional numerical model was used to study the temperature distribution across the different layers of the module, considering solar irradiance ranging from 200 to 1000 Wm^{-2}. The results show that the temperature of PV cells increases with irradiance, rising from 31.71–31.83°C to 53.68–54.25°C depending on the backsheet, with Al having the lowest maximum temperature and Tedlar the highest. This increase in temperature causes a slight decrease in electrical efficiency, from 11.631–11.637% to 10.420–10.451%, with Al maintaining the highest efficiency. In terms of weight, Al is the heaviest (19.9 g), followed by TPU+MXene (11.5 g) and PDMS+BN (10.4 g), while Tedlar is the lightest (8.8 g). Overall, Al offers the best heat dissipation, while TPU+MXene and PDMS+BN composites provide an optimal compromise between thermal conductivity and lightness; Tedlar remains advantageous due to its low mass.

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Evaluation of Litchi Seed Powder (LSP) as an Eco-Friendly Additive for Enhancing Rheological Properties in Water-Based Muds

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ABSTRACT
Oil and gas companies face significant environmental and operational challenges due to the use of conventional drilling fluid additives, which often contain hazardous compounds. This study explores the potential of litchi seed powder (LSP), a biodegradable food waste, to enhance rheological properties, modify pH levels, and mitigate environmental impact. LSP was selected for this experiment due to its high cellulose and tannin content, extensive availability, and cost-effectiveness. LSP was evaluated at concentrations of 1%, 2%, and 3% in a bentonite-based reference mud, and laboratory tests were undertaken encompassing pH, density, plastic viscosity, yield point, and initial and ultimate gel strength. Rheological characteristics were improved, with plastic viscosity increasing by 50%, indicating improved cuttings transport ability. At a 3% concentration of LSP, the yield point demonstrated concentration-dependent behavior. A pH drop of up to 12.25% illustrates LSP's potential as a natural alkalinity modifier. The study indicates that LSP could be utilized as a reference to guide further investigations within the drilling industry.

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Paper ID: 61

Adaptive Channel Regulation in Photobioreactors Using Deep Deterministic Policy Gradient with Finite-Element Structural Validation

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ABSTRACT
The integration of photobioreactor (PBR) design with reinforcement learning (RL) is a breakthrough technology addressing century-old issues in microalgal bioproduction, such as inefficient gas exchange, recirculating flow regimes, and energy-intensive operation. This study presents simulation-based optimization of airflow and gas dynamics in a novel cylindrical PBR through a Deep Deterministic Policy Gradient (DDPG) algorithm. The photobioreactor, engineered and modeled in SolidWorks, incorporates aerodynamic flow channels and sensors for CO_2, O_2, strain, and displacement measurements. Finite element analysis (FEA) validated the mechanical durability of the system under dynamic pressure settings, with stress maintained within the elastic limits of the borosilicate PU composite. Sensor feedback guided the reinforcement learning agent to adjust flow pathways to improve photosynthetic efficiency while preserving structural integrity. Results indicate the potential of intelligent, sensor-controlled operation to provide energy-efficient, adaptive, and biologically optimized PBR performance. Hardware realization and real-time deployment of RL will be the goal in subsequent work to determine scalability and autonomous operation.

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Paper ID: 81

A Comprehensive Mathematical Analysis of Hydrogen Fuel Cell Based Electric Drivetrain and Vehicle Modelling for the Development of Hydrogen Electric Vehicle

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ABSTRACT
The increasing demand for sustainable transportation solutions has led to a surge in the development of electric vehicles (EVs), with hydrogen fuel cell technology emerging as a promising alternative. This study presents a comprehensive mathematical analysis of a hydrogen fuel cell-based electric drivetrain and vehicle modeling for the development of a high-performance, eco-friendly vehicle. A Simulink model was developed in MATLAB to design and optimize a fuel cell-based electric vehicle, enabling the calculation of key performance parameters, such as mean and maximum vehicle speed, power drawn from the fuel cell, and voltage and current distribution. The model also estimates the maximum allowable vehicle mass and aerodynamic properties, including frontal area and coefficient of drag. The results show that a small, two-seater hydrogen electric car requires a 0.9 kW electric motor, with a corresponding vehicle weight of 200 kg. This research provides a valuable framework for the design and optimization of hydrogen fuel cell-based electric vehicles, contributing to the development of sustainable transportation solutions. The findings of this study have significant implications for the automotive industry, highlighting the potential of hydrogen fuel cell technology to reduce emissions and improve vehicle performance. Overall, this research aims to support the development of environmentally friendly and efficient electric vehicles, aligning with global efforts to mitigate climate change and promote sustainable transportation.

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Paper ID: 86

Enhancement of Diesel Engine Performance and Emission Properties Through Al_2O_3 Nanoparticles Using Diesel and Pyrolytic Plastic Oil Blends

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ABSTRACT

Exploring alternative fuels for internal combustion engines is now receiving much more attention to enhance the performance and reduce the pollutants from the engine. From this point of view, the blended fuels of pyrolytic plastic oil (PPO), diesel, and alumina (Al_2O_3) nanoparticles have been utilized in this study to investigate the effects of nanoparticles on Petter diesel engine performance and emission properties. During the blending of fuels through a magnetic stirrer and homogenizer, the ratio of PPO and diesel was varied in volume percentage at a step of 15% increment of PPO with 150 ppm of nanoparticles. From the experimental results, it has been observed that the blended fuel of PPO60D40A150 at 40N loading situation, exhibited the highest BTE of 23.90% as well as an increased BTE is obtained up to 19.29% compared to pure diesel at 21N loading condition. On the other hand, a reduction of BSFC and CO emission at 21N load, and NO emission at 40N loads has been observed of 16.07%, 39.38% and 62.04%, respectively. Among all the blended fuels, PPO60D40A150 has demonstrated an outstanding performance for BTE, BSFC, and NO emissions, while PPO45D55A150 has shown an impressive reduction of CO emissions. Overall, this study with different numerical values provides evidence that the addition of alumina (Al2O3) nanoparticles in the diesel engine fuels can remarkably enhance the performance and improve the emission properties of diesel engines.

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Energy and Environment Protection through Time-Series Accident Forecasting: A Case of Bangladesh's Inland Waterways

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ABSTRACT

Bangladesh, with its vast network of rivers, depends heavily on inland waterways for cargo and passenger transport, offering an energy-efficient and environmentally sustainable alternative to road and rail. However, frequent accidents such as collisions, capsizings, and sinkings undermine both safety and ecological benefits by causing human casualties, economic losses, oil spills, and river pollution. While earlier research has examined structural and operational causes, few studies have developed predictive approaches to anticipate accident-prone periods or assessed the environmental consequences of such incidents. This study addresses these gaps by applying Seasonal Autoregressive Integrated Moving Average (SARIMA) and its extended form, Seasonal Autoregressive Integrated Moving Average with exogenous variable (SARIMAX) to forecast inland waterway accidents in Bangladesh between 2018 and 2022, using data from official records and media sources. The models incorporated seasonal trends, validated stationarity, and employed statistical diagnostics, while SARIMAX considered the COVID-19 lockdowns as an exogenous factor. Findings reveal that accidents follow distinct seasonal and socio-cultural patterns, with climate cycles and travel demand exerting greater influence than temporary disruptions. The results demonstrate that predictive forecasting is not only a safety tool but also an environmental safeguard, enabling early interventions to minimize ecological damage, maintain the energy efficiency of river transport, and reinforce the sustainable development goals of Bangladesh.

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Paper ID: 98

Homogeneous Condensation of HFO-1132a Refrigerants in Refrigeration Systems using MD Simulations

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ABSTRACT

Molecular dynamics simulation was employed to observe the homogeneous condensation of the hydrofluoroolefin refrigerant HFO-1132a in molecular scale. The aim was understanding the phase transition process and analyze the thermodynamic properties. Molecules were simulated by creating a periodic cell at superheated temperature 300 K, subcooled to three different temperature (273.15 K, 284.15 K, and 286.15 K). Density, cell volume and potential energy components were studied though out the simulation time and the results shows a rapid transition from vapor to liquid at the critical time (35.2 ns, 37.9 ns, and 51.3 ns). Trajectory analysis at various time showed the condensation mechanism, where nucleation of small clusters led to a single stable liquid droplet. The abrupt change in density, cell volume and total potential energy coincide with the critical condensation time determined from structural configuration, validating the reliability of simulation results. The analysis of potential energy components showed that van der Waals energy had the dominant contribution whereas valence energy changes are insignificant with electrostatic energy being. The steep decline indicates the strengthening of intermolecular forces during cluster formation. During temperature dependent simulation, lower temperature induce the energy drops and accelerate the condensation wherein higher temperature because of weak attractive force, critical condensation time is increasing. These findings advance understanding of the molecular mechanisms governing HFO-1132a condensation and can inform the design and optimization of low-GWP refrigerants in practical refrigeration systems.

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Paper ID: 112

Techno-Economic Feasibility Study of an Off-grid Hybrid Renewable Energy System for Mirinja Hilltop Community of Bangladesh

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ABSTRACT
In order to meet Sustainable Development Goal (SDG 7), Bangladesh needs to find a solution to provide reliable electrification in the remote hilly region. This paper explores a profound renewable energy solution to the off-grid electricity crisis of Mirinja hill-range of Bandarban district, Bangladesh. Along with the necessary domestic household load, powering of two schools and one general hospital were also considered for the load estimation. Average daily load is estimated to be 93.39 kWh. To meet the demand load, forms of renewable energies considered to integrate to the hybrid power system are wind, biogas as well as high altitude wind potential of Mirinja hills. System size estimation, feasibility check, optimization and life-cycle cost analysis of the system were done using a hybrid power system modelling software called HOMER. The analysis found our proposed system feasible and further optimized the size and number of the system components. The study also estimated the initial cost, net present cost and levelized cost of electricity for a life-cycle of 25 years. The analysis concludes that initial investment of only 43 lakhs BDT can build and run a renewable hybrid power system to facilitate the indigenous people of Mirinja hill range.

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Paper ID: 115

Optimizing Power Management of Fuel Cell Incorporated DC Microgrid

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ABSTRACT

The growing demand for electric vehicles (EVs) and rapid urbanization has accelerated the need for efficient DC microgrids in charging infrastructure and high-rise buildings. However, renewable energy resources (RERs) suffer from intermittency and low power density, limiting standalone reliability. This paper proposes a hybrid DC microgrid (h-DCMG) integrating a proton exchange membrane fuel cell (PEMFC), photovoltaic (PV) array, and energy storage system (ESS) with an optimized decentralized control strategy. Power sharing and bus voltage stability are achieved through proposed control strategy which includes fuzzy controller with PID for PEMFC, load-voltage based maximum power point tracking (LVB-MPPT) for PV, and state-of-charge management (SoCM) for ESS. Simulation results under dynamic loads with (100–150 kW) with proposed control strategy demonstrate fast recovery within 0.012 s with 9.36% maximum overshoot, while fixed loads with disturbances settle in 0.015 s with minimal error. The proposed method optimizes coordinated power utilization, enhances stability, and ensures resilience of fuel-cell-based DC microgrids.

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Performance Assessment of a Heavy Fuel Oil-Based Cogeneration Power Plant Based on Energy, Exergy, Exergoenvironmental and Exergetic Sustainability Analyses

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ABSTRACT

This study investigates a comprehensive thermodynamic, exergy, and exergoenvironmental evaluation of a 54.363 MW heavy fuel oil (HFO)-fired cogeneration power plant in Chittagong, Bangladesh. The facility includes three MAN 48/60 TS diesel engines equipped with dual-stage turbocharging, parallel waste heat recovery boilers (WHRBs), and a steam turbine for additional power generation. The research transcends traditional energy balances by utilizing comprehensive exergy and environmental impact assessments to pinpoint irreversibility hotspots and avenues for efficiency improvement. Under full-load condition, this plant achieves 43.24% energy and 42.47% exergy efficiency. Diesel engine combustion is identified as the dominant source of exergy destruction (60.14%, or 83.87 MW). On the contrary, dual-stage turbochargers have high exergy efficiencies, with 67.37% for high-pressure stages and 57.60% for low-pressure stages. WHRBs have energy, exergy efficiency 51.18% and only 28.37% respectively. This shows that a lot of entropy is created during heat transfer. The exergoenvironmental analysis demonstrates that diesel engines and WHRBs exert the most detrimental impact on the environment per unit of output. Studies on enhancements indicate that employing electronically controlled common-rail injection, modifying the combustion chamber, utilizing multi-pressure waste heat recovery boilers (WHRBs), and incorporating the Organic Rankine Cycle could significantly enhance exergy recovery. These numbers tell us how to improve our technical, economic, and environmental performance. They also set the stage for successful cogeneration retrofits and long-term policy-making in Bangladesh and other areas like it.

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Dynamic Attributes of a Solar Dish Operated Steam Cycle Equipped with Thermal Energy Storage

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ABSTRACT

This study analyzes a solar dish-powered steam cycle integrated with molten salt thermal energy storage (TES) and an Organic Rankine Cycle (ORC) bottoming unit. This study examines a steam cycle that is powered by a solar dish and incorporates an Organic Rankine Cycle (ORC) bottoming unit and molten salt thermal energy storage (TES). To assess system efficiency under changing direct normal irradiance (DNI), temperature, and wind conditions, a thermodynamic model based on Python was created utilizing actual meteorological data from Alice Springs. Supported by TES, the suggested triple-extraction reheat Rankine cycle offers consistent output and up to eight hours of backup power. According to the results, the TES hot tank maintains dependability despite fluctuating DNI by stabilizing at about 975 K. Due to inevitable storage heat losses, production is slightly reduced even if efficiency is almost unchanged during both direct sunlight and TES operation. The ORC increases system flexibility and low-temperature energy recovery.

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Economic and Environmental Feasibility of Renewable Energy Integrated Grid for Charging Three-Wheeler Electric Vehicles in Dhaka City

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ABSTRACT

Bangladesh's growing energy demand and urbanization necessitate a transition to renewable energy to address dependency on fossil fuels, environmental degradation, and energy shortages. This study uses HOMER Pro for system design and optimization to evaluate the feasibility of hybrid solar and wind-powered charging stations for electric three-wheelers (E3Ws) in Dhaka city. By integrating photovoltaic (PV) systems and wind turbines into the charging infrastructure, the proposed strategy achieves a 62% reduction in CO2 emissions compared to grid-only alternatives while maintaining economic viability with a 1.46% increase in net present cost. The analysis considers the city's solar irradiance and wind potential, demonstrating that a hybrid approach effectively reduces reliance on grid electricity, supports financial sustainability through excess energy sales, and enhances energy resilience. This strategy aligns with global sustainability goals, promoting cleaner transportation and renewable energy use. The findings provide a scalable solution for balancing economic and environmental considerations in Dhaka's electric vehicle (EV) ecosystem and urban energy planning.

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Paper ID: 184

Discarded Material Management System in Rajshahi City Corporation (RCC)

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ABSTRACT

The Discarded Material Management System in Rajshahi City Corporation (RCC) faces growing pressure from rapid urbanization, rising population, and inadequate waste infrastructure, leading to indiscriminate dumping, clogged drainage, pollution, and health hazards. To address these issues, this study used a structured methodology with data collected from primary and secondary waste sources. Waste was classified into four categories: biodegradable, combustible, recyclable, and non-recyclable. The key innovation was a color-coded dustbin system, green for biodegradable, red for combustibles, blue for recyclables, and yellow for non-recyclables. Selected households received these bins to separate waste, and the weight of each category was measured daily for one month. At Secondary Transfer Stations (STS), waste weights were also measured by category at 3 to 4 specific points in different RCC areas. Energy generation potential was analyzed using waste-to-energy technologies such as anaerobic digestion and incineration with economic assessments for cost-effectiveness. Results showed RCC's waste stream contains about 72% biodegradable, 14% combustible, 10% recyclable, and 4% non-recyclable materials with significant calorific value suitable for energy recovery. Anaerobic digestion produced the highest energy output of 47.8 MWh, while incineration offered a low-cost option at 0.00048 US$/kWh (0.06 BDT/kWh) with environmental benefits. The study concludes that an integrated waste-to-energy framework supported by policy reform, infrastructure, and community participation can transform waste into a resource, reduce pollution, generate renewable energy, and foster sustainable urban development in Rajshahi.

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Numerical Study on the Effects of Blade Parameters on the Performance of Vertical Axis Tidal Turbines

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ABSTRACT
Tidal energy is one of the few renewable energy sources that can be harnessed easily, reliably, and efficiently to meet global energy needs. This paper presents numerical analysis showing how fundamental blade design parameters, such as number of blades, hydrofoil type, chord length, and blade height, can affect the performance of a Vertical Axis Tidal Turbine (VATT). The analysis has been performed using QBlade software by employing the Double Multiple Streamtube (DMS) approach. For that, the QBlade DMS solving approach has been validated against experimental as well as computational results of other authors. Results show that VATT models with higher chord lengths and greater heights of blades can achieve relatively higher power at lower flow conditions. Dependency on the number of blades has also been studied by varying the blade numbers, ranging from 2 to 4. It is found that the three-bladed design gives the best outputs for energy capture. It is also observed that the asymmetric type NACA airfoils are better suited for low-speed applications. Overall, the study outlines key steps in the design and optimization of tidal stream turbines, providing valuable insights to enhance their operational efficiency.

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Paper ID: 203

Comparative Neutronics Analysis of VVER-1200 Reactor Assembly with Conventional and Nanofluid Coolants

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ABSTRACT

Reactivity feedback is a necessary parameter for safe reactor operation. This study investigates the effect of nanofluid coolant for the VVER-1200 reactor in the neutronic performance at the assembly level using OpenMC Monte Carlo simulation software. Graphene Nanoplatelets (GNP), Tungsten Trioxide (WO3), Copper Oxide (CuO), and Silver Oxide (Ag2O) with 0.1% weight concentrations were taken, and the temperature coefficients of reactivity, absorption, and scattering rates of the coolant for different nanofluids were compared to find a suitable nanofluid for VVER-1200 in terms of their neutronic performances. The modeled assembly was benchmarked against a reference assembly with simulated keff being 1.27762 with an error of 0.1583%. The fuel temperature reactivity coefficient values varied from -1 pcm/K to -4 pcm/K, and the moderator temperature coefficient values varied from -15 pcm/K to -65 pcm/K. The temperature coefficient values are negative, which aligns with the international practices regarding reactivity feedback. GNP showed the most favorable neutronic feedback characteristics among them and can be the optimum nanofluid as the primary circuit coolant for the VVER-1200 reactor model.

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Paper ID: 206

An Endeavor of Designing an ATF Using OpenMC Applying Coating in the Cladding of VVER-1200

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ABSTRACT

The VVER-1200 pressurized water reactor utilizes zirconium alloy as a cladding material for fuel protection. However, conventional cladding experiences difficulties due to hydrogen embrittlement, radiation degradation, and oxidation during a Loss-of-Coolant Accidents (LOCA). This research uses OpenMC simulations in order to analyze four potential Accident Tolerant Fuel (ATF) coatings including ultra-high-temperature (UHT) $ZrB_2.SiC$, high-entropy oxide $(Mg_{0.2}Co_{0.2}Ni_{0.2}Cu_{0.2}Zn_{0.2})O$, nanostructured WO_3, and ceramic oxide $Al_2O_3.Cr_2O_3.TiO_2$. Analyses were performed on relation between keff and temperature, temperature coefficients of fuel and moderator also total temperature coefficient (TTC), and neutron flux profiles. Findings indicate each coatings maintain negative reactivity feedback while WO_3 showing highest negative moderator temperature coefficient (MTC) and $ZrB_2.SiC$ provides strongest negative fuel temperature coefficient (FTC). Neutron flux profiles stay mostly unchanged for all the ATF designs. This study concludes the pre-applicability of these coatings by analyzing only the neutronic aspects of the fuel though these ATF still requires hydrodynamics and material analysis.

