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Contents

Foreword

29th edition of the International Energy and Environment Conference (IEEC) was yet another successful event in a row. The mission of connecting academic and research spheres with industry was duly fulfilled. Renowned researchers from four continents and fifteen countries were able to highlight their up-to-date research and discuss the demands and needs of industrial representatives, forming an exquisite symbiosis gathered in the conference venue. Selected presentations covered multiple fields related to energy conservation, production and utilisation as well as environmental considerations, economic feasibility of novel solutions and attractive technology concepts already applied in the industry. The event allowed for interconnectedness across fields, points of view and countries, and set up new collaborations as well as friendships with promising prospects for the following anniversary edition. This Book of Abstracts covers 48 conference contributions presented in dedicated oral sessions and poster session.

Jakub Čespiva, Ph.D.

Scientific Committee head

Advances in Alkaline Water Electrolyzer Technology: Enhancing Efficiency and Dynamic Performance

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Keywords: Alkaline water electrolyzer, Hydrogen, Gas purity

Abstract

The increasing demand for sustainable energy solutions has made alkaline water electrolyzers a crucial technology for green hydrogen generation. High technological maturity and low cost make alkaline water electrolyzer systems attractive for large-scale industrial hydrogen production. Despite their potential, alkaline water electrolyzers face significant technological challenges under fluctuating conditions associated with intermittent renewable energy sources, particularly in terms of dynamic response, operational safety and efficiency during partial load operations. The minimal operating range of alkaline water electrolyzer systems is often restricted to 10 to 40 % of the nominal load, as the gas crossover and consequently gas impurity increase with decreasing current density. This effect not only deteriorates gas quality, but also risk forming a combustible mixture by increasing the hydrogen concentration in the oxygen stream exceeding a critical safety limit. This operational limitation significantly restricts the effective integration of alkaline water electrolyzer systems into energy infrastructure with high share of intermittent renewable power. Consequently, the development of advanced systems enhanced with optimized operational strategies is crucial to ensure stable and safe, yet efficient operation under dynamically varying load conditions. In this regard, numerous efforts have been directed in our research works towards improving the operational flexibility, efficiency, and reliability of alkaline electrolyzer systems under intermittent operation. This primarily focuses on optimizing the overall system with development of advanced operational strategies based on modeling and simulation frameworks, incorporating transient system capabilities in order to address the challenges associated with fluctuating power input. Particular emphasis has been placed on reducing gas impurity and mitigating gas crossover during dynamic and partial-load operation. We could significantly improve hydrogen purity, operational safety, while maintaining high efficiency. The presented work therefore establishes an integrated approach combining modeling, transient simulation and system design to support the systematic development and the comparative assessment of enhancements for operational strategies and system design for alkaline electrolyzer. Ultimately, the objective is to minimize gas impurity formation, improve the operational flexibility and to enhance the reliability, so that the resulting electrolyzer systems can sustain high efficiency across a wide range of dynamic operating conditions.

Plasma-assisted Gasification for Turning the Solid Residue into Hydrogen Energy

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Keywords: Hydrogen, Plasma, Waste-to-energy, Gasification, Net Zero

Abstract

Hydrogen is crucial for achieving net-zero emissions, and gasification offers strong potential for sustainable hydrogen production. Polyethylene was selected as the feed stock due to its high hydrogen-to-carbon ratio, widespread availability as plastic waste, and favorable characteristics for producing hydrogen-rich syngas. This study proposes a waste-to-hydrogen process in which polyethylene is converted into hydrogen-rich syngas using plasma-assisted gasification. A downdraft gasifier was evaluated under varying reaction temperatures (650–850 °C) and feedstock feeding rates (10–50 g/min) to investigate syngas composition and tar formation. The interaction between plasma with different current (15–90 A) in generated syngas was examined to assess its effect on gas quality and tar decomposition. The syngas composition was strongly influenced by feeding rate and temperature. At the lowest feeding rate of 10 g/min, hydrogen and methane concentrations reached approximately 43% and 53%, respectively. Increasing the reaction temperature to 800 °C yielded a maximum hydrogen concentration of 46.53%, ac companied by 53% methane. Non-thermal plasma sets at 90 A reduce tar content from 53% to 19%, corresponding to an absolute reduction of ~35%. These findings demonstrate that plasma-assisted gasification effectively enhances hydrogen production while mitigating tar formation, improving syngas quality, and offering a promising strategy for sustainable hydrogen production and plastic waste management.