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The Global Energy Paradox: GDP, CO_2 Emissions, and Energy Capacities

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ABSTRACT

Rapid decarbonization requires evidence on how national economic scale and the power mix relate to emissions. Using cross-country data on CO_2 (Mt), GDP (trillion current US$), and installed renewable and non-renewable capacity (GW), for 188 countries, this study combines simple correlations, partial correlations, and out-of-sample predictive modeling to separate scale effects from conditional relationships. Pearson correlations show very strong positive links between CO_2 and non-renewable capacity ($r = 0.981$, $p < 0.001$) and between CO_2 and renewable capacity ($r = 0.974$, $p < 0.001$), a strong correlation between the two capacity measures ($r = 0.946$), and a positive GDP–CO_2 association ($r = 0.783$). Partial correlations (residual method) clarify mechanisms: holding GDP constant, CO_2 remains tightly tied to non-renewables (partial $r \approx 0.987$) and strongly to renewables (partial $r \approx 0.940$); holding non-renewables constant, the GDP–CO_2 link turns negative (partial $r \approx -0.862$), consistent with higher-income countries emitting less at a given capacity level due to efficiency, technology, or policy. For prediction, ridge-regularized linear and polynomial (degrees 2–3) models were trained on 80% of countries and tested on 20% with standardized features. The linear Ridge model performed best ($R^2 = 0.956$; RMSE = 99.667 Mt; $\alpha \approx 0.562$), outperforming higher-degree alternatives. In original units, the final equation is: $CO_2 = -0.263 - 84.625$ GDP $+ 3.085$ Renewable $+ 6.982$ Non-renewable. The positive renewable coefficient alongside a much larger non-renewable effect illustrates a “renewables paradox”: countries with more renewables also tend to have higher emissions because renewables often expand alongside, rather than replace, fossil capacity. These findings imply that emissions fall when non-renewable capacity is retired or repowered, not simply when renewables are added. Policy should prioritize displacement of fossil assets and efficiency gains so that renewable growth translates into real decarbonization.

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Enhancement of the PV Solar Panel Efficiency Using Hybrid Mode Cooling System

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ABSTRACT
The performance of photovoltaic (PV) modules is strongly affected by their operating temperature, which rises significantly under high solar irradiance and reduces electrical efficiency. This issue is especially critical in tropical regions such as Bangladesh, where high ambient temperatures and strong sunlight exacerbate the problem of overheating. To mitigate these effects, this study proposes and experimentally investigates a hybrid cooling technique that integrates front-surface closed-loop water circulation with rear-mounted aluminium fins. Two identical 50 W PV modules were tested outdoors, with one serving as a reference under natural conditions and the other equipped with the cooling system. The experimental results revealed that the fin-only configuration provided a temperature reduction of 5.24 °C, yielding a small efficiency gain of 0.42%. Water cooling at a flow rate of 3 L/min reduced the panel temperature by 13.24 °C and improved efficiency by 4.08%. The hybrid system achieved the best results, lowering the temperature by 14.05 °C and enhancing efficiency by 4.37% compared to the reference panel. When the energy consumption of the circulating pump was considered, the net efficiency gain was 3.52%, with the system being most effective during peak irradiance hours between 11:00 and 15:00. The outcomes of this research confirm that combining front-surface water cooling with rear aluminium fins provides a practical and cost-effective solution for reducing PV operating temperature and improving performance under hot and humid conditions. Although the efficiency improvement is modest compared to some advanced cooling methods, the simplicity, affordability, and adaptability of this system make it highly suitable for real-world applications in regions such as Bangladesh.

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The First-principles study of the structural, optoelectronic, and photocatalytic properties of lead-free halide perovskite RbGeCl3 for CO_2 photo-degradation application

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ABSTRACT

This has been motivated by the acute necessity of alternative energy sources that are sustainable, and as such, there is interest in photocatalytic reduction of CO2 by using halide perovskites as catalysts. This work gives a first-principles study of the structural, electronic, optical, and photocatalytic characteristics of lead-free halide perovskite RbGeCl3 in the density functional theory framework based on CASTEP. Thermodynamic stability was verified by structural analysis, which had a tolerance factor of 0.98 and negative formation enthalpy. The direct band gap that was identified in the band structure at the R point is 1.018 eV. The optical calculations had high dielectric constants, high visible-light absorption, and low reflectivity, which implied efficient solar energy collection. Moreover, the positions of bands were observed to correlate with the redox potentials of CO2 reduction reaction, which proved that RbGeCl3 is suitable to be used in the process of photocatalytic degradation of CO2 into value-added fuels. These results make RbGeCl3 a stable, non-toxic and effective lead-free perovskite photocatalyst that has a high potential of application in the environment and energy.

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Paper ID: 291

Technoeconomic and Environmental Assessment of Microbial Fuel Cell (MFC) for Wastewater Treatment: Bangladesh Perspective

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ABSTRACT

Microbial fuel cells (MFCs) are bio-electrochemical systems that transform organic pollutants in wastewater into electricity while simultaneously treating the water. This study presents a technoeconomic and environmental evaluation of a 1,000 m^3/day double-chamber MFC system for industrial wastewater treatment in Rajshahi, Bangladesh. By combining literature-based performance metrics with local economic data, a 15-year project lifetime is modeled with capital expenditures of about 20 crore Tk, operational expenditures fixed at 4% of capital costs, and a discount rate of 10%. Revenues are derived from electricity generation at 8 Tk/kWh and a treatment credit of 50 Tk/m^3. Under baseline assumptions, the system achieves an annual energy recovery of roughly 3.72 million kWh, producing a net present value (NPV) of Tk 1.03×10^8, an internal rate of return (IRR) of 18.3%, and a discounted payback period of 7 years. Environmentally, the system could reduce greenhouse gas emissions by 100–200 tCO_2 per year compared to fossil-fuel electricity and lower sludge output by about 390 t/year. Sensitivity analysis highlights that project economics are strongly affected by the discount rate and wastewater flow. The results indicate that MFCs are a technically feasible, economically promising, and environmentally sustainable alternative for wastewater management in Rajshahi, Bangladesh.

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Paper ID: 318

Sustainability Prospects of Three-Wheeled Transport in Bangladesh under Changing Energy Mix Scenarios

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ABSTRACT

This study applies a life cycle assessment (LCA) approach to evaluate the environmental impacts of three standard para-transit modes in Bangladesh: CNG-fueled auto rickshaws, battery-powered easy bikes, and retrofitted electric rickshaws. The analysis was conducted using openLCA software with the ecoinvent database, following ISO 14040/44 guidelines. The system boundaries include manufacturing, use, and end-of-life stages, with impacts assessed in terms of global warming potential (GWP), ozone formation (human health), fine particulate matter formation, and terrestrial acidification. Results show that the use phase dominates overall emissions for all vehicle types, making operational energy the most decisive factor. Under the current fossil-fuel-dominated electricity mix, CNG-fueled rickshaws exhibit lower life cycle emissions than both battery-powered options. Even under projected near-term grid improvements, electric vehicles remain disadvantaged, as reductions are insufficient to offset high upstream electricity burdens. Retrofitted electric rickshaws perform somewhat better by reducing manufacturing impacts, yet their benefits also depend on the availability of cleaner electricity. Only with significant decarbonization of the grid can battery vehicles consistently outperform CNG-fueled vehicles. The findings highlight that while electrification has long-term potential, short-term sustainability improvements in Bangladesh should prioritize cleaner electricity generation and battery recycling infrastructure.

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Spiral Copper-Tube Glycol Loop for Boosting PV Panel Efficiency

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ABSTRACT

Photovoltaic (PV) modules lose efficiency rapidly when their operating temperature rises, a limitation that is especially severe in high-irradiance climates. To address these challenges, a compact spiral copper-tube heat exchanger that circulates a glycol-water mixture beneath a 50 W PV panel. The high specific heat and thermal stability of glycol were leveraged to maintain a narrow temperature band without evaporation losses. Outdoor experiments compared four scenarios - uncooled, overheated, water cooled, and glycol cooled - under identical irradiance. Glycol cooling lowered panel surface temperature by as much as 9˚C relative to the uncooled case and sustained a near-constant output voltage. Electrical conversion efficiency increased from 19% to 35%, with high-load conditions showing a near-doubling of average power compared to water cooling. These results demonstrate that a simple glycol loop can deliver robust thermal management, improve energy yield and extend module lifetime, offering a low-cost upgrade path for both new and existing PV installation.

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Ensemble Learning-Based Seismic Hazard Forecasting for Safety Enhancement in Underground Coal Mine

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ABSTRACT
The dynamic and unpredictable nature of seismic hazards in underground coal mines demands accurate and reliable forecasting to ensure safety in mining operations. Traditional hazard assessment approaches often fail to capture the intricate non-linear patterns underlying seismic activity and often overlook the inherent class imbalance between high and low-energy seismic events. This study aims to investigate the predictive performance of ensemble models for forecasting high-energy (E>104J) seismic bumps. This study adopts some novel steps including the one-hot encoding technique for categorical feature handling, the SMOTETomek resampling technique to address class imbalance and sensitivity analysis to evaluate the contribution of individual features to hazard prediction. Four ensemble learning based boosting algorithms (AdaBoost, XGBoost, LightGBM, and CatBoost) are implemented using a highly imbalanced micro-seismic monitoring dataset comprising 170 hazardous and 2414 non-hazardous instances. The models were evaluated through standard classification metrics including accuracy, precision, recall and F1-scores. Among the models, AdaBoost and XGBoost exhibited poor performance. Although LightGBM achieved a high precision of 96.1% but it's relatively low recall score for hazardous states limits its effectiveness for hazard prediction. In contrast, CatBoost model exhibited reliable performance across both classes, achieving a recall score of 97.4% and predicting 166 out of 170 hazardous instances. Furthermore, sensitivity analysis using SHAP revealed that gpuls is the most significant predictor variable while features (nbumps5- nbumps89) had negligible impact to hazard prediction. Overall this data-driven study advances the forecasting of hazardous seismic events by effectively addressing class imbalance, providing engineers valuable insights for hazard mitigation strategies and contribute to improve safety and operational resilience in underground mining environments.

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Techno-Economic Assessment of a 500 MW Offshore Wind Farm at Cox's Bazar, Bangladesh

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ABSTRACT

The rising electricity demand and decarbonization goals make offshore wind a practical path to energy security for Bangladesh. Yet country-specific, end-to-end studies that connect wind resource to investable economics are limited. This paper evaluates a 500 MW wind farm project of Cox's Bazar using a transparent, reproducible resource to revenue workflow. ERA5 (2020–2024) wind data are vector combined at 100 m, extrapolated to 150 m and converted to turbine power with air density correction. The model consists of a layout of 42 turbines and considers a conservative, multiplicative loss stack. Techno-economics are calculated in HOMER software and cross checked with a discounted cash flow model reflecting relevant financing (10% nominal WACC, 2% indexation for tariff and O&M) for Bangladesh. The project delivers a net annual energy production of 1.48 TWh at a capacity factor of 33.4% and an engineering LCOE of $98/MWh. The first year tariff $0.11/kWh, the base case delivers an NPV of $0.41B with a discounted payback in Year 13. Sensitivity results indicate bankability is dominated by WACC and CAPEX while O&M and the capacity factor have secondary influence. Relative to today's grid, the project would avoid 0.94 Mt CO_2 annually. Overall, the offshore wind project studied here for Bangladesh appears feasible within a $0.10–$0.11/kWh PPA corridor provided policy measures reduce financing risk and support from local supply chains. The workflow and dataset are openly reproducible and can guide site screening and investment decisions in emerging offshore wind markets.

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A Framework for Modeling Frost Formation Initiation on Metallic Surfaces

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ABSTRACT

Frost on cold surfaces is a major challenge in energy, transport, and environmental systems, since it reduces heat transfer, raises energy use, and creates safety risks. Accurate frost prediction requires that we account for radiative cooling, convection, and surface nucleation under changing weather conditions. We present a mathematical framework that couples sky temperature models, radiative–convective energy balance, and nucleation physics to model initiation of frost formation on metallic surfaces. We mapped supersaturation fields in the relative humidity–wind speed plane. We modeled frost formation boundaries for a range of cloud fractions, surface wettabilities, and ambient weather conditions. This approach provides a novel framework for frost formation initiation study, which may offer insights for anti-frost surface design, environmental risk assessment and frost formation prediction on metallic surfaces.

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A Data-Driven Framework for Optimal Solar Photovoltaic Siting at International Airports: A Techno-Economic Case Study of HSIA

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ABSTRACT
The decarbonization of energy-intensive transport hubs is a critical component of national sustainability strategies. This paper presents a comprehensive techno-economic feasibility study for optimizing solar photovoltaic (PV) deployment at Hazrat Shahjalal International Airport (HSIA) in Dhaka, Bangladesh. A replicable framework integrating five years of high-resolution satellite irradiation data and GIS-based analysis was developed to identify optimal sites for PV installation. The analysis identified a 30.6-hectare "persistent hotspot" zone with a reliable 5-year average annual irradiation of 1,612 kWh/m²/year. A techno-economic

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Computational Model Development and Feature Attributes Analysis for Formation Bulk Density: Insights of Sandstone Reservoir Evaluation

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ABSTRACT

Accurate prediction of formation bulk density (ρb) of reservoir rock is a crucial parameter for hydrocarbon reservoir evaluation and pore pressure prediction for safe drilling operation. When direct testing of core analysis is a tedious and time-consuming approach, then ρb is estimated from density logs, using empirical relationships and a computational approach. In this paper, the major objectives are to assess the developed log-data driven computational models and use feature attribute analysis to find the most important contributing predictor variables while predicting ρb for sandstone reservoir rocks. The two widely used ensemble machine learning techniques of bagging-based random forest (RF) and boosting-based extreme gradient boosting (XGB) algorithms for computational models' development and statistical model performance indicators are applied to evaluate model reliability and robustness. An explainable artificial intelligence technique of SHapley Additive exPlanations (SHAP) is utilized to interpret and measure each feature importance for ρ_b estimation. The XGB model demonstrates better generalization performance with high determination of coefficient, R2 (99.88%) and lower error compared to the RF model with R2 of 92.65%. Considering the single variable elimination process with XGB approach, it is found that formation photoelectric factor and true resistivity are the two most significant feature attributes while gamma-ray is the least contributing feature to obtain ρb for the studied sandstone gas reservoir. The same relative feature importance ranking is also confirmed by RF and XGB-based SHAP techniques. The proposed modeling strategies and feature scoring can be systematically applied to the precise forecasting of dynamic ρb profile, porosity and pore pressure prediction for integrated reservoir analysis and hydrocarbon exploration, thereby advancing environmentally sustainable practices while ensuring cost-effectiveness.

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Fluid Mechanics

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Numerical Investigation of the Effect on Modifying Corrugated Peak Ratio of the Dragonfly Wing Section

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ABSTRACT

The design of the wing of the MAVs should be done in such way that it can glide more. In general, The dragonfly's wings are capable of producing more lift than traditional wings at low Re. That's why it is suitable for the MAVs application. This research is a 2D numerical investigation of the effect of modification of peak ratio of the pleated section of Aeshna cyanea in gliding phase. The numerical analyses were conducted in Ansys Fluent at low Re 200, 1600 and 2400 where the MAVs typically fly and at the angle of attack 0˚ to 30˚. Also, the effect of the modification of the different peak ratios were analyzed and achieved the maximum coefficient of lift on the peak ratio 2.0 model. The effect of the peak ratio on the coefficient of drag, Gliding ratio and the flow field was also investigated.

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Paper ID: 27

Curvature Effect Analysis of MHD Multi-Phase Flow along an Eccentric Curve Duct of Square Shape in a Porous Medium with Differently Heated Wall

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ABSTRACT
This study investigates the impact of the radius of curvature (L) and Hartmann number (Ha) on magnetohydrodynamic (MHD) multiphase flow within an eccentric curved duct including differentially heated walls, employing a finite element method (FEM). The governing equations for mass, momentum, and energy conservation are combined with the magnetic induction equation, which considers Lorentz force and buoyancy effects. The curved duct geometry is precisely captured by a non-uniform, body-fitted mesh, and the velocity, pressure, and temperature fields are precisely ensured by applying higher-order Lagrange interpolation functions. The Galerkin weighted residual formulation is used, with stabilizing techniques applied to deal with convection-dominated regimes. Appropriate boundary conditions, including no-slip velocity, constant wall temperature, and insulated outside surfaces, are applied alongside specified magnetic field orientations. Parametric simulations are carried out across a wide variety of Hartmann numbers and curvature radii to evaluate secondary vortex generation, flow physical characteristics and heat transfer behavior. The findings demonstrate an extremely strong relationship between magnetic dissipation and geometric curvature, resulting in large magnetic field strength reducing strong but stable secondary flows and moderate curvature increasing more stable and predictable flow patterns.

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Unsteady Natural Convection Flow within a Thermally Stratified Air-Filled Rectangular Cavity

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ABSTRACT

This paper offers a detailed numerical analysis of unsteady natural convection (NC) and heat transfer (HT) in a rectangular cavity filled with thermally stratified air. The enclosure consists of an evenly heated bottom wall, thermally stratified vertical sidewalls, and a cooled top wall. Simulations utilize the finite volume method (FVM), maintaining a constant Prandtl number (Pr) of 0.71 and an extended spectrum of Rayleigh numbers (Ra) ranging from 10 to 10^8. The analysis includes streamlines and isotherm plots, temperature time series (TTS), spectral analysis, limit point and limit cycle analyses, and a thorough investigation of bifurcation behavior, emphasizing transitions in flow regimes. As Ra increases, the flow transitions from a stable symmetric state to chaos, characterized by many bifurcations: a pitchfork bifurcation between Ra of 10^4 and 5×10^4, a Hopf bifurcation between Ra of 10^6 and 5×10^6, and chaos at Ra 10^8. The current numerical results were evaluated through comparison with established numerical findings, thus proving their dependability.

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Effect of Hydrofoil on the Resistance and Maneuvering Performance of KCS Hull Using Orca3D

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ABSTRACT

This paper aims to investigate the hydrodynamic performance of KRISO Container Ship (KCS) hull and the effect of a bow-mounted hydrofoil on its performance using Orca3D (Evaluation license) software. The Reynolds-Averaged Navier-Stokes (RANS) equation (the k-omega SST turbulence model) and non-linear free surface equation are discretized by means of Finite Volume Method (FVM). The computational results are compared with the experimental data in order to check the validity and show a good correlation with total resistance coefficient (CT) deviating by less than 5% across the five different Froude numbers ranging from 0.108 to 0.260. After that, a NACA 0012 hydrofoil appendage is added to the bow of the hull model. The inclusion of hydrofoil on the KCS hull somewhat increases the overall resistance but provides a significant improvement in the vessel's stopping performance, reducing both the stopping distance and stopping time by an average of approximately 58.7%. A graphical comparison for the stopping characteristics between the bare hull and the hull with the hydrofoil appendage also drawn.

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Performance Analysis of a Single Helix Screw Turbine Under Varying Inclined Angles and Flow Rates

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ABSTRACT

The hydraulic screw turbine has emerged as a promising technology for low-head hydropower generation, particularly under heads below 10 meters. Its performance is influenced by multiple parameters, including screw geometry, inclination, and flow conditions. This study experimentally investigates the effect of inclination angles and flow rates on the efficiency and power output of a single-helix screw turbine. The turbine was tested under varying discharge rates and inclination angles to identify the optimal operating range. Results show that the highest power output of 4.20 W was achieved at a 50° inclination, while maximum efficiency of 27.46% occurred at 35°. Efficiency and rotational speed increase with angle up to an optimum range before declining due to turbulence and sliding losses at steeper inclinations. The findings indicate that the optimal operational range lies between 35° and 50°, offering a practical balance between efficiency, turbine speed, and power output. This research highlights the potential of screw turbines for efficient energy recovery in low-head, low-flow hydropower applications.

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A Robust Wells Turbine Inspired by Sailing Aerodynamics for Wave Energy Conversion

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ABSTRACT
This study presents the design and performance evaluation of a Wells turbine with enhanced robustness, inspired by sailing aerodynamics, for application in oscillating water column (OWC) wave energy converters. Conventional Wells turbine suffers from limited operational range and performance degradation under fluctuating airflow conditions typical of ocean waves. To address these challenges, we introduce a novel blade design that incorporates aerodynamic principles derived from sailing, such as lift optimization and flow stability under bi-directional airflow. Wind tunnel experiments and computational fluid dynamics (CFD) simulations were conducted to assess the turbine's behavior across a wide range of flow velocities and oscillation frequencies. The results demonstrate significant improvements stall resistance and starting characteristics compared to conventional Wells turbine. The proposed design maintains stable performance even under irregular wave conditions, indicating high robustness and suitability for real sea conditions. This work contributes to the development of more reliable and efficient wave energy systems, promoting sustainable energy harvesting from ocean resources.

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Numerical Analysis on MHD Convection Heat Transfer in Hybrid Nanofluid Flow inside Wavy Channel

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ABSTRACT
A computational study has been conducted on MHD convective thermal performance in hybrid nanofluid (Al_2O_3 – Cu – H_2O) flow within a wavy channel. One surface of the channel takes a constant heat flux, whereas the remaining surfaces and the upper wall of a channel are adiabatic. The Galerkin weighted residual approach is operated to discretize the governing partial differential equations in finite element formulation. The grid sensitivity test is also implemented for five types of grids, and a grid refined with an optimal number of elements (21,818) has been calculated. The stimulated results are graphically presented for various parameters, such as Richardson number ($0.01 \leq Ri \leq 20$), Hartmann number ($0 \leq Ha \leq 80$), and volume fraction of nanoparticle ($0.01 \leq \varphi \leq 0.10$) at Reynolds number ($Re = 100$), $Pr = 6.837$, amplitude ($\lambda = 0.15$), and ventilation ($D = H/2$). The calculations are carried out on the performance of the velocity vectors, isotherms, streamlines and average Nusselt number. This work's outcomes are compared with published results. The heat transfer rate is enhanced by increasing Ri and φ while decreasing Ha in the proposed flow model.

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Proper Orthogonal Decomposition of Velocity Field for Tandem Square Cylinder Arrangement

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ABSTRACT

This study investigates the physics of the velocity field generated by the 2D unsteady flow over two tandem square cylinders for Re=100 at a specific spacing ratio of L/D=8 by means of the data-driven modal decomposition method. Proper Orthogonal Decomposition (POD) was applied to the velocity fields to identify hidden coherent structures that are not very clear from the CFD simulation alone. Most of the previous studies are conducted for the circular cylinder and their various arrangements. For the two tandem square cylinder arrangements, the previous studies are mainly concerned with the effects of various spacing ratios and Reynolds numbers on the velocity field. In this study the CFD simulation was carried out using the open-source CFD solver OpenFOAM. Then 306 snapshot data were collected and analyzed using the POD modes that mainly characterize the wake dynamics. The results obtained showed that the first ten POD modes capture almost 99% of the kinetic energy of the flow:mode 1: 59.18%, mode 2: 40.53%, mode 3: 0.109%, mode 4: 0.12%, mode 5: 0.017%, mode 6: 0.016%, mode 7: 0.004%, and higher modes contain negligible amounts. The spatial structures appeared as pairs while phase shifting was observed. The POD modes showed that the most important dynamics were captured in the first few modes. Higher-order modes exhibit smaller-scale coherent structures that grow downstream and contain progressively less energy. Insights into the flow physics are obtained.

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Pulsatile Blood Flow Simulation in a Bifurcated Stenosed Artery Based on the Finite Element Method

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ABSTRACT

This study presents a finite element analysis of pulsatile blood flow in a bifurcated artery with three stenosed configurations: parent artery only, parent with right daughter, and parent with both daughters. The unsteady Navier-Stokes equations were solved under physiological boundary conditions, considering both Newtonian and Non-Newtonian (Carreau) models. Validation ensured numerical accuracy. Results show that multiple stenoses intensify jet velocities, enlarge recirculation zones, and elevate hemodynamic disturbances, including WSS and OSI, with the most severe effects observed when all branches are stenosed. The Carreau model predicted reduced velocities, WSS, and OSI, highlighting shear-thinning effects compared to the Newtonian model.

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Paper ID: 150

Airflow and particle Dynamics Behavior in Alveolar Space with rhythmic breathing : Modeling and CFD study

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ABSTRACT
The alveoli are the fundamental structures in the lung responsible for gas exchange, and their function relies on convective airflow patterns that transport and deposit aerosol particles. This study analyses fluid flow and particle transport using a computational fluid dynamics (CFD) model of a single acinar region coupled to a bronchiole. The model is composed of some elastic spherical adjacent caps (alveolus) connected to a rigid rectangular tube (bronchiole). Particular attention was given to the effects of Reynolds number and alveolar sac size, which strongly influence the nature of airflow, mixing intensity. Lower Reynolds numbers, typical of pulmonary conditions, promote diffusive transport and uniform mixing, whereas higher Reynolds numbers induce more complex vortical structures. The result show that the maximum velocity 5.7×10^{-3} ms^{-1} occurs at time t=1s in the alveolar duct. With the rhythmic breathing the velocity and pressure increases and decreases with time period. The findings also provide insight into the interplay between flow regime, and particle behavior under controlled conditions, contributing to a better understanding of respiratory mechanics and aerosol transport in the lungs.

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MHD Natural Convective Flow and Heat Transfer of Non-Newtonian Ferrofluids in an Inclined Magnetic Field: Resolution Enhancement Approach with ANN and PINN

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ABSTRACT

Natural convection of non-Newtonian ferrofluids in wavy enclosures with heated cylinders requires computationally expensive high-fidelity simulations for accurate flow and heat transfer predictions under magnetic fields. This work develops a physics-informed neural network (PINN) framework for super-resolution reconstruction of velocity, pressure and temperature fields from extremely coarse-mesh solutions containing errors, substantially reducing computational cost and increasing accuracy. The PINN embeds governing PDE residuals and boundary conditions directly into the loss function, ensuring physical consistency while upscaling low-resolution inputs. For a representative case (Ha=10, =0.06, Ra=104), the PINN demonstrates superior kinematic structure preservation compared to purely data-driven approaches, achieving R^2=0.9677 for u-velocity and R^2=0.9780 for v-velocity on high-resolution meshes whereas for ANN the values are 0.8811 and 0.9292. While requiring longer training time (1.5 hours vs. 2 minutes for conventional ANNs), the PINN provides enhanced boundary-layer fidelity and consistently lower RMSE for velocity fields.

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Paper ID: 177

An Analysis of Algebraic Wall Model in LES of Turbulent Channel Flow Employing Artificial Neural Network Technique

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ABSTRACT
This study employs an artificial neural network (ANN) to forecast the performance of the algebraic wall model (AWM) within a large eddy simulation (LES) of turbulent channel flow(TCF) with a particular focus on the near-wall region. A thorough process of testing, validation, and training is undertaken to develop the ANN technique, utilizing data from both LES-AWM and direct numerical simulation (DNS). The LES employs a low-storage explicit Runge-Kutta method to achieve3rd order precision in time, alongside a finite difference method for second-order spatial precision. The Levenberg-Marquardt backpropagation algorithm (LMBP)is utilized to minimize the loss function of the trained ANN through second-order backpropagation. The trained ANN demonstrates strong performance regarding turbulence statistics with its forecasts surpassing those of both LES-AWM and DNS outcomes. Regression analysis facilitates a comparison of the turbulence characteristics predicted by the ANN against the data from LES and DNS. Notably, the ANN-LES data provides improved predictions of near-wall effects compared to the LES-AWM data. Additionally, contour plots illustrate the behavior of flow structures within the computed flow field.

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Numerical Study of The Thermal Performance of a Counterflow Heat Exchanger: Geometry Effects and Regression Analysis

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ABSTRACT
The thermohydraulic performance of counterflow heat exchangers is crucial in compact cooling systems. This paper presents a three-dimensional numerical study of heat transference and fluid movement characteristics in a counter-flow heat exchanger using Galerkin's weighted residual finite element technique to solve the conjugate heat transfer equations. The research focuses on the effects of circular, square, and triangular microchannel 3D configurations on data analysis, including heat transfer effectiveness, heat exchanger performance, and pressure drop, particularly using nanofluid (Al_2O_3-water) as a working fluid. Regression analysis is done to interpret and assess the link between key design factors and heat exchanger performance when nanofluids are used. This investigation uses nanofluids in laminar flow conditions with particle concentrations for Reynolds numbers . Microchannel dimensions, particle concentration, and Reynolds number affect heat exchanger effectiveness, thermal performance, and pumping power. Channel geometry, especially square and circular designs, significantly impacts heat transmission and pressure drop, with square channels offering the best blend of high performance and low-pressure loss. Overall, circular channels provide the most balanced performance, while triangular channels are advantageous for maximum heat removal. Nanofluids boost heat transmission, particularly at lower concentrations, and the regression model optimises microchannel heat exchanger designs. The research shows that nanofluids may improve heat management systems in microelectronics and other high-performance applications.

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Magnetic Nanofluid Transport in a Corrugated Enclosure with a Rotating Hollow Cylinder for Thermal and Magnetic Control

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ABSTRACT

Magnetically assisted nanofluid convection offers new thermal control opportunities, but its interaction with rotational forcing in complex enclosures is still poorly quantified. This study investigates the flow of Fe3O4-water nanofluid in a corrugated cavity with a rotating cylinder under the influence of a periodic magnetic field. The nondimensional governing partial differential equations associated with boundary constraints are utilized using finite element approach via Galerkin residual in COMSOL Multiphysics on an 8GB RAM, Core i5 machine. Simulations are conducted for varying Hartmann numbers (Ha), rotational parameter (ω), periodic magnetic field wave numbers (λ), and Rayleigh number (Ra) with 5% Fe3O4 nanoparticle concentration. The results reveal that magnetic fields suppress buoyant recirculation and collapse thermal plumes, while rotation restructures the damped flow into vigorous multi-vortex patterns and partially restores mixing. The average Nusselt number exhibits a pronounced increase with Ra and λ, declines with higher Ha, and is modestly enhanced by suspended Fe_3O_4 nanoparticles. These inspections provide design-level insights for exploiting magnetic–rotational interactions to improve the thermal performance of next-generation cooling architectures.

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Study on the Airfoil Guide Vane for Counter-rotating Impulse Turbine for Wave Energy Conversion

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ABSTRACT

One method for harnessing ocean energy is the oscillating water column (OWC) wave energy converter, which utilizes a turbine designed for reciprocating flow that always rotates in one direction. A specific turbine applied in this system is the counter-rotating impulse turbine. Computational fluid dynamics (CFD) analysis has revealed that the efficiency of this turbine is significantly reduced in the low flow coefficient range due to the difference between the downstream rotor inlet angle and the relative inlet angle. To mitigate this limitation, previous studies introduced middle vanes between the two-rotor cascade. Earlier CFD results indicate that an airfoil-type guide vane offered higher turbine performance than the original-type guide vane. However, the relative inflow angle was found to increase with the airfoil-type guide vane. In the present study, the guide vane setting angle was varied, and a peak efficiency of 0.512 was achieved at a setting angle of 25°.

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Enhancing Savonius Turbine Performance with Zigzag on the Concave Surface and Dimple on the Convex Surface: A Computational Fluid Dynamics (CFD) Study

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ABSTRACT

This study investigates the effect of surface modification on a Savonius wind turbine by using a zigzag pattern on the concave side and a dimple on the convex side. The zigzag pattern helps capture the wind more effectively, while the dimple reduces negative drag. This study examines the effect of surface modifications on turbine efficiency. A modified model has been found through CFD simulations using ANSYS software that shows a higher power coefficient than the conventional model. It has a zigzag pattern on the concave surface and dimples on the convex surface. For the simulation, the Shear-Stress Transport (SST) k-ω turbulence model is used. For a single rotation, the coefficients of power and torque are calculated at different tip speed ratios (TSR). This investigation shows the effect of blade modification on torque and power coefficients. It is found that the modified model leads to a 16.7% increase in power coefficient at a TSR of 1.2. This study indicates that the blade design has the potential to increase the power coefficient of the Savonius wind turbine.

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Paper ID: 234

Computational Study of TiO_2 –Kerosene Nanofluid Transport within a Star-Shaped Enclosure Featuring a Heated Obstacle

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ABSTRACT
This computational work aims to investigate the natural convective flow and thermal transmission properties of TiO2-kerosene nanofluid within a star-shaped enclosure containing a centered square obstruction while being subjected to a magnetic strength and internal heat generation. These nonlinear PDEs are solved through the Galerkin finite element technique, implemented in COMSOL Multiphysics 6.3 software. Validation utilizing benchmark studies demonstrates that expected streamlines and isotherms are very consistent. Numerical simulations are performed to examine the impacts of different parameters, including Rayleigh number (Ra=103-106), Hartmann number (Ha = 0,25,50 and 100), and internal heat generation parameter (Q=0,10,20, and 25). All findings are reported for a consistent nanoparticle volume fraction of 2% TiO2. Numerous vortices develop within the enclosure, and $|\psi|$max grows from 0.29 to 35 as Ra varies from 103 to 106. The discovery of the current study is pertinent to the field of high-temperature industrial research, particularly in relation to electronics cooling and solar thermal applications.

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MHD Double-diffusive Free Convection of Al_2 O_3–water Nanofluid in a Square Cavity with Circular Heater

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ABSTRACT

This study numerically investigates magnetohydrodynamic (MHD) double-diffusive free convection of Al_2O_3–water nanofluid in a square cavity containing a circular heater. The left and right wall of the cavity are maintained at a cold temperature while the others are adiabatic. The continuity, momentum, energy, and concentration equations, along with boundary conditions, are non-dimensionalized using appropriate transformations and solved with the finite element method based on the Galerkin weighted residual approach. The impacts of Rayleigh number ($Ra = 10^3, 10^4, 10^5, 10^6$) and Hartmann number ($Ha = 0, 20, 40, 80$) are examined through isotherms, streamlines, and iso-concentrations. The results demonstrate the change with increasing Ra from conduction-dominated to convection-dominated regimes, while Ha suppresses fluid motion due to the Lorentz force. In addition, Nu_{av} and Sh_{av} are evaluated to quantify the rates of heat and mass transfer under several parametric conditions. The findings provide insight into coupled heat and mass transport in nanofluid-filled enclosures under magnetic fields, with potential applications in thermal management and energy systems.

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Investigation of Co-firing Characteristics Using Oxy-fuel Technologies in a 125 MW Power Plant

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ABSTRACT

Bangladesh's growing energy demand and reliance on coal indicate a pressing need for cleaner power generation pathways. This study investigates co-firing rice husk biomass with coal in the 125 MW tangentially fired subcritical boiler of the BTPP under both AF and OF combustion environments integrated with carbon capture and sequestration (CCS). A CFD model was developed using ANSYS Fluent 2025 R1 to analyze combustion performance, flame temperature distribution, gas flow dynamics, and emission characteristics across twelve operating cases with varying biomass ratios (20–60%) and oxidizer conditions (AF, OF23, OF27, OF31). Grid-independence testing and validation against plant data confirmed model reliability. The dynamics of flame, flame temperature distributions, and gaseous emissions, including O_2 and CO_2 distributions, were used to present the results. They show that increased biomass share reduces peak flame temperature but enhances flame volume due to higher volatile content, while oxy-fuel conditions significantly elevate CO2 concentration, improving CCS effectiveness. The findings provide practical insights for retrofitting coal-fired plants in Bangladesh to enhance sustainability and energy security.

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Paper ID: 299

Aerodynamic Performance Investigation of Albatross-Inspired Fixed-Wing Micro Aerial Vehicle.

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ABSTRACT

Micro Aerial Vehicles (MAVs) are increasingly used in surveillance, environmental monitoring, and rescue operations, yet their aerodynamic performance remains constrained by low Reynolds number flight regimes. This study investigates the aerodynamic performance of a fixed-wing MAV designed with a biomimetic airfoil inspired by the albatross wing (GOE 174) and compares it with a baseline MAV using the S5010 airfoil. Both designs were modeled in SolidWorks and analyzed using ANSYS Fluent with a poly-hexcore meshing strategy and ID-DES turbulence model. Numerical simulations were conducted at a flight velocity of 6.5 m/s under chord-based Reynolds numbers typical for MAV operations. Results demonstrated that the Albatross-inspired MAV produced higher lift coefficients across all angles of attack (AoA) and delayed aerodynamic stall by 7° compared to the baseline model. The maximum lift coefficient was observed at 26° AoA. The lift-to-drag ratio (L/D) of the Albatross model exceeded that of the baseline by 30.32% at its optimum AoA of 5°, confirming its superior aerodynamic efficiency. Velocity and pressure contours revealed larger pressure differentials and delayed flow separation in the Albatross design, contributing to improved post-stall performance. Vortex visualization and skin-friction analysis further validated reduced turbulence and enhanced lift generation. These findings highlight the potential of biomimetic wing designs in enhancing MAV aerodynamic performance under low Reynolds number conditions. The albatross-inspired configuration offers improved lift, delayed stall, and higher efficiency, establishing it as a promising candidate for sustainable MAV applications in challenging environments.

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CFD Assessment of a Branch-Mounted Swirler in a 90° Mixing Elbow

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ABSTRACT

Mixing elbows are common components found onboard ships in ballast, fuel transfer and seawater cooling lines. However, the induced secondary flow tends to separate at the inner wall, resulting in the lack of mixing uniformity and the increase in wear and noise. Previous work simulating 90° mixing elbows has involved variation of curvature ratio and Reynolds number. Still, the notion of a swirler introduced directly in the smaller-sized branch concerning the side inlets has not been investigated, leaving the practical retrofit potential unquantified. Hardly any information was obtained on where the swirler should be located in the branch. This paper examines the impact of a simple swirler on the hydrodynamics of the mixing elbow and determines the optimal axial position on the side branch. An eight-vane swirler is considered at five axial stations ($L_b/5$, $2L_b/5$, $L_b/2$, $3L_b/5$ and $4L_b/5$, where L_b is the branch length) with respect to a 90° mixing elbow. The three dimensional RANS (k–ε) equations were solved using a second order upwind scheme. All swirler positions dissipated the recirculation bubble found in the untreated elbow and instead generated a coherent helical core which induced early interstream mixing. Locating the device between $3L_b/5$ and $4L_b/5$ yielded the flattest velocity profiles and reduced velocity non-uniformity compared with the baseline by over an order of magnitude, at the expense of an increase in the pressure drop which is also quite low. Mounting the swirler closer to the inlet ($\leq 2L_b/5$) provided only a partial relief. As the swirler is small and can be easily fabricated, it can be installed at a regular dry dock maintenance interval. The CFD analysis shows that it can reduce the mixing straight run by a lot from the conventional lengths, meanwhile reducing erosion risk and improving chemical or thermal conditioning that may provide ship operators with a lighter, quieter and more durable piping system.

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Effect of Relative Orientation of Body Fin and Tail Fin on the Aerodynamic Characteristics of a Missile in Subsonic Flight - An Experimental Study

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ABSTRACT

This study investigates the effect of the relative orientation of fins on the mid-section (body fin) and tail-section (tail fin) of a missile on its aerodynamic characteristics, particularly in the subsonic regime relevant to cruise missiles. It addresses the interaction of the body fin, a critical component affecting range and maneuverability, with the tail fin due to the relative angular position around the missile body, affecting its aerodynamic efficiency. Through systemic wind tunnel experimentation of a scaled missile model derived from N1G missile baseline geometry and fabricated with two double wedge-shaped body fin, two different body fin-tail fin orientations were examined: '0° orientation', where body and tail fins lie in the same plane, and '45° orientation', where the tail fins are rotated relative to the body fins. A zero angle of attack of the missile during testing, while varying the body fin incidence angle (0°, 10°, 15°) across subsonic airspeeds, isolated the effect of fin orientations during the recording of the corresponding aerodynamic efficiency dataset. Results reveal that the 45° orientation consistently enhances lift and aerodynamic efficiency at low to moderate incidence angles (~10°), offering range and maneuverability advantages. However, it becomes unsuitable for high-agility missions due to non-linear drag penalties at high incidence angle (~15°). Findings from this study establish that the relative orientation of the body fin and tail fin is a critical but understudied parameter in missile aerodynamics. Additionally, experimental datasets from this work provide the groundwork for numerical validation and further numerical study, including high-speed implications, thereby contributing to the broader goal of missile design optimization.

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The Investigation of Successive Coalescence and Droplet Orientation in Coalescence-Induced Droplet Jumping

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ABSTRACT
The coalescence-induced droplet jumping has gained major attention in recent times due to its capability of enhancing the condensation heat transfer efficiency by several degrees, as it keeps the condensing surface dry without any external energy. However, the numerical studies of jumping droplet velocity and jumping kinetic energy due to coalescence conducted till now overpredict the velocity and kinetic energy because of not accounting for the successive nature of coalescence. This study investigates the successive coalescence-induced jumping in three different orientations. In each of the orientations, a droplet with an initial velocity comes toward two coalescing droplets to simulate the successive nature in reality. This multi-phase study is carried out via the open source CFD tool OpenFOAM, and for the solver, the multi-phase solver interFoam was modified to accommodate accurate coalescence control and the dynamic contact angle input. The study shows that the successive nature causes a longer period of oscillation and mass redistribution of complex shapes. This increases the time required for the droplet to become stable and spherical. The orientation of droplets in the same number of droplets turns out to be an important factor, as the energy conversion shows that the velocity of the moving droplet relative to the oscillation of coalescing droplets affects conversion efficiency. This study gives further insight into the dynamics of droplet jumping on a super-hydrophobic surface due to coalescence and the optimization of the process through practical engineering applications.

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CFD Analysis of the Impact of Fuel Pressure Ratios in Enhancing Mixing Efficiency with Upstream Rectangular Cavity of Scramjet

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ABSTRACT

This study numerically investigates the non-reacting flow field in an upstream rectangular cavity scramjet combustor under varying fuel-to-freestream pressure ratios (PR) of 4.5, 9.0, 13.5, and 18.0. The influence of PR on fuel-air mixing efficiency (MxE), total pressure recovery (TPR), and mass-averaged Mach number (MAMN) is analyzed with particular attention to shock wave interactions and their strength. Simulations are conducted by solving the 2D RANS equations coupled with species transport equations (Menter SST k-ω turbulence model). Shock-shear layer interactions (SSLIs) are identified as key mechanisms for controlling cavity mixing. A PR of 13.5 optimizes fuel-air mixing, while higher pressures shift shock formation toward the combustor outlet, reducing shock interactions in the combustion zone and limiting overall performance.

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Flow Control and Drag Reduction of a Triangular Bluff Body with Splitter Plate at Low Reynolds Numbers

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ABSTRACT

Flow simulation around a stationary 2-dimensional triangular bluff body was performed to analyze the effectiveness of a splitter plate in minimizing drag over the bluff body at low Reynolds numbers ($50 \leq Re \leq 250$). At these Reynolds numbers, the drag, specifically pressure or form drag, rises due to the Von-Kármán vortex over the triangular body. A splitter was introduced behind the geometry of the body to alter the vortex shedding and minimize the drag coefficient. The splitter plate position was fixed at the center of the base of the body, and three different sizes of splitter plates were used to assess the efficiency of plate size on controlling the flow at different Reynolds numbers. A significant reduction in time-averaged drag coefficient (CD) was observed in the presence of splitter plates of all lengths, while the flow stabilization was found to be dependent on the plate length.

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A Comparative Analysis of Machine Learning Algorithms for Airfoil Performance Prediction

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ABSTRACT

The aerodynamic lift-to-drag (L/D) ratio is critical for optimizing aircraft and wind turbine performance, yet traditional computational fluid dynamics (CFD) simulations and wind tunnel experiments are computationally expensive and time-consuming. This study presents a comprehensive benchmarking of eight machine learning algorithms for predicting airfoil L/D ratios, spanning from Linear Regression to advanced ensemble methods like XGBoost, LightGBM, and CatBoost. Using a systematically generated dataset for over 200 NACA airfoils with varying geometric parameters simulated across a wide range of angles of attack and Reynolds numbers using XFoil, we evaluated algorithm performance on both predictive accuracy and computational efficiency. Random Forest achieved the highest performance with an R^2 of 0.9995, followed closely by other tree-based ensemble methods. These advanced models consistently outperformed simpler parametric approaches, which struggled to capture the complex aerodynamic relationships. While ensemble methods demonstrated superior accuracy, a clear trade-off emerged between predictive performance and computational cost. These findings provide practitioners with empirical guidance for selecting appropriate ML algorithms for airfoil optimization workflows and establish a benchmark for future aerodynamic surrogate modeling research.

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Unsteady Magneto-Porous Convective Boundary Layer Flow over an Inclined Plate: Influence of Thermal and Mass Buoyancy Forces

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ABSTRACT
This study provides a comprehensive numerical investigation of unsteady magneto-porous convective transport in boundary layer flow over an inclined vertical permeable plate. The flow is governed by nonlinear, time-dependent partial differential equations (PDEs) representing momentum, thermal, and concentration fields. The numerical solution is obtained through a finite difference method (FDM) to examine the velocity, temperature, and concentration distributions within the boundary layer. Stability analysis is conducted to evaluate the flow behavior under varying conditions, identifying the key parameters that affect flow stability and the transition among different regimes. The findings indicate that the Grashof number enhances the velocity in the boundary layer over an inclined vertical porous plate by inducing fluid motion due to temperature-driven density differences. To validate the present study, these outcomes are compared with those reported in other published works. This in-depth understanding is crucial for improving precise predictive modeling and advancing engineering design strategies. It has wide-ranging applications in areas such as petroleum and agricultural engineering, gas turbine systems, nuclear energy generation, heat exchangers, chemical processing industries and cooling technologies.

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Machine Learning-Enhanced Investigation of Mixed Convection MHD Flow in a Lid-Driven Square Cavity with Semi-Circular Heaters and a Central Hollow Cylinder

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ABSTRACT
Abstract. This study presents a computational analysis of fluid flow and temperature distribution in a lid-driven square cavity containing two isothermal semi-circular heaters and a central solid hollow circular domain. The vertical walls, flat bottom sections, and hollow domain wall are adiabatic, while the top wall moves at a constant velocity along the positive x-axis and is cooler than the heaters. Each heater has a radius equal to one-tenth of the cavity length. The governing continuity, momentum, and energy equations are nondimensionalized and solved using the finite element method with the Galerkin weighted residual approach. Simulations are performed for Reynolds numbers from 100 to 500, Hartmann numbers 0–50, Richardson numbers 0.1–10, and a fixed heater spacing of D = 0.6. Results show that heat transfer decreases with increasing Hartmann number, while higher nanoparticle volume fractions (φ = 0.1–0.4) in the hybrid nanofluid enhance thermal performance. The hollow domain modifies flow and temperature patterns. Additionally, a machine learning model accurately predicts system behavior, highlighting its potential as an efficient tool for optimizing thermal systems.

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Reinforcement Learning-Based Controller for Automated Choke Operation

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ABSTRACT

Precise control of surface pressure is crucial in Managed Pressure Drilling (MPD) as its a key element to control the bottom hole pressure and ensures safe and stable wellbore conditions under different operating conditions. Controllers such as PID and Nonlinear Model Predictive Control (NMPC) are well-established and widely implemented for automated MPD operations. However, reinforcement learning techniques like Deep Q-Learning can be explored within a commercial flow loop system. An agent interacts with a simulated environment represented by an LSTM model, which is developed through real data from a commercial flow loop system. By episodic training, the agent iteratively interacts with the environment and observes its current state, selects actions according to policy, and receives scalar reward signals that quantify control performance. These interactions allow the agent to update its Q-value estimates via temporal-difference learning and change its decision-making policy toward maximizing cumulative rewards under varying flow and pressure conditions. The key advantage of this approach is that it reduces dependency on an explicit dynamic model of the system, which is sometimes hard to develop for the highly nonlinear system and challenging operating conditions and wellbore characteristics.

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Dynamics of Droplet Formation in Microchannel with Assymetrically Positioned Constricted Outlet

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ABSTRACT

This study investigates the effects of constricted outlet position in a T-junction microchannel on the frequency of droplet formation, droplet size, and monodispersity using computational fluid dynamics (CFD). Volume of Fluid (VOF) based multiphase model was used to capture the interfacial dynamics between the continuous phase (sunflower oil) and the dispersed phase (deionized water). The contact angle was set to 165°, and the ratio of flow of dispersed phase to continuous phase 0.25, 0.5 and 0.75. The position of microchannel outlet which is geometrically constricted was varied along the direction normal to the direction of droplet formation. The position of the outlet was defined using a parameter called -Degree of Asymmetry (DoA) which was calculated in percentile as the difference of constriction position and half width of the channel to the channel width. The DoA was varied in the range of -20 to 65% to analyze its effect on dynamics of droplet formation. Results demonstrate that increasing the DoA significantly enhances the droplet generation. This indicates that droplet formation can be effectively controlled by optimizing the Degree of Asymmetry without altering the inlet or outlet dimensions. The findings provide valuable insights into the design and optimization of T-junction microchannels for applications requiring precise control over droplet, such as emulsification, drug delivery, and lab-on-a-chip devices.

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Numerical Study of the Effect of Reynolds Number on Underexpanded Microjet at Fixed Nozzle Pressure Ratio

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ABSTRACT

In this paper, the effect of varying the Reynolds number (Re) of a microjet at fixed nozzle pressure ratio (NPR) is studied numerically. Underexpanded microjets issuing from a nozzle of exit diameter of 1.0 mm are developed for NPR = 3.0. The plenum pressure and back pressure are varied simultaneously to maintain a constant NPR = 3.0 for developing under expanded microjets of varying Re = 10,191, 15,265, 25,340, 40,622, and 51,765. The Re is calculated using the flow properties at the nozzle exit condition. The numerical model is validated against both experimental and numerical data available in the literature. The result shows that Reynolds number has a significant effect on the centerline Mach number, shock strength inside the first shock cell, supersonic core length, and the thrust generated by the microjet. The time-averaged centerline Mach number shows that for lower Re (10,191, 15,265, and 25,340), the flow becomes subsonic inside the first shock cell, which suggests the appearance of an infinitesimal barrel shock inside the first shock cell. The first shock cell locations and size appear to remain unaffected with the change of Re, while the shock strength inside the first shock cell is found to increase with the increase of Reynolds number from Re = 10,191 to Re = 25,340 and then suddenly drops for Re = 40,622 and increases again. This pattern supports the possibility of the appearance of barrel shock at low Re. The supersonic core length is found to increase by 3.5% with a decrease of Re from Re = 51,765 to Re = 10,191. The thrust and specific impulse produced by the jet are also computed. It is found that, with the increase of Re from 10,191 to 51,765, the thrust force increases nearly 5 times while the specific impulse remains unchanged.

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Material Science

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The Flexural Performance of JUCO-Al_2O_3 Fiber Composites in Multi-Environmental Aging Conditions: An Experimental and FEM Analysis

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ABSTRACT

To The flexural performance of epoxy composites reinforced with JUCO fibers and enhanced with alumina ($Al2O_3$) nanofillers is examined in this work under various environmental circumstances. Four filler loadings (0%, 2.5%, 5%, and 7.5% by weight) were used to fabricate the composites, which were then exposed to control, water immersion, acidic exposure (pH 3), and thermal aging (80°C). Three-point bending tests were used to assess flexural properties in accordance with ASTM D790, and ABAQUS numerical simulations confirmed the experimental findings. The results show that 5 weight percent Al2O3 produced the highest flexural strength (94.1 MPa in dry condition and 101.3 MPa after heat treatment), indicating the best possible filler dispersion and matrix–fiber interaction. Strength was diminished by environmental deterioration, but the decrease was lessened by the addition of filler. Finite element analysis verified the model's dependability by closely matching experimental behavior. JUCO-$Al2O_3$ composites are highlighted in this study as viable, sustainable substitutes for structural applications that demand environmental durability and mechanical resilience.

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Mechanical Behavior of Hybrid Glass-Jute Fiber Composite Sheet in Honeycomb Core Sandwich Panels

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ABSTRACT
This study aims to enhance the mechanical properties of natural fiber-reinforced composites by hybridizing jute with synthetic glass fibers in various stacking sequences, both with and without an aramid honeycomb core. Four composite types [WG-J-WG], [WG-J-H-J-WG], [CG-WG-H-WG-CG], and [CG-J-H-J-CG] were fabricated using a hand lay-up method cured for 36 hours at 100 kg uniform pressure, and it is maintained at a 25°C ambient temperature and tested for tensile, flexural, impact, hardness, and moisture absorption properties. The panel made without a core ([WG-J-WG]) showed the best tensile strength, reaching 125 MPa, which was up to 81% higher than the weakest sample. It also had the highest flexural strength, while others showed a drop of more than 50%. On the other hand, the sample with the chopped glass and honeycomb layers ([CG-J-H-J-CG]) demonstrated the greatest stiffness, almost 39 times more than the lowest one. In terms of impact resistance, [CG-WG-H-WG-CG] absorbed the most energy at 19.61 J, nearly 49% more than the weakest sample. It also had the highest hardness value, while [WG-J-WG] had the lowest, showing a 54% difference. When it came to moisture absorption, [CG-J-H-J-CG] performed the best, taking in only 10.73% water, 79% less than the most absorbent sample. These results demonstrate that combining natural and synthetic fibers with strategic core design can significantly improve mechanical performance, making these composites suitable for lightweight, moisture-resistant, and impact-tolerant applications such as automotive panels, structural cores, and protective equipment.

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Effect of building orientation and thermomechanical processing on Ti64 alloy made by LPBF technique

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ABSTRACT

Titanium alloys, namely Ti-6Al-4V, are utilized extensively in the biomedical and aerospace industries because of their excellent corrosion resistance and mechanical qualities. However, their high cost and processing complexity pose challenges in manufacturing precision components. Initially, additive manufacturing techniques have proven very promising, but additive manufacturing components with metals always provide some boundaries for real-world applications. More recently, hybrid additive manufacturing, which combines additive techniques with conventional manufacturing, has emerged as a promising solution for producing near-net-shaped parts. In such a technique, the inherent anisotropy due to the building orientation is a crucial parameter that needs more understanding for process optimization. This study systematically investigates the effect of hot compression and building orientation on Ti-6Al-4V alloy, considering the vertically built samples as standard samples, fabricated by laser powder bed fusion (LPBF). Cylindrical samples, built in two orientations and stress relieved at 950°C, were examined for α-lath thickness. Subsequently, vertically built samples were compressed at 850°C, with a strain rate of 10 s−1. The impact of mechanical and thermal variables on dynamic softening mechanisms was demonstrated by flow stress analysis and post-deformation microstructural evaluation. The results contribute to understanding the hot workability and microstructural evolution of LPBF Ti-6Al-4V, supporting process optimization for advanced manufacturing applications.

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Comparative Analysis of Glass Fiber and Carbon Fiber for Enhancing Jute Characteristics: Evaluating the Superior Reinforcement in Composite Materials Using Finite Element Method

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ABSTRACT

Hybrid reinforcement techniques are gaining much attention due to the growing demand for sustainable, lightweight, and high-performance composite materials. This study presents a comparative finite element analysis (FEA) of jute fiber-reinforced composites and hybrid composites where glass and carbon fibers were incorporated into jute to evaluate their mechanical properties. This research aims to enhance the mechanical performance of jute-based composite by analyzing deformation, von Mises stress, and shear stress under different ply orientations and thicknesses. For determining the effective macroscopic properties of the composites, a computational micromechanics approach was employed. According to the simulation results, hybrid composites, particularly jute-carbon fiber laminates demonstrated superior mechanical properties including low deformation and high strength compared to pure jute and jute-glass composites. The optimal configuration was identified as 4 mm jute-carbon fiber hybrid laminate with a 0° ply orientation exhibit high equivalent stress, shear stress and low deformation. Without compromising performance, these findings highlight future opportunities for aerospace and automotive applications through light weight and eco-friendly alternatives.

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Property Evaluation and Structural Optimization of Nymphaea nouchali-Inspired Metamaterials

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ABSTRACT

Natural structures lead a doorway for metamaterials for developing lightweight, energy absorbing materials with desired properties. This study evolves a detailed evaluation of mimicking a bio inspired Nymphaea nouchali-based metamaterials for its structural configuration contribute to buoyancy and mechanical stability. Observing the aerenchyma chambers in Nymphaea's vascular bundle an octagonal shaped unit cell was developed consisting of circular and elliptical hollow following its anatomic pattern. Later, this microstructure was simulated in an explicit model having 55% strain, from there stress strain curve, energy absorption rates were recorded. To validate the numerical predictions, experimental compression test was performed on fabricated specimen of PLA material. This comparative analysis revealed that elliptical hollow distributed stress more uniformly with higher densification points, enabling progressive collapse and 37.4% higher absorption rate than hollow structure. Such performance highlights an insight of practical application include automotive crash protection, railways buffers, seismic dampers and protective equipments.

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Effect of Calcium (Ca) Doping on the Dielectric Properties of Barium Titanate ($BaTiO_3$)

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ABSTRACT

Calcium (Ca)-doped barium titanate ($BaTiO_3$) offers promising potential for enhancing the efficiency and reliability of electronic devices. This study aims to examine the role of Ca doping in the dielectric properties of $BaTiO_3$ ceramics. By doping $BaTiO_3$ with changing concentrations of Ca (0%, 6%, 9%, and 12%), fluctuations in its density and dielectric behavior were investigated. The samples were prepared by applying the conventional solid-state method and characterized by dielectric property measurement, X-ray diffraction (XRD) analysis, and impedance test. The study findings revealed that the maximum stability is achieved with 6% Ca-doping, while higher doping levels (≥ 9%) reduce permittivity due to defects and lattice strain. All samples have dielectric permittivity (ε') becoming roughly constant at high frequencies (> 10 MHz), with 12% Ca-doped $BaTiO_3$ having the lowest permittivity. XRD confirmed tetragonal $BaTiO_3$ for all samples, with peak shifts indicating lattice contraction from Ca2+ substitution. Both 6% and 12% Ca-doped samples showed successful doping without impurity phases, though slight distortions were evident at higher concentrations. 6-9% Ca doping makes it appropriate for electronic applications by balancing conductivity and resistance. Ca doping increases charge transport while lowering resistance. Excessive doping (≥ 12%) may cause undesired leakage currents in capacitors. The optimal doping levels for $BaTiO_3$ in capacitors, sensors, and high-frequency electronics are 6-9%. These findings provide useful insights for designing and optimizing Ca-doped $BaTiO_3$ ceramics for advanced electronic applications.

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A Workflow for Stress-Aware Topology Optimization and Fabrication of Lattice Structures by Additive Manufacturing

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ABSTRACT

This study presents an integrated workflow for stress-based topology optimization (TO) tailored to additive manufacturing (AM). Using the Solid Isotropic Material with Penalization (SIMP) method on tetrahedral meshes, localized stress gradients are captured more accurately than with traditional uniform meshes. A custom Python framework was developed for post-processing, including nodal density parsing, variable-thickness lattice generation, and tool path generation. For smooth transitions in lattice thickness, a k-d tree nearest-neighbour algorithm interpolates densities from non-uniform data. The optimized lattices are converted into G-code through image-based rasterization and extrusion path planning, bridging computational design and physical fabrication. The workflow was validated experimentally. Bending tests on 3D-printed specimens showed that topology optimization significantly increased peak load capacity, particularly in cross-braced designs, while triangular lattices provided higher stiffness and energy absorption. These results demonstrate the trade-off between strength and ductility in lattice structures. Overall, the proposed workflow offers a reproducible, scalable approach for designing structurally efficient, manufacturable AM components.

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Microstructural Characterization and Electrochemical Analysis of a Rare-Earth-Free Mg-1Ca-1Sn Alloy

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ABSTRACT
Magnesium alloys constitute a broad category of materials with significant application potential, primarily attributed to their low density and high strength. However, the widespread application of magnesium and its alloys is significantly hindered by their inherently poor corrosion resistance. In the present study, a rare-earth-free Mg-1Ca-1Sn alloy was introduced as a cost-effective solution for obtaining better performance. The primary objective is to investigate the microstructural evolution, phase formation, and corrosion behavior of the Mg-1Ca-1Sn alloy. The Mg-1Ca-1Sn alloy was cast using an induction furnace, homogenized, and artificially aged at 200°C for 6 hours. X-ray diffraction (XRD) and X-ray fluorescence (XRF) were performed to analyze material phases and elemental composition, respectively. Optical Microscopy was carried out before and after heat treatment for microstructural observation. Scanning Electron Microscopy (SEM) with Energy Dispersive Spectroscopy (EDS) analysis was conducted for further investigation. The corrosion behavior of the alloy was evaluated using both non-electrochemical and electrochemical techniques, including Potentiodynamic Polarization (PDP), Open Circuit Potential (OCP), and Electrochemical Impedance Spectroscopy (EIS). The formation of secondary phases, along with the solid solution of Sn within the magnesium matrix, contributes to the stabilization of the protective oxide film formed during corrosion, thereby improving the alloy's corrosion resistance. This enhancement is consistent with the trends observed in Tafel, Bode, and Nyquist plots.

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Fabrication and Characterization of Nanocellulose-Reinforced PVA Films Derived from Water Hyacinth

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ABSTRACT

The exponential growth of plastic pollution has driven the search for sustainable alternatives to petroleum based packaging. This study explores the extraction of nanocellulose from Eichhornia crassipes (water hyacinth), an invasive aquatic weed, and its incorporation into polyvinyl alcohol (PVA) films for biodegradable packaging applications. Cellulose was extracted through sequential alkaline and bleaching treatments, followed by sulfuric acid hydrolysis and ultrasonication to isolate nanocellulose. The nanocellulose was then blended with PVA, glycerol, and acetic acid to fabricate composite films using solution casting. The resulting films were characterized through FTIR, TGA, tensile testing, water absorption, and biodegradability analysis. FTIR confirmed the presence of functional groups from all components and strong compatibility in the matrix. TGA showed thermal stability up to 300 °C with a major degradation stage between 300–400 °C. Mechanical testing revealed moderate tensile strength (7.41 MPa) with high elongation (81.5%), while water absorption was limited to 13.33% after six hours. Biodegradability tests demonstrated a 21.05% weight loss within four weeks, highlighting the film’s eco-friendly potential. The study demonstrates that nanocellulose-reinforced PVA films derived from invasive water hyacinth are promising candidates for sustainable packaging solutions.

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Optimization of Machining and Nano MQL Parameters in High Speed End Milling of Titanium Alloy Ti-6ALV using RSM and GA for Tool Wear and Nose Wear

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ABSTRACT
Titanium alloys, including Ti-6Al-4V, are widely utilized in aerospace, biomedical, and automotive applications due to their excellent strength-to-weight ratio and corrosion resistance. They are still considered difficult-to-machine materials due to their limited heat conductivity and high cutting forces, which cause increased tool wear and poor surface smoothness. The purpose of this study is to optimize machining parameters and Nano Minimum Quantity Lubrication (MQL) conditions in high-speed Ti-6Al-4V end milling. The Response Surface Methodology (RSM) was used to develop regression models for tool and nose wear, and the Genetic Algorithm (GA) was utilized to choose the best parameters. The data indicate that Nano-MQL significantly reduces tool wear, and that combining RSM with GA results in an excellent approach for anticipating and optimizing cutting performance. The findings focus on optimal machining settings that decrease wear while maintaining high efficiency, giving useful insights for industrial titanium alloy machining.

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Numerical study of microstructural evolution of IN625 during Pulsed Laser Welding

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ABSTRACT

This study investigates melt pool morphology and microstructural evolution during single-track pulsed laser welding of IN625 on bare plate substrates, using a coupled Cellular Automata-Finite Volume solver. Both thermo-fluid and microstructure models were validated against NIST Additive Manufacturing 2018 Challenge 2 results. The CFD model validation employed melt pool dimensions and cooling rates from experimental results across three different process conditions, while the CA model was validated using experimental EBSD imaging for a single case. Using these validated models, simulations were performed for four pulsed laser frequencies: 2, 8, 20, and 50 kHz. NIST AM Bench 2018 Case B process parameters (179.8 W, 0.8 m/s) were applied for the pulsed welding cases. Comparisons between pulsed welding (PW) and continuous welding (CW) cases were conducted across three categories: equivalent grain diameter, misorientation angle, and grain shape morphologies. Cooling rates for different cases were also compared with the CW reference case. This research addresses the knowledge gap in pulsed laser welding applications for IN625.

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Synthesis and Characterization of Silica Gel-Based Solid Composite Desiccants for Numerous Applications

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ABSTRACT

This study investigates the synthesis and characterization of solid composite desiccants based on silica gel, with added components such as bentonite powder, activated carbon, and calcium chloride, aiming at a variety of applications. The synthesis of the composites was carried out using silica gel, bentonite powder, calcium carbonate, and different concentrations of activated carbon (0%, 5%, and 10%). X-ray diffraction (XRD) analysis showed a decrease in crystallinity with increasing amounts of activated carbon, indicating higher surface heterogeneity. Scanning electron microscopy (SEM) revealed that increasing activated carbon content changed the surface from relatively smooth at 0% to highly porous and irregular at 10%, indicating greater adsorption capacity. Increasing the amount of activated carbon enhanced the open pores, which is why moisture uptake rose from 59.16% to 93.81%. This addition also reduced thermal conductivity from 0.47 W/mK to 0.41 W/mK, improving the material's insulating properties. However, higher levels of carbon incorporation decreased the mechanical resilience of the composite. The mechanical properties, including bending strength and impact strength, declined as the percentage of activated carbon increased. Bending strength dropped from 0.52 N/mm^2 to 0.11 N/mm^2, and impact strength decreased from 30.25 psi to 2.22 psi. The composite with 10% activated carbon showed better adsorption and thermal properties, making it a good option for passive desiccant systems. With just 5% activated carbon, the desiccant composite achieved an impressive harmony of moisture control and mechanical strength. These results strongly suggest that silica gel-based desiccant composites could serve as sustainable, long-lasting, and adaptable solutions across a wide range of industrial applications.

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Effect of Processing Route on the In Vitro Corrosion Behavior of a Biodegradable Magnesium-Zinc-Yttrium-Erbium Alloy for Biomedical Applications

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ABSTRACT
The impact of processing routes such as as-cast, rolled, and extruded—on the microstructure and in vitro corrosion behavior of a biodegradable Mg-2Zn-1Y-0.5Er alloy for potential orthopedic applications is investigated. The alloy's performance was assessed in Simulated Body Fluid (SBF) using a comprehensive suite of characterization techniques, including X-ray Diffraction (XRD), Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDS), immersion tests, hydrogen evolution measurements, and electrochemical tests. The results revealed that the processing method significantly impacts the alloy's microstructure. The highest rate of corrosion was caused by the as-cast condition, which had a coarse, dendritic microstructure with an ongoing network of intermetallic secondary phases. Rolling mechanically disassembled this network, refining the microstructure. With a solute-enriched α-Mg matrix and a fine, homogeneous microstructure with fractured secondary particles, the hot extrusion method yielded the biggest improvement. With the lowest mass loss in immersion testing, the lowest corrosion current density, and the largest charge transfer resistance in electrochemical experiments, the extruded alloy therefore showed exceptional corrosion resistance. A more consistent and stable protective surface layer is responsible for this improved performance. showed Mg-Zn-Y-Er alloys may be tailored to degrade at a faster pace by hot extrusion, increasing their viability for clinical usage as biodegradable implants.

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Fabrication and Electrochemical Performance Evaluation of Zn-Al-Sr Layered Double Oxide (LDO) as an Anode Material for Zn-Ion Batteries

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ABSTRACT

The widespread implementation of zinc ion rechargeable batteries in commercial settings is constrained by their inadequate cycle stability and susceptibility to short circuit issues. In this work, the structural design and element doping of Sr in Zn-Al layered double oxides (Zn-Al LDO) to produce a zinc anodic material with high cycle stability has been investigated. Zn-Al-Sr LDO is synthesized by facile hydrothermal synthesis method and calcination process. Compared with pure Zn ion batteries. Traditional MnO_2 is used as a cathode material and both Cathode and anode were prepared using graphene oxide (GO) synthesized using Hummer's Method as a carbon additive material. The electrochemical performance was assessed through a charge-discharge test and juxtaposed with traditional rechargeable zinc-ion batteries. The battery underwent cyclic charging and discharging processes. After charging for 45 minutes, it experienced a natural self-discharge for 20 hours and discharge with load up to reach at cut-off voltage. The electrochemical prowess exhibited by the Zn-Al-Sr/Graphene battery surpassed that of the conventional Zn-ion battery. This battery exhibited initial specific discharge capacity of 177.76 mAh/g. Furthermore, the Zn-Al-Sr/Graphene battery demonstrated enhanced cycle stability and there was no indication of short circuit problems.

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Mechanistic Mapping of Chirality–Functionalization Interplay in CNT Polymer Nanocomposites

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ABSTRACT

The interplay between carbon nanotube (CNT) chirality and surface functionalization critically governs the multi-property performance of CNT–polymer nanocomposites, yet a unified mechanistic framework remains indefinable. In this study, we employ reactive molecular dynamics (ReaxFF) simulations to systematically investigate polyvinyl alcohol (PVA) nanocomposites reinforced with armchair CNTs of (10,10) and (12,12) chirality, both pristine and polydopamine (PD)-functionalized. We quantify mechanical properties (Young's modulus, ultimate strength, toughness), transport behavior (mean squared displacement), and structural features (porosity evolution) under uniaxial deformation. Results reveal that larger-diameter CNTs enhance stiffness and strength, whereas PD functionalization promotes toughness and interfacial mobility, with a striking chirality-dependent response—acting as a porogen for (10,10) CNTs but a densifier for (12,12) CNTs. To integrate these effects, a dimensionless multi-property order parameter (Ω) and a mechanistic descriptor Λ(d) are developed, which together distinguish porogen-like from crosslinker-like behavior. The proposed concepts will provide a quantitative design map describing the interactions of stiffness, toughness, and barrier properties including detailed methods that can be applied for rational development of multifunctional nanocomposites for numerous engineering applications.

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Irradiation-Induced Defects Evolution and Investigation of Tensile Behavior in Zr–2.5Nb Alloy: A Molecular Dynamics Study

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ABSTRACT
Zirconium-2.5%Niobium alloys serve as cladding materials in thermal reactors due to their low neutron absorption and excellent corrosion resistance. However, prolonged neutron irradiation induces Frenkel pair defects that significantly alter their mechanical properties and compromise structural integrity. This study employs Molecular Dynamics (MD) simulations to analyze the evolution of irradiation-induced defects in Zr-2.5%Nb alloy under varying temperature (100-1000 K) and primary knock-on atom energies (0.1-5 keV). Defect analysis using Wigner-Seitz, Common Neighbor Analysis, and Dislocation Extraction Algorithm shows increasing PKA energy proportionally increases Frenkel pair concentrations with extended ballistic and recombination phases. Temperature effects exhibit non-monotonic behavior indicating complex recombination dynamics. Tensile testing simulations at a strain rate of reveal radiation hardening at low temperatures and enhanced ductility at elevated temperatures due to improved defect mobility. The computational framework captures the transition from point defect dominated behavior at low PKA energies to defect cluster formation at higher energies providing insights for nuclear reactor component integrity assessment.

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Optimization of Reflector Materials for Neutronic Performance in a Nuscale-Like Small Modular Reactor

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ABSTRACT

Reflectors are essential to the design of small modular reactors (SMRs) because they improve the economy of neutrons and the retention of nuclear fuels. While the NuScale SMR design is the first to be licensed in the United States and holds promise for commercial development in the near term, further optimization of reflector performance is an active area of research. This work evaluated the performance of several reflector materials —light water, heavy water, graphite, beryllium, beryllium oxide (BeO), steel and tungsten carbide—using neutron transport Monte Carlo calculations in the context of a NuScale-like core. Key neutronic parameters, including effective multiplication factor (keff), neutron scattering and absorption rates, fast and thermal neutron flux profiles in the reflector, core and reflector, and fuel utilization rates, were assessed throughout the burnup cycle. The results clearly indicate that reflector designs using beryllium components yield the greatest improvement in performance, with beginning-of-cycle keffs of 1.1989 (Be) and 1.1960 (BeO) and depleted reactivity exceeding 19,900 pcm, and notably better performance than heavy water, graphite and steel. Be and BeO also exhibited the highest scattering of neutrons (25.9 and 23.9 per source particle, respectively) with low absorption, which results in fuel utilization factors exceeding 0.934. Taking into account these results, the beryllium reflectors offer balanced neutronic performance and practicality.

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Effect of Magnesium Addition on the Mechanical and Microstructural Properties of Al-5%Sn Alloys

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ABSTRACT

The influence of magnesium (Mg) addition on the mechanical and microstructural properties of an Al-5%Sn alloy was systematically investigated. The base alloy (Alloy 1: Al-5%Sn) was modified with different Mg contents to obtain Alloy 2 (Al-5%Sn-2%Mg), Alloy 3 (Al-5%Sn-4%Mg), and Alloy 4 (Al-5%Sn-6%Mg), and a series of mechanical tests was carried out. The results revealed that Alloy 1 exhibited the lowest tensile strength (20.52 MPa), while Alloy 3 showed the maximum tensile strength (33.87 MPa); however, further increasing the Mg content to 6% (Alloy 4) resulted in a notable decline in tensile strength. A similar pattern was observed in yield strength, indicating a close correlation between tensile and yield behavior. The impact strength decreased progressively with Mg addition, whereas the Vickers hardness increased with Mg addition up to 4% but decreased again when the Mg content reached 6%. These variations can be attributed to microstructural changes, as revealed by optical microscopy, which showed grain refinement along with the formation of intermetallic phases that became more pronounced at higher Mg levels. Furthermore, SEM analysis of Alloy 1 and Alloy 3 provided detailed insights into surface morphology.

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Numerical Investigation on Bending Behavior of Modified Honeycomb Sandwich Structure

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ABSTRACT
This present paper presents a comprehensive numerical study on the bending response of sandwich structures with a square honeycomb core, modified by introducing a non-honeycomb configuration. The main aims are to compare the yield load, stiffness, energy absorption ability and stress concentration features of those lightweight but high performing structures under 3-point bending loading. Finite element models created in ABAQUS consist of square honeycomb core between two face sheets with an accurate geometric representation. The constitutive model and failure criterion incorporated account for both material nonlinearities as well as progressive failure behavior. Parametric studies are performed to explore the effects of core and material properties, and boundary conditions on the bending behavior. The yield load and stiffness are calculated from the Load Displacement curves of both types to deduce elastic regions. The energy absorption capacities of the composites are determined by analysing area under load-displacement curves, making it possible to assess these structures for impact protection purposes. The von Mises stresses, the maximum principal stresses and displacement contour plots are obtained to show the stress distribution and deformation modes of sandwich panels. High stress concentration critical regions are identified, which can be used to develop an optimized design against early thermal fracture. The results of this numerical study provide a reference for the bending behaviour of square honeycomb sandwich structures. They can be used as a comparative tool to support rational design choices in applications that include transportation, aerospace and construction industries, where light-weight, high-performance materials are desired.

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A Study on Springback Analysis of Steel-Based FML Through V-Bending Test

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ABSTRACT
Fiber Metal Laminates (FMLs) have earned significant research interest due to their superior mechanical properties. However, the study and manufacturing of aerospace materials, particularly hybrid or advanced materials, remain largely unexplored within the research landscape of Bangladesh. This research focuses on the fabrication and spring-back analysis of steel-based FMLs (2/S FMLs) using a V-bending test. The fabrication method for this material involved a hand layup of glass fiber, accompanied by an additional SS layer on both sides. Different tool parameters were optimized to ensure minimal spring-back, delamination, and other types of failure. V-bending tests suggested the SS-based FMLs (2/S FMLs) exhibited the least spring-back compared to single and double layers of SS304 (without fiber). This reduced spring-back behavior indicates a significant advantage for manufacturing applications. Hence, the research demonstrated the feasibility of manufacturing FMLs if proper facilities are provided. With the availability of low-cost manufacturing and labor, a mass production line for such materials can revolutionize the industry and elevate Bangladesh to new heights.

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Tensile and Morphological Analysis of Unidirectional Jute Fiber Nano Composites

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ABSTRACT
The unidirectional jute fiber–reinforced epoxy composites were fabricated using the hand layup and cold press technique with varying silica (SiO_2) filler contents (0–3 wt. percentage). Unidirectional jute mats were weaved by a custom designed handloom. Tensile and morphological characterizations were conducted to evaluate the effect of the silica nanofiller. The tensile strength of the composite without filler (52.75 MPa) increased to 58.99 MPa at an optimum filler concentration of 1.5 wt%. Similarly, the tensile modulus increased from 8894 MPa to 9382 MPa. Beyond this optimum, both strength and modulus declined but remained higher than those of the composite without filler. SEM fracture surface analysis revealed improved fiber–matrix adhesion and homogeneous filler distribution at 1.5 wt. percentage of SiO_2, whereas 3 wt. percentage of SiO_2 led to agglomeration, void formation, and weak interfacial bonding. XRD analysis indicated that the 1.5 wt. percentage nano filler retained a predominantly amorphous structure, supporting toughness retention. In contrast, the 3 wt. percentage of SiO_2 exhibited sharper crystalline peaks, reflecting higher crystallinity and reduced ductility. Overall, these results demonstrate that controlled incorporation of silica at low concentrations enhances strength and stiffness, whereas excessive nano filler induces microstructural defects and crystallinity changes that impair toughness. The main objectives of this study are to analyze the impact of nano SiO_2 on the tensile and morphological characterization of jute fiber composites.

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Utilization of Waste Bio fillers in Glass Fiber Reinforced Polymer Composites: An Analytical Evaluation of their Mechanical Properties

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ABSTRACT
This research explores the incorporation of waste bio fillers (snail shell, chicken bone, and coconut fiber or coir) in Glass Fiber Reinforced Polymer (GFRP) composites and investigates their impact on the mechanical properties of these composites. GFRP composites were manufactured by using a hand lay-up method. The mechanical properties were measured according to ASTM. The flexural strength of 3.94 GPa was maximum for coir-incorporated GFRP composites. It also exhibited the highest tensile strength of 43.51 MPa. Conversely, the non-filler composites derived the highest microhardness and impact strength, with around 601 HV and 80.02 kJ/m2, respectively. The XRD analysis confirmed the presence of cubic silicon, rhombohedral calcium carbonate and hexagonal quartz. Meanwhile, the interconnected fibrous network was observed by Scanning Electron Micrographs (SEM). However, this research showcased the potentiality of waste materials as bio-fillers in the area of polymer matrix composites.

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Effect of Si Doping on Mechanical, Thermal, and Fracture Behavior of Monolayer Graphene: A Molecular Dynamics Approach

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ABSTRACT

Monolayer graphene is an important material for various applications - such as electronics, semiconductors, medical devices, thermal management, energy storage, and solar cells - owing to its exceptional thermal and mechanical properties. These properties, however, can be influenced by the introduction of impurities such as Si, N, and B. In this study, we focused on how the thermal and mechanical properties of graphene are affected by doping with different percentages of Si. Since doping involves replacing C atoms with Si, the total number of atoms in the doped system remains the same as in pristine graphene. Molecular dynamics (MD) simulations were performed using LAMMPS to investigate these changes, with the Tersoff potential employed to model atomic interactions. For the tensile tests used to determine mechanical properties such as ultimate tensile strength (UTS) and its corresponding strain, accuracy depends strongly on the choice of Tersoff parameters. Therefore, two different sets of Tersoff potentials were applied in this work, and variations in UTS and strain values were observed. Our MD simulations revealed that the strength of monolayer graphene decreases as the concentration of Si dopants increases. Similarly, Young's modulus was found to decrease with increasing Si content. The fracture mechanisms of Si-doped graphene were also examined, along with its thermal behavior. Our results show that the thermal conductivity of graphene decreases significantly with the addition of Si atoms. These results highlight that Si doping, while reducing intrinsic performance, enables tunable modification of graphene's stiffness and thermal transport – useful for designing application specific materials.

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The Performance Evaluation of the 3D Re-entrant with Hexagonal Hollow Tube Auxetic Structure

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ABSTRACT

Auxetic structures, characterized by a negative Poisson's ratio (NPR), have attracted significant interest for their superior stiffness, crashworthiness, and energy absorption capabilities. This study proposes a novel 3D re-entrant auxetic structure incorporating a centrally positioned hollow hexagonal tube to enhance load-bearing capacity and energy absorption performance. Finite element (FE) simulations were conducted using ABAQUS under quasi-static compression to evaluate elastic–plastic responses, deformation mechanisms, and key mechanical parameters, including Youngs modulus, plateau stresses, crush force efficiency (CFE), specific energy absorption (SEA), and negative poisons ratio (NPR). The structure exhibited an improved Youngs modulus of 3.09 MPa and two distinct plateau regions in the stress–strain response. The mean stresses of the first and second plateaus were 0.25 MPa and 1.2 MPa, respectively, with corresponding CFEs of 78% and 71%. The second plateau stress was nearly five times higher than the first, attributed to the load-bearing contribution of the hollow tube. The SEA values reached 0.2 kJ/kg in the first plateau and 0.97 kJ/kg in the second, while the NPR attained –0.25 in the first plateau before gradually decreasing with densification. The deformation mechanism revealed initial energy dissipation through bending of the re-entrant walls, followed by buckling of the hollow tube at higher strains. These findings demonstrate that the proposed structure achieves enhanced stiffness, auxeticity, and energy absorption capacity, making it a promising candidate for protective and load-bearing applications.

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Evaluation of Mechanical Properties of 3d Printed Bilayer PLA/TPU with and without Surface Activation and Post process Treatment

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ABSTRACT
This study investigates the influence of surface activation and post-process treatments on the mechanical properties of 3D printed bilayer samples made with polylactic acid (PLA) and thermoplastic polyurethane (TPU). Samples were fabricated using a 3D printing technique, likely Fused Deposition Modeling (FDM). The impact of surface activation methods on interlayer adhesion will be explored. Additionally, the effects of post-processing treatments on the mechanical performance were examined. Tensile, bending, shear and dimensional accuracy tests will be carried out to understand how these factors influence the final material behavior. This research aims to identify optimal configurations for 3D printed PLA/TPU parts by correlating surface treatment and post-processing with their mechanical characteristics. The result shows that annealing with surface activation increases both tensile and bending strength while it reduces the shear strength. Without surface activation, all dimensions shrink with annealing, but surface activated samples show different trends.

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DFT Insights into Structural Stability, Mechanical Properties, and Optoelectronic Characteristics of Lead-free Cubic Perovskite ABeBr3 (A = Li, Na, and K)

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ABSTRACT

This study investigates the physical properties of non-toxic lead-free cubic perovskites ABeBr3 (A = Li, Na, and K) using first-principles density-functional theory (DFT). The lattice parameters calculated with GGA-PBE functionals are consistent with previous research and show an increase with the size of alkali atoms. The negative formation energies (〖ΔE〗 _f) confirm that all three compounds—LiBeBr3, NaBeBr3, and KBeBr3—are thermodynamically stable. The elastic constants C_ij confirm that these materials are mechanically stable by meeting the Born stability criterion. Additionally, Poisson's ratio and Pugh's ratio indicate that all three compounds are ductile. LiBeBr3, NaBeBr3, and KBeBr3 exhibit indirect bandgaps of 2.262, 2.259 and 2.260 eV, respectively, calculated by the HSE06 hybrid functional. The static dielectric constants ε_1 (0) for the studied materials LiBeBr3, NaBeBr3, and KBeBr3 are 3.14, 3.10, and 3.08, respectively. The absorption edges of LiBeBr3, NaBeBr3, and KBeBr3 are observed at 2.44, 2.21, and 2.25 eV, respectively. The strong absorption peaks in the UV region highlight their potential for use as top-layer absorbers in tandem solar cells, as well as in UV–visible photodetectors and other optoelectronic applications.

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Characterization of Carbon Materials Found From Jute Pyrolysis in an Inert Atmosphere

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ABSTRACT

This study examines the impact of chemical pre-treatment on the carbonization of woven jute fibers. We clean raw jute with isopropyl alcohol (IPA), and then we treat raw jute with solutions of potassium hydroxide (KOH), sodium hydroxide (NaOH), or potassium permanganate ($KMnO_4$) as separate pretreatment processes. We pyrolyze the woven jute fibers with a two-step pyrolysis process, at 250°C and 650 °C under an inert atmosphere. We measure dimensional shrinkage and mass loss dimensions of woven raw jute after pyrolysis. Furthermore, we analyze chemical structural changes using FTIR spectroscopy. Our results show that mass loss is reduced after chemical treatment compared to untreated fibers, the treatment with $KMnO_4$ shows the least loss of mass. However, the raw jute treated with chemicals demonstrates higher dimensional shrinkage compared to non-treated ones where the treatment with $KMnO_4$ shows the highest dimensional shrinkage. Fourier Transformed Infrared (FTIR) spectroscopy analysis shows that 7.5 wt.% NaOH pretreatment of jute performed optimally to remove non-cellulosic components like hemicellulose and lignin. Through our method, we synthesize carbonized structures with minimal residual oxygenated functional groups. This work characterizes carbon materials derived from raw jute fibers to assess their suitability for applications in composites, water purification, and energy-storage electrodes.

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Data Driven Explainable Machine Learning for Predicting Mechanical Properties of Copper-Based Multi-Principal Element Alloys

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ABSTRACT
Copper (Cu)-based multi-principal element alloys (MPEAs) possess optimal strength and electrical conductivity, yet they are difficult to tailor due to their large compositional space. This work utilizes machine learning (ML) for explainable AI (XAI)-based prediction of YS and UTS in Cu-based MPEAs. A data set covering 1,545 alloys with composition, processing and microstructural description was considered. The feature engineering involved elemental fraction, processing route, grain size and density and phases. After dimensionality reduction, 95% variance was preserved. Several ML models were trained by cross-validation, combining the hybrid oversampling (CTGAN+SMOGN) for balance of under-represented high strength alloys. And Gradient boosting got the best performance (Yield strength $R^2 \approx 0.90$, UTS $R^2 \approx 0.88$) compared with baselines. Based on SHAP analysis, Ni, Si and Sn significantly improved strength whereas high Cu content and annealing weakened it. Also of importance were processing (e.g., cold work, aging) and microstructure (e.g., intermetallic phases, grain size). Principles like precipitation hardening and the Hall–Petch effect were re-rediscovered by the model thereby restoring confidence in its validity. This interpretable ML model offers a fast screening of alloy compositions by focusing experimental efforts on promising candidates and accelerating the design of new alloys. The methodology combines prediction accuracy and scientific transparency, providing a promising way for designing high-performance Cu based alloys and generalizes to other complex systems.

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Effect of Ca and Fe substitutes on multiferroic properties of BaTiO3 ceramics

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ABSTRACT
A comprehensive investigation was carried out on the structural and magnetic properties of ceramics in the Ba1-xCaxTi1-yFeyO3 (BCTF) system, with compositions varying as (x, y = 1 mol%, 1.5 mol% and 2 mol%) denoted as BCTF 1, BCTF 2 and BCTF 3 respectively. The study focused on understanding how the doping of calcium (Ca) and iron (Fe) affects critical properties such as density, microstructure, magnetic hysteresis (M-H loops), and optical behavior on BaTiO3. These ceramics have the potential for significant applications due to the interaction between structural and magnetic characteristics when doping with transition metals. The influence of sintering temperature (Ts) on phase formation, as well as the structural and magnetic properties of the Ba1-xCaxTi1-yFeyO3 ceramics, was studied. The microstructure analysis was carried out by XRD and Vibrating sample magnetometer (VSM) analysis was conducted at room temperature and the magnetic hysteresis (M-H) curves revealed paramagnetic behavior across all compositions. The highest saturation magnetization (Ms) was recorded as 0.163 emu/gm for the sample Ba0.98Ca0.02Ti0.98Fe0.02O3 (BCTF 3).

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Finite Element Analysis of Hydrogen Desorption Behavior in Hyper-Elastic Materials using Coupled Diffusion Deformation Model

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ABSTRACT

Hydrogen gas storage and transportation infrastructure relies heavily on hyper-elastic polymer seals, such as O-rings and liners, which undergo cyclic pressurization and depressurization cycles with hydrogen gas. The polymers are susceptible to rapid decompression failure (RDF) during depressurization, posing a safety risk to hydrogen infrastructure. This study analyzes two commonly used hyper-elastic polymers, EPDM (Ethylene Propylene Diene Monomer) and NBR (Nitrile Butadiene Rubber), under hydrogen depressurization conditions using a coupled diffusion-deformation finite element model. A single-cavity model was used first to study hydrogen retention and stress evolution in both EPDM and NBR during depressurization. The results showed that NBR performed better, forming a smaller blister and developing lower stress levels around the cavity region, even though it retained more hydrogen than EPDM. Next, a double-cavity model was developed for NBR only to examine how the distance of each cavity from the hydrogen-exposed surface affects hydrogen retention. The examination revealed that a cavity closer to the exposed surface released hydrogen more easily, while the one located farther from the surface retained higher hydrogen concentrations during depressurization.

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Paper ID: 396

Influence of Excessive Alloying Elements on the Microstructure and Brittleness of Al-Mg_2Si Casting Alloys

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ABSTRACT
The study explores the influence of high content of magnesium (Mg) and silicon (Si) as far as the microstructure and the mechanical properties of sand-cast Al-Mg_2Si casting alloy are concerned. Microstructural examination also showed that the addition of more Mg decreased the α-Al and favored the development of coarse Mg_2Si particles, and addition of more Si further decreased α-Al and formed a more brittle microstructure. There was an apparent increase in hardness with excess alloying: Brinell hardness rose as the excess alloying increased; 35.7 BHN of the base alloy to 47 BHN of 6% excess Mg and 43.5 BHN of 6% excess Si. Tensile tests showed that addition of both Mg and Si increased ultimate tensile strength (UTS), with the highest UTS of alloy 123.7 MPa being observed in the alloy with 6% excess Si. Nonetheless, there was a great loss of elongation in alloys that contained large amounts of Si, which proved the augmentation of the brittleness. Conversely, 6% excess Mg alloys had a superior balance, a combination of ultimate tensile strength of 98.25MPa and 8% elongation. Compression strength was relatively similar to compositions because all alloys contained Si. The compressive strength was maintained at approximately 475 MPa in the case of the base and +3 percent alloys but reduced to approximately 420 MPa in the case of 6 % Mg and 444 MPa alloyed Si indicating that alloying had made them more brittle. SEM fracture analysis showed casting defects, pores and intermetallic inclusions which led to early fracture and strength variation. On the whole, the findings suggest that excess Mg can be beneficial to strength-ductility balance, whereas excess Si can be beneficial to strength, but at the cost of toughness, which are valuable insights to optimizing Al-Mg_2Si alloys to structural use in aerospace and automotive sectors.

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Maritime Anti-Piracy Defense through Controlled Zigzag Maneuvering

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ABSTRACT

Maritime transport faces a persistent threat from piracy, exacerbated by the increased automation and reduced crew complements on modern merchant vessels. While static defenses exist, their implementation can be limited by cost and vessel type, leaving many ships vulnerable. This paper presents a non-lethal, maneuver-based countermeasure to deter piracy against unarmed ships. A control system is developed that initiates a programmed zigzag maneuver to disrupt the approach of small, fast-moving pirate craft. The study employs a second-order Nomoto model to simulate the ship's dynamics during a 10°/10° zigzag maneuver and quantifies the resulting unsteady hydrodynamic forces exerted on the pursuing boat. Analyzed the impact of these forces on the attacker's speed, required rudder corrections, and overall seakeeping ability as a function of the lateral separation between the two vessels. The simulation results demonstrate that the zigzagging merchant ship's alternating wake and pressure fields significantly degrade the pirate craft's stability and control, particularly at close quarters. At minimal separation distances, the attacker's seakeeping ability is reduced by more than 50%, compelling significant rudder adjustments that hinder its capacity to maintain an intercept course and attempt a boarding. Recommendations are made for further developments.

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Design and Characterization of a Three-Axis Aerial Drone Test Bench for Control Algorithm Validation

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ABSTRACT
The validation of UAV control algorithms requires safe, repeatable testing environments that accurately replicate flight dynamics. This paper presents a cost-effective three-axis gimbal test bench for quadcopter control validation, designed using locally available components and standard manufacturing techniques. The system dynamics were modeled using Newton-Euler formulations and validated experimentally through Model Predictive Control (MPC) implementation for helical and conical-spiral trajectory tracking. Real-time data acquisition employed AS5600 magnetic encoders (12-bit resolution) interfaced with ESP32 microcontrollers via MQTT protocol. Experimental results demonstrated strong correlation with simulations: roll angle tracked within ±1.5°, while pitch and yaw angles showed dependency on moment of inertia ratios. Linear regression models were developed to compensate for inertia mismatches, achieving R^2~0.9 for all axes. PWM-to-thrust calibration yielded a linear relationship (R^2=0.99) enabling precise motor control. The platform's total cost of under $500 makes it accessible for educational institutions and research laboratories, especially in Bangladesh. The developed mathematical characterization enables accurate prediction of test bench behavior from simulation parameters, facilitating rapid control algorithm prototyping and validation.

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Design and Performance Optimization of a Multi-Purpose Autonomous Rover for Planetary and Terrestrial Applications

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ABSTRACT

Autonomous rovers are essential for space exploration and terrestrial applications including search and rescue, surveillance, and industrial inspection. This paper presents Prochesta V3.0, a cost-effective modular autonomous rover platform developed by Bangladesh University of Engineering and Technology, demonstrating significant technological advancement while maintaining economic accessibility for developing nations. The rover achieves a 30.7% mass reduction compared to its predecessor while enhancing scientific capabilities through modular architecture prioritizing weight optimization and operational versatility. Key technical achievements include a four-wheel bar-differential suspension system enabling obstacle traversal up to twice wheel diameter, a five-degree-of-freedom robotic arm with 5 kg payload capacity, and advanced scientific analysis capabilities featuring 30 cm drilling depth with threefold sample storage capacity. Enhanced vision systems utilizing Zed 2 cameras provide double detection range and 54% wider field of view compared to previous configurations, enabling superior autonomous navigation. The communication system achieves 5 km line-of-sight range with industrial-grade reliability. Comprehensive field testing validates performance across diverse terrain conditions including rocky surfaces, sandy substrates, and structural debris. At $3,800 USD compared to commercial alternatives exceeding $10,000 USD, Prochesta V3.0 offers compelling economic advantages while supporting applications spanning space exploration, emergency response, defense operations, and industrial inspection. This work demonstrates developing nations' capability to achieve world-class engineering solutions through innovative resource-efficient design approaches.

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MuADDIBBS: A Hierarchical Outdoor Swarm System with Aerial Supervision Guiding Local Interaction

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ABSTRACT
Coordinating multiple autonomous agents without a central controller remains a significant challenge in robotics, particularly for low-cost, real-world applications. This paper presents MuADDIBSS (Multi-Agent Doubly Decentralized Bio-Inspired Swarm System), a ground-aerial hybrid swarm framework in which a drone and multiple ground robots cooperate to detect and navigate toward targets. The drone identifies objects using onboard image detection and transmits GPS coordinates to a leader ground bot via LoRa communication. The leader navigates using GPS and compass data, while follower bots align to the leader's heading to maintain formation. A feasibility study stimulating a hazard, validated the system's ability to detect target, communicate coordinates wirelessly, and execute coordinated navigation. Minor deviations due to GPS noise and compass drift were observed, yet the swarm remained within the target perimeter. This work shows that a low-cost, doubly decentralized UAV-UGV system can achieve robust swarm-like behavior, offering potential for applications in disaster response, agriculture and logistics.

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Advancing SLAM Evaluation: Introducing Novel Metrics for Map Quality and Performance Assessment for Mobile Robots Using ROS

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ABSTRACT
Simultaneous Localization and Mapping (SLAM) is essential in mobile robotics, with many algorithms freely available in the robotics community. The evaluation of these SLAM algorithm is crucial for optimum performance and proper implementation. Existing evaluation metrics captures the blurriness, completeness, extra corners, trajectory errors, trajectory mismatch etc. but often overlook key aspects such as area efficiency, noise content, and structural integrity of the map. This paper introduces three novel metrics to address these gaps and demonstrates those metrics via a comparative study of the performance of three popular LIDAR-based SLAM algorithms (Gmapping, Hector SLAM, Karto SLAM). To minimize human error in scene construction and equipment calibration, all experiments were conducted in simulated environment created in the Robot Operating System (ROS). The simulation is done with a differential drive robot using 2D lidar and odometry. These methods provide a new perspective to SLAM evaluation technology. For the area and Structural Integrity Hector SLAM showed better performance and for noise tolerance Karto SLAM performed the best. The properties are given in the form of a table for easy referencing.

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Thermal Engineering

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Thermal Behavior of a Microchannel Heat Sink with Water-Droplet-Grooved Cone-Column Channel: Inlet Velocity Variation

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ABSTRACT

A microchannel heat sink is a microelectronic device that is mostly used as a small channel for heat dissipation through large electronic devices (such as mobile phones, computers, etc.) to improve their performance by preventing overheating. As the days pass, the utility of microchannel heat sinks is increasing. Due to the growing effects of global warming, it has become more crucial to find a better model to improve their thermal performance. This research introduces a new model of microchannel heat sink with a water-droplet-grooved cone-column channel and also a new type of ionanofluid (Sat (22%) ethylammonium nitrate (Sat EAN) as ionic liquid and boron nitrate as nanoparticle) to improve its thermal performance and analyze the effect of various parameters. The effect of various inlet velocities on the Nusselt number, pumping power, thermal resistance, friction factor, and pressure drop is analyzed, and it is found that the Nusselt number, pumping power, pressure drop, and friction factor are rising in accordance with the increasing Reynolds number, ranging from 20 to 1000. This statistic indicates the improvement in the convective heat transfer as a result of the enhanced fluid velocity of the system. While the increase in pumping power and pressure drop indicates that more energy is needed to overcome flow resistance, the rise in the Nusselt number indicates greater thermal performance. The system's thermal resistance dramatically drops in spite of the increased input energy, which is a positive result. This decrease in thermal resistance suggests more effective heat dissipation, demonstrating how well the new design performs with the introduced ionanofluid to improve overall thermal performance.

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Deep Learning on Hybrid Nanofluid over Magnetically Induced Thermal Convective Moving Surface

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ABSTRACT

This study explores the unsteady boundary layer flow of a viscous hybrid nanofluid over a magnetized moving plate, incorporating convective boundary conditions with the base fluid water. The plate's motion introduces flow dynamics akin to stretching and shrinking sheet behaviors, depending on the slot velocity. Using appropriate similarity transformations, the governing partial differential equations are reduced to a system of coupled nonlinear ordinary differential equations, solved numerically via MATLAB's bvp4c solver. The influence of key physical parameters— Magnetic force parameter (Mf), Prandtl number (Pr), Magnetic Prandtl number (Pm), Temperature ratio (θ), and Slot parameter (α) on velocity distribution, temperature profile, and skin friction coefficient is thoroughly examined. Comparative analyses are carried out with existing literature, and model predictions are cross-validated using deep neural networks (DNN), highlighting the potential of AI-assisted fluid modeling. The findings offer enhanced understanding of MHD hybrid nanofluid behavior under unsteady thermal conditions, with direct implications for the design and thermal optimization of high-temperature engineering systems such as heat exchangers, electronic cooling devices, and magnetically controlled flow systems.

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Experimental Study on PCM-Based Thermal Energy Storage under Parabolic Trough Operation

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ABSTRACT

This study presents an experimental evaluation of sodium acetate trihydrate (SAT)-based thermal energy storage (TES) integrated with a parabolic trough concentrator. Three PCM configurations were examined: pure sodium acetate trihydrate (SAT), SAT with a bio-inspired cylindrical structure, and SAT with aluminum chips embedded within the structure. The system was tested outdoors in Rajshahi, Bangladesh, with thermal response characterized through PCM and water temperature profiles, charging/discharging rates, heating/cooling rates, after-sunset retention, and energy stored per unit mass. The hybrid configuration (SAT + structure + Al chips) showed the highest performance, achieving peak PCM and water temperatures of 92°C and 124°C, respectively. Charging and discharging rates reached 1.865 and 0.825 kJ/min, representing significant improvements over pure sodium acetate trihydrate. Heating and cooling rates improved from 0.65 to ~1.2°C/hr and from 0.33 to 0.20°C/hr, indicating faster charging and superior post-sunset retention. The maximum storage density of 0.56 kWh/kg was ~37% higher than the baseline. These outcomes are consistent with literature reports on conductivity-enhanced PCMs but demonstrate greater improvements under real concentrator operation, confirming the potential of bio-inspired and metallic enhancements as scalable, low-cost strategies for medium-temperature solar TES.

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Thermal Assessment of Next Generation Supercritical CO_2 Power Blocks Equipped with Concentrated Solar Tower System

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ABSTRACT

This study presents a comparative thermodynamic and exergy analysis of three supercritical carbon dioxide (s-CO_2) Brayton cycle configurations of 10MW capacity— recompression, intercooling, and partial cooling— integrated with a high-temperature concentrating solar power (CSP) system using dense particle suspension as the heat transfer fluid. Numerical models were developed and validated against published studies, showing close resemblance at design conditions. Results reveal that intercooling cycle provides the highest design-point thermal (51.28%) and exergy (78.46%) efficiencies. Exergy destruction analysis reveals significant irreversibility in the high-temperature recuperator, while the cooler in the recompression cycle shows notable exergy loss due to high mass flow. Parametric studies show that increasing turbine inlet temperature (TIT) enhances efficiency, while higher compressor inlet temperature (CIT) reduces it. Multi-variable analysis proves that the partial cooling cycle is the most efficient configuration with maximum thermal efficiency of 61.9% at 47-50°C compressor inlet temperature and 800°C turbine inlet temperature and the recompression cycle performs best only at low CIT and high TIT.

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Thermal _ Hydraulic Performance Of Shell And Tube Heat Exchangers With Combined Elliptical And Corrugated Tubes: A CFD Approach

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ABSTRACT

This study investigates the thermal–hydraulic performance of a shell-and-tube heat exchanger featuring combined elliptical and corrugated tubes with Al_2O_3–water nanofluid. Using computational fluid dynamics (CFD) simulations, steady-state analyses were conducted at mass flow rates of 0.5, 0.8, and 0.9 kg/s. The results demonstrated significant enhancement in heat transfer: the hot-side coefficient increased from 17,117 to 27,844 $W/m^2 \cdot K$, while the cold side improved from 8,962 to 19,084 $W/m^2 \cdot K$. Corresponding heat transfer rates rose from ~38.2 kW to ~54.3 kW. Although the pressure drop increased from ~2,357 Pa to ~7,827 Pa, the overall thermal efficiency gain outweighed the hydraulic penalty. The findings confirm that integrating advanced tube geometries with nanofluid technology effectively augments heat exchanger performance, enabling more compact and energy-efficient designs. This work highlights the potential of hybrid passive techniques for industrial thermal systems and provides a foundation for future optimization and experimental validation.

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Thermal Performance of Carbide Tools with Optimized Textured Rake Surface Filled with Conductive Materials

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ABSTRACT
Advancing into Industry 4.0, efficient thermal management of the cutting insert remains a significant challenge because in machining, high heat generation influences tool life, surface finish, and metallurgical properties of the workpiece and the tool. The study numerically analyzed the thermal behavior of textured cutting insert with various geometrical aspects in the rake surface deposited with conductive material (Cu) in contrast with conventional ISO SNGA 120408 T2, utilizing a conjugate heat transfer CFD model developed. The study reveals that the texture rake surface filled with conductive material provides a minimized maximum cutting tool temperature in comparison with conventional ones. Among all geometrical configurations of textured rake surface, elliptical textured surface facilitates the most uniform heat dissipation and provides a minimum temperature at the tip of the insert. The maximum temperature of the cutting insert also demonstrates a positive dependence on the textured rake surface depth and width. The optimized outcomes were obtained with elliptical textured rake surface with 250 μm depth and 50 μm width, where the maximum temperature drops to 624.26 °C.

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Performance and Emission Characteristics of Pyrolytic Plastic Oil–Diesel Blends with Al_2O_3 Nanoparticles in a CI Engine: Experimental and ANN-Based Prediction

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ABSTRACT

This study examines the feasibility of utilizing Pyrolytic Plastic Oil (PPO), which derives from plastic waste, as a partial replacement for diesel in compression ignition (CI) engines. PPO was blended with diesel in different amounts (PPO10 to PPO80) and Al2O3 was used as a nano-additive. Then it was examined how well it performed and how much it contaminated a single-cylinder, four-stroke, water-cooled diesel engine. Important factors such as Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Brake Power (BP), and the amounts of NOx and CO that were released at various engine loads were examined. Results indicated that lesser blends like PPO10 and PPO30 operated practically like diesel, while higher blends like PPO70 and PPO80 cut NOx emissions by a lot but raised CO emissions and lowered braking power. An Artificial Neural Network (ANN) model was developed for utilizing the experimental data to accurately forecast engine performance and emissions. The ANN model had a correlation coefficient (R) close to 0.999 for all three types of data: training, testing, and validation. This showed that it could make predictions. Overall, PPO50 was the best-balanced blend, offering good engine performance with lower emissions, making it a suitable alternative to replace some diesel fuel.

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Paper ID: 119

Explosive Boiling of Thin Film Liquid on Functionally Graded Nano-Engineered Surface

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ABSTRACT

The present study investigates the boiling characteristics of thin liquid films on nano-engineered platinum surfaces with functionally varying wettability. Non-equilibrium molecular dynamics (NEMD) simulations are employed to model a nanoscale system of liquid and vapor argon interacting with nanostructured substrates. The wettability of the FGW surface was modeled using a power-law function and different FGW surfaces were investigated by altering its functional parameter. Following system equilibration, the platinum substrate is heated linearly to initiate phase change and the resulting evaporation and heat transfer are analyzed. The findings indicate that the surface's wettability pattern greatly influences boiling behavior and the incorporation of nanoscale features results in a significant augmentation of the evaporation rate when compared with smooth surfaces. The study offers guidance for designing surfaces to improve boiling heat transfer.

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Study on Thermal Performance of a Closed Loop Pulsating Heat Pipe Using Different Working Fluids With & Without Insert

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ABSTRACT

As passive heat transfer devices, pulsating heat pipes (PHP) have opened up a brand-new world of opportunities, especially for the thermal control of electronics. Due to their high-power density and high heat dissipation rates, modern small-scale electronic equipments, such as microprocessors, microchips, and hard disk drives, faces significant thermal management challenges. Modern devices generate 75–85 W of heat, while traditional fan cooling removes only ~50 W. PHPs, when integrated into motherboards, can dissipate nearly all of this heat. This study examines the heat transfer performance of a Closed-Loop Pulsating Heat Pipe (CLPHP, 2 mm ID, 3 mm OD) using distilled water, ethanol, methanol, and acetone as working fluids. Experiments were conducted at filling ratios of 20–80%, heat inputs of 5–50 W, and with rosette inserts of 15 mm and 25 mm spacing. The aim was to identify the optimal fluid, filling ratio, and insert configuration for maximum heat transfer from the evaporator to the condenser. Results show that acetone provides superior thermal performance, with the optimum filling ratio in the range of 50–60%.

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Property Analysis of Bio-diesel Produced from Vegetable Oil Sources by Trans-esterification Process

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ABSTRACT
Energy is distinctive and irreplaceable. It is fundamental to the functioning of every mechanical equipment and every living thing. Energy can be produced from a multitude of sources in many different ways. The need for clean, sustainable energy production has been more important in recent years due to the depletion of petroleum-based fuels due to excessive usage. Among renewable fuels, biodiesel may soon surpass all others in popularity and efficiency. This investigation aimed to find a more suitable feedstock for biofuel production. The specific goal was to convert used cooking oil, soybean oil and sesame oil into biodiesel. In this study, the highly efficient biodiesel synthesis technology known as trans-esterification was utilized. The alcohol chosen for this experiment was ethanol, while the catalyst employed was KOH. The molar ratio of oil to ethanol employed in this investigation was 1:3. Here, for the used cooking oil based biodiesel the percentage yield was highest and it was 88.33% and lowest for the sesame oil based biodiesel and it was 78%. But sesame oil based biodiesel had the highest calorific value among all of the produced biodiesel and it was 40.07 MJ/kg and used cooking oil based biodiesel had the lowest calorific value and it was 38.02 MJ/kg. It can also analyzed that, sesame oil based biodiesel had the lowest viscosity and it was 4.28 cSt but soybean oil based biodiesel had the highest viscosity and it was 5.08 cSt. Various characteristics of multiple diesel-biodiesel blends were also presented for the purpose of comparison. Based on the comparison, it may be concluded that the B5 (5% biodiesel and 95% diesel) to B15 (15% biodiesel and 85% diesel) blends exhibited qualities that were similar to those of diesel fuel. Therefore, B15 and lower-level blends contained a certain amount of substance that may impact emissions, making them suitable for use in engines without any changes.

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Enhanced Thermal Conductivity in hBN Nanocomposites through Plasma-Etching-Induced Surface Roughness Alteration

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ABSTRACT

Advances in thermal interface materials have highlighted the importance of filler alignment, interfacial bonding, and microstructural design in enhancing heat transport. However, the direct influence of surface morphology on interfacial resistance and anisotropic conductivity has received limited attention. This work examines how engineered nanoscale roughness at the filler–matrix boundary can influence overall thermal performance. Instead of relying on idealized geometries, surface features derived from experimental etching processes are integrated into Galerkin finite element simulations to capture realistic filler–matrix interactions. The results show that thermal conductivity improvements depend the degree of surface modification, with optimized profiles yielding more than an order-of-magnitude increase in in-plane conduction compared to unmodified cases, while through-plane transport also benefits, though to a lesser extent. Heat flow analyses confirm that surface modification reduces interfacial barriers, promotes smoother conduction pathways, and enables more continuous heat transfer networks within the composite. By quantitatively linking morphological characteristics with directional transport behavior, this study provides a framework for designing next-generation thermal management materials. More broadly, the findings emphasize that nanoscale surface engineering can be as critical as filler loading or alignment in achieving high-efficiency thermal performance across a wide range of composite systems.

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Thermal Management of Single-Cylinder Four-Stroke Engine: A Focus on Piston Heat Distribution and Material Optimization

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ABSTRACT
Single-cylinder four-stroke engine performance and durability are largely affected by effective thermal management. The pistons being essential components are subjected to heavy thermal and mechanical loading that has direct bearing on the efficiency and strength of the engines. This paper examines the thermal dynamics of pistons and seeks optimization of thermal distribution and materials choice with a view of improving thermal efficiency and strength. Through the use of advanced ANSYS tools and other simulation software tools, this work assesses the thermal and mechanical performance of new and innovative materials such as aluminum-silicon alloys (AlSi4032), silicon carbide-aluminum composite (AI-SiC), and titanium alloy. Although earlier works examined the performance of piston materials and their dissipation of heat in other configurations, extensive works remain absent that are pertinent and focused on single-cylinder engine configurations. This paper fills that gap by examining steady heat loading, material stress distribution, and resilience of materials under conditions of single-cylinder engines and derives information on new and innovative piston configurations that can offer better performances and strength.

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Sustainable Thermal Energy Storage Solutions Using Coated Perlite-Encapsulated PCMs with Nanostructured Enhancements

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ABSTRACT

This study focuses on improving the performance of thermal energy storage (TES) systems by integrating paraffin wax with expanded perlite (EP) and aluminum oxide (Al_2O_3) nanoparticles. The goal was to overcome common challenges in phase change materials (PCMs), such as low thermal conductivity, leakage during phase transitions, and thermal degradation. Experimental results show that adding Al_2O_3 nanoparticles increased the thermal conductivity of paraffin by 38%, from 0.315 W/m·K to 0.436 W/m·K. The inclusion of 20% perlite effectively prevented PCM leakage by enhancing the material's structural stability during phase changes. Differential Scanning Calorimetry (DSC) analysis indicated that the melting point remained stable around 58°C, while Energy Dispersive X-ray Spectroscopy (EDS) confirmed the presence of both Al_2O_3 and perlite. Scanning Electron Microscopy (SEM) images showed uniform dispersion of the nanoparticles within paraffin. The results suggest that the optimized material improves thermal conductivity, latent heat storage, and phase transition stability, making it a promising solution for thermal energy storage in renewable energy systems.

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A Comprehensive Study on Energy, COP, and Exergy of a Coupled ORC–VCC Cogeneration System Employing DualWorking Fluids

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ABSTRACT
This paper aims to provide a detailed performance evaluation of a combined power and refrigeration system consisting of an organic Rankine cycle driven vapor compression cycle employing dual fluids. Performance of the combined system is systematically interrogated utilizing the strategically chosen working fluids- MM, R-1234yf, R236ea, R245ca, R113, R124, based on their critical temperature ranging from 94℃ to 250℃. Thermal and Exergetic efficiencies of the combined system at various turbine inlet temperatures are observed to establish the thermodynamic analysis. The optimized results indicate that the highest energy and exergy efficiencies, achieved using a combination of R113 and R124 as working fluids, are over 70% and 27%, respectively. Results from the analyses indicate that fluid pairs with intermediate critical temperature differences yield superior thermodynamic performance, whereas larger differences reduce both types of efficiencies. The findings of this study underscore the importance of the prudent selection of working fluid pairs in the advancement of highly efficient integrated power generation and refrigeration systems.

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Mixed Convection in a Lid-Driven Square Cavity with an Internally Heated Rotating Solid Cylinder

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ABSTRACT
The present work explores mixed convection in a square lid-driven cavity with an internally heated, rotating solid cylinder. As the solid cylinder rotates clockwise and counterclockwise at different rotational velocities, the scenario entails a configuration where the upper wall is kept cold and the bottom wall is maintained
at a constant hot temperature (Th). While the vertical sidewalls of the enclosure are considered adiabatic, the cylinder's boundary surface is kept at a cold temperature (Tc). The finite element approach is used to conduct a parametric study by modifying the Grashof and Richardson numbers, as well as the rotational speed, which involves volumetric heat generation within the cylinder. Streamline and isotherm outlines are used to qualitatively depict flow and thermal behaviors. In contrast, the average drag coefficient (Cd), average fluid temperature (Ɵav), average Nusselt number (Nu), and normalized Nusselt number (Nunor) are used to assess quantitative performance. The findings show that convection is improved and drag is decreased at reduced buoyancy, whereas buoyancy dominates heat transfer at high Ri and Gr. These results provide recommendations for indicating the best parameters to improve mixed convection structures' ability to regulate temperature.

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Mixed Convection In An H-Shaped Cavity Having Inlets And Outlets: Effects Of Iso-flux Cooling With Nanofluid

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ABSTRACT

Internal convection heat transfer is one of the basic heat transfer scenarios throughout the scientific and industrial fields. Nevertheless, the enormous development in this particular side of science, the industry and its demand goes on evolving and creating new challenges relating to the geometry, flow condition and heat transfer challenge. This study investigates numerically the mixed convection in an H-shaped cavity subjected to iso-flux cooling, with nanofluid (Al–water) as the working medium passing through the cavity along inlets and outlets. A two-dimensional finite element model is developed in COMSOL Multiphysics to analyse flow structures, temperature distributions, and heat transfer characteristics under varying nanoparticle concentrations, inlet flow velocity of fluid which will make the study distinctive. The inlet velocity was changed in the range $0.1 \leq u \leq 10$ m/s and nanoparticle concentration was changed from 0-3%. It was found that inlet velocity plays a pivotal role in cooling down the heated wall of such a cavity raising the Nusselt number reach up to double its value upon making the velocity ten times. However, the nanoparticle concentration leaves minor effect on heat transfer performance. The outcomes highlight the potential of H-shaped geometries and nanofluid-based mixed convection to enhance thermal management in electronic and energy systems.

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Numerical Study of Double-Diffusive Mixed Convection Inside an L-Shaped Cavity Containing Hybrid Nanofluid

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ABSTRACT
This study uses central composite design method to investigate the effects of double diffusive mixed convection in an L shaped enclosure that is partially heated and concentrated with a hybrid nanofluid. With the Boussinesq approximation, the hybrid nanofluid is taken into consideration. Newtonian constant laminar flow with incompressible mixed convection is the definition of the flow. The nanoparticles (Al2O3 and Cu) and base fluid (water) molecules are homogenous in size, shape, and no slip and there won't be any chemical reaction between the base fluid and the nanoparticles, leading to a thermal equilibrium. The nanofluid's viscous dissipation effect, and radiation effect are assumed as negligible. A technique with finite elements, namely the Galerkin method is employed to find out dimensionless governing equation with boundary constraints. The study investigates the influence of various dimensionless parameters including the range of Richardson number ($0.01 \leq Ri \leq 10$), Lewis number ($0.01 \leq Le \leq 10$), Reynolds number ($10 \leq Re \leq 60$) along with nanoparticles volume fraction ($1\% \leq \phi hnf \leq 4\%$) on temperature distribution, mass distribution, average Nusselt numbers (Nuavg) and average Sherwood numbers (Shavg) within the cavity. The overall heat transfer rate increase with the increase in the hybrid nanoparticle volume fraction (ϕhnp), Richardson number (Ri), Reynolds number (Re) while it negatively affects Lewis number (Le). The negative buoyancy ratio (Br) performs slightly better for convective heat and mass transfer. Convective mass transfer increase with increasing Lewis number (Le).

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Paper ID: 357

Design and Numerical Analysis of a Hybrid Rectangular Fin for Enhanced Heat Dissipation and Mechanical Strength

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ABSTRACT
This study presents a comparative numerical investigation of three rectangular fin designs; conventional, tube-in-rectangular, and hybrid rectangular louvered tube fins (HRLTF), with the objective of enhancing thermal management and structural integrity in heat sink applications using steady-state thermal and static structural analyses. The performance of each fin configuration was evaluated under consistent boundary conditions. Results demonstrate that the hybrid rectangular louvered tube fin outperforms the other designs, exhibiting an 86% increase in heat flux, a more uniform temperature distribution, and the fastest cooling rates. Structural assessment revealed that it also experiences 68% lower Von Mises stress, indicating superior mechanical robustness. Conversely, the conventional rectangular fin showed the lowest thermal efficiency and the highest structural stress. These findings emphasize the hybrid design's potential as an optimal solution for improved heat dissipation and mechanical strength in electronic and engineering cooling systems.

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Energy Recovery from Vehicle Exhaust Using Thermoelectric Generator

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ABSTRACT

Internal combustion engines dissipate a significant portion of fuel energy as waste heat, presenting a significant opportunity for energy recovery. This study investigates the practical feasibility of using commercially available Thermoelectric Generators (TEGs) to recover energy from a vehicle's exhaust stream for supplementary battery charging. A combined theoretical and experimental approach was employed, beginning with a thermal analysis to optimize the geometry of air-cooled heat sinks, which identified rectangular fins as superior to square grid patterns. Subsequently, an experimental prototype was constructed using TEG modules to simulate the thermal output of a standard passenger car engine. While theoretical calculations projected a moderate power output, experimental operation yielded a significantly lower conversion efficiency. The resulting system generated a very low charging current, leading to an impractically long charging time for a standard automotive battery. These findings demonstrate that while TEG-based exhaust heat recovery is functionally possible, its practical implementation for meaningful battery charging is currently unfeasible with common, low-cost thermoelectric modules. The study concludes that significant advancements in thermoelectric material efficiency are required before this technology can become a viable solution in automotive applications.

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Thermal performance of rectangular fins within a vented enclosure for various geometric configurations

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ABSTRACT

Steady-state mixed convection in low-speed water flows is commonly observed in applications such as liquid-cooled heat exchangers, electronic cooling modules, and passive safety systems in nuclear power plants.When fins are employed to enhance heat transfer, their geometry strongly influences overall thermal performance. This study investigates mixed convective heat transfer from rectangular fins to the surrounding fluid within a vented enclosure. The enclosure is equipped with two inlets to facilitate fluid entry, while a solid block with attached fins dissipates heat to the flowing fluid. The analysis focuses on the influence of geometric parameters on thermal performance, aiming to determine the optimum configuration for maximum heat dissipation.The study examines the effects of inlet spacing, enclosure height and fin width on thermal performance. For purely mixed convection, the Richardson number is fixed at Ri= 1. Parametric variations include Reynolds numbers ($100 \leq Re \leq 300$) and Rayleigh numbers (6.2×104≤Ra ≤ 55.8×104). The results indicate that fin width is the dominant factor governing the heat transfer rate. Although an increase in fin width reduces the overall wetted perimeter of the fin, the heat transfer rate improves due to the enlarged surface area aligned with the flow direction. Conversely, an increase in enclosure height or inlet spacing tends to diminish heat transfer; however, this adverse effect can be mitigated by increasing the fin width.

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Other Related Topics

Paper ID: 21

Process Design of Condensate Fractionation Unit (CFU) Using Aspen HYSYS with Petroleum Products Yield and Specifications Produced from Natural Gas Condensate

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ABSTRACT

This study represents a comprehensive design of a Condensate Fractionation Unit (CFU) of a petroleum refinery industry with a processing capacity of 8600 barrels per day (BPD), utilizing Aspen HYSYS V10.0 and the Peng-Robinson thermodynamic fluid package. The model replicates the operational behavior of a distillation column processing natural gas condensate into commercially significant fractions such as light naphtha, heavy naphtha, kerosene, jute batching oil, and high-speed diesel. Employing a plate-by-plate calculation method and pseudo-component generation, the simulation integrates surge drums, heat exchangers, centrifugal pumps, and a heater to ensure effective thermal recovery and separation efficiency. The simulation results demonstrate a predominant yield of heavy naphtha (63.84%), followed by light naphtha (17.42%), kerosene (11.82%), and high-speed diesel (3.42%), with physicochemical properties such as density, boiling point, and vapor pressure aligning with commercial standards utilizing ASTM D86 distillation method. The findings validate the practical relevance of the simulation framework, offering a valuable reference for petroleum refinery optimization, energy integration strategies, and design improvements in the context of natural gas condensate processing.

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Paper ID: 29

Predicting Globe Temperature: Model Development and Analysis

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ABSTRACT

This study develops Globe Temperature (GT) prediction models using the following input features: air temperature, mean radiant temperature, and air velocity. Globe temperature is a more comprehensive indicator of thermal stress than air temperature or mean radiant temperature. And GT is often used as a proxy for Mean radiant temperature (MRT) for estimating thermal comfort metrics (e.g., Predicted Mean Vote). However, measuring Globe Temperature in real-time is challenging due to the slow response of black globe thermometers. Also, the complexity of the black globe thermometer sensor setup limits its usability outside laboratory rooms. We trained four machine learning models (Deep Neural Network, Random Forest, Multiple Polynomial Regression, and Multiple Linear Regression) on the ASHRAE Global Thermal Comfort Database-II. The Deep Neural Network outperformed other models, achieving an MSE of 0.03174, MAE of 0.09805, MAPE of 0.00315, and an R-squared value of 0.99763. The feature importance analysis found that air temperature and mean radiant temperature are the most important factors in predicting globe temperature, with air velocity being the least significant. The error metrics indicate that the model is well-trained and demonstrates a high degree of predictive accuracy. These models can predict the Globe Temperature in real-time, which allows us to calculate the Predicted Mean Vote (PMV). A PMV-based controller can then automatically adjust the AC temperature to maintain a comfortable, pre-set level (like a PMV of 0). This automated system improves comfort and saves energy by preventing the waste that occurs when occupants rarely adjust the AC settings themselves.

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Paper ID: 47

Modeling and Validation of Tool-Chip Interface Temperature in Dry and HPC Milling of Ti-6Al-4V

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ABSTRACT
This study presents a three-dimensional finite element model (3D FEM) to investigate the effect of process parameters on tool-chip interface temperature during end milling of Ti-6Al-4V alloy under dry and high-pressure cooling (HPC) conditions. The complex thermo-mechanical behaviour of milling is simulated using ABAQUS/Explicit, incorporating Johnson-Cook plasticity and damage models, frictional heat generation, and realistic boundary conditions. The model accounts for dynamic contact, heat transfer mechanisms, and film coefficients under HPC. Simulation results reveal that cutting speed, feed rate, and depth of cut significantly influence temperature rise, with dry conditions generating higher temperatures due to poor thermal conductivity and lack of lubrication. HPC effectively reduces temperature by enhancing convective heat dissipation and reducing friction. Experimental validation using thermocouples shows a maximum deviation of 14% from simulated results, confirming the model's reliability. The findings demonstrate the feasibility and advantage of using HPC over dry milling for thermal management in machining titanium alloys. This integrated simulation-experimental approach provides critical insights into temperature behaviour at the tool-chip interface, aiding in process optimization and tool life enhancement for high-performance machining of difficult-to-cut materials like Ti-6Al-4V.

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Computational Assessment on Molten Metal Fluidity in Casting Process by Ultrasonic-Assisted Vibration

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ABSTRACT

The fluidity of the molten metal during the casting process is essential as it has a direct effect on the integrity and quality of the cast components. High fluidity by UAV approach speeds up production, increases surface smoothness, and lowers faults by reducing surface tension, minimizing flow resistance. It also avoids incomplete mold filling by facilitating a correct and uniform flow of the molten metal. In this study, during pouring, several ultrasonic frequencies were applied to find out the impact on the fluidity of molten metal in different types of mold design. To determine the optimal frequency that promotes fluidity while reducing turbulence, flow disturbances were evaluated to assess their effects on flow behavior, filling efficiency, and flow resistance throughout the casting process. It has been observed that application of ultrasonic frequencies improves metal fluidity and lower flow resistance

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Data-Driven Estimation of Hydrostatic Parameters in Early-Stage Ship Design

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ABSTRACT
Accurate hydrostatic estimation is essential in ship design, yet traditional formulas are simplistic and modern stability tools demand full 3D geometry, which is rarely available during preliminary design. This study employs supervised machine learning (ML) to predict hydrostatic parameters directly from principal particulars-waterline length , breadth , draft , and block coefficient - enabling early evaluation of hull dimensions and linking hydrostatics to static stability. A combined dataset of 17 real inland vessels and 80 synthetically generated hulls was used to train and compare several ML models. Among Linear Regression, Support Vector Machine (SVM), Neural Network (NN), Ensemble, and Gaussian Process Regression (GPR), the GPR model achieved the highest composite accuracy (0.985), followed by SVM (0.925). The approach captures complex nonlinear relationships between geometry and hydrostatics, enabling rapid early-stage evaluation of inland vessel designs without full 3D modelling.

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Optimization of AGV Sorting Systems in Electric Vehicle Battery Manufacturing Distribution: A Two-Stage Package Assignment and Simulation Approach

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ABSTRACT

Automated Guided Vehicles (AGVs) are increasingly used to transport heavy and hazardous EV-battery packs, yet many facilities still rely on ad-hoc rules for assigning packages to induction stations and dispatching AGVs. Such uncoordinated practices often lead to congestion, excessive empty travel, and long cycle times. This study addresses the problem by identifying simple operating rules that can increase throughput, shorten cycles, and reduce the fleet size required to meet demand. We develop a two-stage assignment framework and evaluate four practical policies Random-Random (RR), Random-Dedicated (RD), Shortest-Random (SR), and Shortest-Dedicated (SD)-through a discrete-event simulation of an industrial-scale layout. The model captures real operational features. Performance is assessed using throughput (packages per hour), AGV utilization, cycle time, and a fleet-sizing metric based on the minimum number of AGVs required to achieve at least 95% of peak throughput. The results show that the SD policy consistently delivers the best overall performance. It achieves near-peak throughput of 4,326 packages per hour with only 40 AGVs, whereas SR requires 63 and both RR and RD require 65 and 57 to reach their thresholds. SD also attains the highest utilization (87%), the shortest cycle time (37 seconds), and the lowest share of empty travel (31%). While RD reaches the highest absolute peak throughput (4,425 packages per hour), SD comes within 0.3% of this value while requiring a smaller fleet. The main point is that a simple rule-shortest-distance induction and a specialized AGV return may give you performance close to the best with fewer vehicles and more stable cycles. This shows that EV-battery distribution may be improved in a significant way without the requirement for complicated or highly specialized control systems.

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Enabling Explainable Artificial Intelligence (XAI) Capabilities for Smart Manufacturing Decision Support Systems

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ABSTRACT
Cyber-physical systems, IoT, and machine learning, have led to the rapid development of smart manufacturing with opportunities and challenges of decision-making under uncertainty. Traditional decision support systems (DSSs) do not offer the transparency that the complex industrial world needs. The following paper discusses how Explainable Artificial Intelligence (XAI) can be implemented into smart manufacturing DSSs to make them more interpretable, trustworthy, and collaborate better with humans. On a total of 315 production cases with machine parameters, machine energy consumption and process results, we model with Shapley Additive Explanations (SHAP) and complementary algorithms. Results suggest that SHAP is applicable to deliver interpretability both locally and globally in order to support stakeholders with their tool of tracking the process through which AI-directed predictions may be connected upon the presence of specific operation phenomena such as quality measures and machine states. This visibility can support more responsible predictive maintenance, manufacturing planning, and sharing resources. The study also outlines the applied relevance of XAI to promote reliable and feasible Industry 4.0 environments, and prospects of future research in blended modelling, cost-benefit in computing and moral.

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Paper ID: 158

Experimental Performance Investigation of a Double-tube Heat Exchanger for Ground Coupled Air Conditioning System

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ABSTRACT
Growing energy demand for cooling has increased interest in alternative condenser designs that can deliver higher efficiency with reduced environmental impact. This work presents an experimental investigation of a double-tube heat exchanger (DTHX) integrated into a ground-coupled air-conditioning system. Unlike conventional air-cooled condensers, the DTHX employed groundwater as a cooling medium in a counter-flow arrangement with the refrigerant. Tests were conducted at water flow rates of 0.076 kg/s, 0.11 kg/s, and 0.145 kg/s, and under varying inlet water temperatures. The findings show that the DTHX consistently enhanced heat rejection and subcooling, leading to improved cooling capacity and coefficient of performance (COP). The maximum cooling capacity of 2.877 kW and COP of 2.96 were recorded at 0.145 kg/s, outperforming the conventional air-cooled condenser by nearly 28%. Moreover, system performance was strongly affected by inlet water temperature, with lower temperatures yielding notable efficiency gains. These results suggest that DTHXs can provide a reliable, compact, and sustainable alternative for high-efficiency air-conditioning systems in regions with accessible groundwater resources.

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A Machine Learning Approach to Ship's Offset Table & Lines Plan Generation

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ABSTRACT
Preliminary ship hull design is an essential but time-consuming part of shipbuilding, which was traditionally dependent on empirical formulae and freehand draughting. Nowadays, various specialised software tools are being used to increase the efficiency, but there is still a lot of space for improvement. In this work, a machine learning-based approach is used that can automatically generate a ship's offset table and corresponding lines plan drawings by taking the major ship parameters, such as ship type, length, width and draft as input parameters. A number of regression models were tried using a dataset of 39 inland non-class vessels which have a simpler shape of hull form. Among them, the random forest regression model showed higher prediction accuracy, and its coefficient of determination (R^2) value was 0.765, which is higher than the other models. This model was also tested for an inland oil tanker vessel, in which the offset table and the lines plans were correlated well with actual data. The comparison of the hydrostatic parameters shows minor differences, which ensures that the model preserves relevant geometric and performance properties of the model. This work paves the way for the incorporation of machine learning in the future preliminary ship design process, which may be used to guide a naval architect to ensure a minimum manual workload and fast hull design.

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Application of the Ishikawa Diagram on the Oil and Gas Carrier Ship Accidents

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ABSTRACT

This paper applies the Ishikawa Diagram (6M framework) for the first time to analyze accidents involving oil and gas carrying ships in Bangladesh. Using the case of the B-LPG Sophia fire at Kutubdia anchorage, contributory factors were systematically categorized under Manpower, Methods, Machines, Materials, Measurement, and Environment. The analysis revealed that preventable human and organizational failures, inadequate detection and suppression systems, procedural lapses, and weak regulatory enforcement converged to escalate the incident. By mapping these interrelated causes, the Ishikawa Diagram clearly visualizes systemic vulnerabilities and highlights priority areas for safety improvement. The study demonstrates the method's effectiveness in maritime accident investigation and its potential to strengthen safety management across Bangladesh's oil and gas industry.

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The Application of Game Theory in Maritime Safety for Prevention of Pollution, Preservation of the Environment, and Promoting the 4th Industrial Revolution

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ABSTRACT
To ensure maritime safety, this research explores game theory and its application, underscoring the prevention of environmental pollution and promoting the Fourth Industrial Revolution (4IR). Traditional maritime safety measures are orthodox and perception-based, not that dynamic, and challenging to manage stakeholder relationships, especially in light of new technological breakthroughs and the growing threat of environmental damage. Strategic decision-making processes are simulated through this research among pivotal stakeholders, such as ship operators, regulatory authorities, and technology providers, to confirm the establishment of the best safety measures and pollution avoidance techniques. Players' rational behavior and identifying optimal solutions are accomplished through developing and examining payoff matrices, which ensure lower environmental risks for smart technology uptake and sustainable operations. The competitive and collaborative factors are analyzed, which shape the use of autonomous systems, real-time data processing, and other 4IR technology applications for developed navigation, risk assessment, and environmental surveillance. This research facilitates finding the factors behind maritime accidents that drastically impact the marine environment and provides an environmentally friendly solution with well-developed technology from the Fourth Industrial Revolution. The research highlights how a game-theoretic approach can harmonize maritime players' interests with broader environmental objectives and create a safer, more sustainable, and technologically superior maritime sector.

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Paper ID: 227

Cellulose-Based Biodegradable Plastics Derived from Water Hyacinth (Eichhornia crassipes): Extraction, Fabrication, and Property Evaluation

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ABSTRACT
The excessive use of petroleum-derived plastics has raised critical environmental concerns due to their persistence and contribution to global waste accumulation. In this study, cellulose was extracted from water hyacinth (Eichhornia crassipes), an invasive aquatic weed, and subsequently utilized to fabricate biodegradable plastic films in combination with arrowroot starch. Cellulose was isolated through sequential bleaching and alkaline treatments, achieving a yield of 28.5% from dried biomass. The extracted cellulose was blended with starch at varying ratios to produce thin films, which were characterized for density, water absorption, and biodegradability. The density of the fabricated films ranged between 1.82 and 1.96 g/cm³, comparable to commercial plastics. Incorporation of cellulose improved water resistance, with the lowest water uptake (53%) observed at a starch-to-cellulose ratio of 3:2, compared to 150% for starch-only films. Soil burial tests confirmed complete biodegradability of the films within 15 days, with cellulose-reinforced composites showing faster degradation than starch-only films, attributed to microbial cellulase activity. These findings demonstrate the potential of water hyacinth as a low-cost, sustainable source for cellulose-based biodegradable plastics, offering a promising strategy for addressing both plastic pollution and aquatic weed management.

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Sensor-Lite Model for Thermal Comfort Prediction Using Contextual Proxy Features

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ABSTRACT

The Predicted Mean Vote (PMV) is a widely used measure of thermal comfort. It needs six inputs, including mean radiant temperature. Measuring mean radiant temperature (MRT) often needs sensors like black globe thermometers, which are slow to respond and difficult to set up. Existing AC or HVAC systems rarely include these sensors, and adding them increases cost. This makes it harder for current AC systems to scale for monitoring occupants' comfort and autonomously adjust to a target comfort level (e.g., a PMV of 0). This study estimates PMV without directly measuring MRT by using easily available context variables that reflect radiative conditions, such as season, building type, monthly outdoor air temperature, and climate. From the ASHRAE Thermal Comfort Database II, we selected nine features: five standard inputs (air temperature, air velocity, relative humidity, metabolic rate, and clothing insulation) and four contextual proxies for MRT (season, building type, monthly outdoor air temperature, and climate). Three machine learning models—Deep Neural Networks, Gradient Boosting Regression, and Random Forest—were developed to estimate PMV. Among the models, the DNN performed best, with an MSE of 0.01865, MAE of 0.08821, and R^2 of 0.96681. This shows that MRT can be effectively replaced with proxy variables such as season, climate, building type, and monthly outdoor temperature while still achieving high prediction accuracy. These results suggest that existing AC/ HVAC systems do not need additional radiant temperature sensors to monitor and maintain a target thermal comfort level. The corresponding source code is available at: https://github.com/MdSyamul/Sensor-Lite-Model-for-Thermal-Comfort-Prediction-Using Contextual-Proxy-Features.

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Design and Fabrication of an Ergonomic Convertible Wheelchair-Stretcher

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ABSTRACT

Traditional wheelchairs and stretchers are inefficient during transition processes, despite the urgency of safe and swift patient transfers in emergency medical responses. These conventional methods necessitate extensive physical maneuvering, thus escalating the potential risk posed to both patients and medical staff. This research presents the innovative design and development of such dual-functioning wheelchair cum stretcher, in order to optimize transitional efficiency between wheelchair and stretcher modes in emergency situations. Emphasizing patient safety, comfort time efficiency, the model ensures durability. During the design phase, CAD modeling was deployed to augment the strength of the materials, ergonomic concerns, and to streamline the transition between its dual functionalities. Stainless steel was used for the whole wheelchair-stretcher for a strong structure and to avoid rustiness. The design underwent refinements based on the expertise and input from experienced medical professionals. For testing fidelity, prospective users were engaged in enacted emergency scenarios which encompassed diverse potential outcomes. To validate the final prototype against safety regulations and emergency scenario responsiveness, supplementary stress tests and simulations were affected. These evaluations were designed to ensure the wheelchair stretcher can withstand field conditions. The functionality and intelligent design of this apparatus could significantly enhance patient prognoses in emergent situations.

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Effect of Heating Rate on Low-temperature Sintering of Copper Nanoparticles: A Molecular Dynamics Study

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ABSTRACT

In the present study, molecular dynamics simulations are utilized to investigate the low-temperature sinterability of nanocopper, an emerging interconnect material in the electronics packaging industry. The primary objective is to optimize the process parameters, specifically heating rate and sintering temperature, to achieve the desired coalescence between two nanoparticles. The desired coalescence is assessed considering the key sintering parameters: mean square displacement (MSD), sintering shrinkage (ξ), relative sintering ratio (κ), and sintering neck width (x). First, the influence of heating rate is examined while maintaining a constant sintering temperature. An optimum rate of 3 K/ps is identified, producing stable and substantial neck growth. Subsequently, the role of sintering temperature is analyzed, revealing that 575 K provides the most favorable diffusion and atomic mobility. The study successfully identifies the optimal sintering performance of nanocopper under different heating rates and sintering temperatures, and these findings demonstrate that the interplay of heating rate and sintering temperature critically governs the densification behavior of nanocopper.

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Accelerated, Cost-Effective, and Accurate Prediction of Carbon Nanotube Stress–Strain Characteristics under Thermal Vibration

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ABSTRACT
This study presents an ensemble learning framework combining Random Forest, Gradient Boosting, and Extra Trees regressors to efficiently predict the full stress–strain response of carbon nanotubes (CNTs) with varying chirality and diameters up to 4 nm. The dataset comprises 816 CNT configurations generated through molecular dynamics simulations, with strain values incremented on average by 0.01%. A group-based splitting strategy ensures that CNTs with identical chirality indices are strictly separated between training and testing sets, thereby enforcing true generalization. The ensemble model achieves high predictive accuracy, with R2 exceeding 0.999, normalized RMSE below 0.005, and low mean absolute errors, while capturing subtle stress fluctuations due to thermal vibrations. Comparative analysis with existing machine learning approaches demonstrates that the proposed method provides accelerated, cost-effective, and robust predictions, reconstructing complete stress-strain curves and outperforming single-model approaches. This framework offers a practical tool for rapid and reliable assessment of CNT mechanical behavior, facilitating accelerated design and optimization of nanomaterial-based devices.

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Paper ID: 333

Fabrication and Characterization of PVA/TiO_2/Jute Fiber Composite Film Via Solution Casting Method

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ABSTRACT

Thin films of PVA reinforced with TiO_2 particles and natural jute fiber were prepared by solution casting method to be used as UV protective masks for various applications such as anti-reflection coatings, food packaging, solar cells and mulching sheet in agriculture. The fabrication steps included dissolving PVA in deionized water with stirring and heating, adding TiO_2 and dispersing jute fiber as a reinforced material. Jute stems were chemically treated with sodium hydroxide (NaOH) to extract the fiber. Tensile test and UV-Vis spectroscopy analysis were performed in order to evaluate tensile properties and photocatalytic properties. Compared to PVA/TiO_2 alone, the addition of jute fiber significantly increased ductility and Young's modulus and improved photocatalytic degradation efficiency significantly. The enhanced mechanical and photocatalytic performance is attributed to the synergistic effect of TiO_2 and jute fiber. TiO_2 provides UV absorption and photocatalysis while jute fiber reinforces the matrix. These composites show promise for applications requiring strong, UV-protective films such as sustainable mulching sheet in agriculture, solar cells and food packaging. The incorporation of jute fiber (JF) is the novelty which significantly enhances mechanical and photocatalytic properties of the film.

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Comparative Finite Element Analysis of Metallic and Composite Wing Materials for Aerospace Structures.

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ABSTRACT

This study presents a systematic structural analysis of a full-scale aircraft wing using FE analysis under static pressure load. The analysis was conducted using six different design concepts: all composite (Carbon, E-glass, and mixed), all aluminum, and hybrid aluminum-composite. The overall target was to find mass-sensitive arch configurations without violating structural integrity, including the yielding limit and Hashin composite failure mode. Analysis was performed using ANSYS Workbench 2025 R1, and the results were presented as total deformation, von Mises stress, and Inverse Reserve Factor (IRF) for composites. According to the results, a hybrid aluminum frame-carbon fiber surface design carrying 65.77 kg was an option because it provided the optimum combination of low stress (120.7 MPa), elasticity (336.3 mm max deflection), and a substantial safety margin (IRF = 0.824). The best lightweight substitute was a fully carbon-fiber design, weighing 57.64 kg (a 48.25% reduction compared to aluminum). It also proved to be safe (IRF = 0.40) and had an acceptable deflection (~400 mm). According to this study, selecting the right materials and placing them strategically are crucial, and fully carbon fiber (IRF=0.4) and hybrid (aluminum frame with carbon fiber surface) are the two best options for aerospace applications.

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Optimization of Turning Parameters for AISI 410 Martensitic Stainless Steel Using Deform 3D Simulations and Taguchi Method

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ABSTRACT
This work aims to improve the turning performance of AISI 410 martensitic stainless steel by reducing both the cutting zone temperature and resultant force. The Taguchi orthogonal array was applied to evaluate the impact of cutting speed, feed rate, and depth of cut, while DEFORM 3D simulations were carried out to predict temperature distribution and cutting forces. The best setting for minimum temperature (639.22 °C) was found at 80 m/min cutting speed, 0.12 mm/rev feed rate, and 0.1 mm depth of cut. In contrast, the lowest force (80.48 N) occurred at 240 m/min, 0.08 mm/rev, and 0.1 mm depth of cut. Analysis of variance (ANOVA) confirmed the reliability of these results, and regression analysis showed strong agreement with high R^2 values. Overall, the optimized parameters provide a practical guideline for enhancing machining efficiency and surface quality in AISI 410 stainless steel.

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Comparative Evaluation of Supervised and Unsupervised Machine Learning Methods for Predictive Maintenance in Manufacturing

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ABSTRACT
This work aims to improve the turning performance of AISI 410 martensitic stainless steel by reducing both the cutting zone temperature and resultant force. The Taguchi orthogonal array was applied to evaluate the impact of cutting speed, feed rate, and depth of cut, while DEFORM 3D simulations were carried out to predict temperature distribution and cutting forces. The best setting for minimum temperature (639.22 °C) was found at 80 m/min cutting speed, 0.12 mm/rev feed rate, and 0.1 mm depth of cut. In contrast, the lowest force (80.48 N) occurred at 240 m/min, 0.08 mm/rev, and 0.1 mm depth of cut. Analysis of variance (ANOVA) confirmed the reliability of these results, and regression analysis showed strong agreement with high R^2 values. Overall, the optimized parameters provide a practical guideline for enhancing machining efficiency and surface quality in AISI 410 stainless steel.

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