Multielement oxides as catalysts for alkaline water splitting

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Keywords: Hydrogen energy, material engineering, alkaline electrolysis, transition metal oxides

Abstract

Alkaline water electrolysis is a well-established technology for hydrogen production; however, further improvement of electrode efficiency remains essential to reduce energy losses and increase the overall performance of water splitting. One promising approach involves the fabrication of highly active catalytic microlayers directly on conductive electrodes, enabling faster reaction kinetics and improved oxygen and hydrogen evolution. Transition-metal-based oxides are considered a competitive alternative to noble-metal-based electrocatalysts due to their lower cost, chemical stability, and tunable electrochemical properties. In alkaline media, these materials are particularly attractive for the oxygen evolution reaction (OER), while selected compositions may also exhibit activity toward the hydrogen evolution reaction (HER). Their stable solid-state structure under alkaline operating conditions is advantageous for electrode applications, while the combination of different transition metals enables modification of the electronic structure, surface chemistry, and catalytic behavior. In this work, binary and multicomponent oxide layers based on nickel, cobalt, chromium, manganese, and iron were synthesized directly on nickel foam substrates using a one-step microwave-assisted hydrothermal method. Investigated compositions included selected binary systems, such as MnFe and NiCo, as well as a multicomponent CrMnFeCoNi system. Nickel foam was used as a highly porous and conductive support to increase the electrochemically active surface area and facilitate charge and mass transport. The obtained catalytic layers were characterized by scanning electron microscopy and X-ray diffraction to evaluate their surface morphology and crystalline structure. Electrochemical performance was investigated mainly toward OER, with complementary HER measurements, using linear sweep voltammetry, cyclic voltammetry, electrochemical impedance spectroscopy, and Tafel analysis. The results indicate that multicomponent oxide layers exhibit improved catalytic properties compared with single-element-based systems, suggesting a beneficial effect of compositional complexity on electrochemical activity. The enhanced performance of multielement materials may be attributed to synergistic interactions between transition-metal species, modification of the electronic structure, improved charge-transfer behavior, and increased availability of active sites. These findings highlight the potential of multielement transition-metal oxide compounds as efficient and tunable catalytic materials for alkaline water electrolysis.

Manufacturing Strategies for Functional Layers in Carbonate-Oxide Fuel Cells

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Keywords: Carbonate-oxide fuel cells, hybrid fuel cells, ultrasonic spray coating, porous materials, functional layers

Abstract

Fuel cells are widely recognized as a high-efficiency and low-emission technology for converting chemical energy into electrical power, offering quiet operation and strong potential for sustainable energy systems. Among the emerging concepts, carbonate-oxide fuel cells (COFCs) represent a hybrid configuration that integrates key features of molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs). By combining the transport of carbonate and oxide ions, COFCs enable improved electrochemical performance at intermediate temperatures, positioning them as promising candidates for next-generation stationary applications. The functionality and durability of COFCs depend critically on the composition, microstructure, and interfacial quality of their anode, electrolyte, and cathode layers. Achieving precise control over these parameters is essential for enhancing ionic conductivity, catalytic activity, and long-term stability. This work explores manufacturing strategies aimed at producing COFC functional layers with tailored architectures and controlled material properties. Particular attention is given to combining complementary deposition techniques – such as tape-casting for bulk layer formation and ultrasonic spray coating for fine surface structuring – to generate uniform, adherent multilayer structures with reproducible thickness and microstructural consistency. Comprehensive morphological and structural characterization was conducted to evaluate layer quality and interface integrity. The findings demonstrate that modern deposition-based manufacturing routes offer significant flexibility in shaping layer morphology and provide a viable pathway toward the scalable production of high-performance COFC components. The insights gained contribute to the broader development of robust COFC architectures and highlight the potential of advanced fabrication methods to support future fuel cell technologies with enhanced efficiency and durability.

Acknowledgements

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Transition from natural gas to hydrogen in the fired clay brick industry

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Abstract

Hydrogen is increasingly recognized as a key energy carrier in future energy systems, particularly for decarbonizing hard-to-abate industrial sectors. This study investigates the feasibility of substituting natural gas with hydrogen in the fired clay brick industry in Hungary, where natural gas combustion currently plays a central role but contributes significantly to carbon emissions. Combustion trials were conducted at both pilot and industrial scales using

pure natural gas, pure hydrogen, and hydrogen-natural gas blends. At the pilot scale, a dedicated chamber furnace operating at 850-925 °C was used to evaluate the direct replacement of natural gas with hydrogen under identical firing schedules. Key parameters, including combustion behavior, flue gas composition, and final product properties, were systematically analyzed. Hydrogen combustion enabled stable furnace operation and produced temperature profiles comparable to those of natural gas. However, due to its distinct combustion characteristics, including higher flame temperature, an increase in burner temperature was observed. As expected, hydrogen firing eliminated fuel-related CO_2 emissions and increased water vapor content in the flue gas, while moderately elevating NO_x formation. Material characterization demonstrated that hydrogen firing had no adverse effects on brick quality, including bulk density, shrinkage, and color. Notably, compressive strength increased consistently across all investigated temperatures, a result further supported by XRD analysis. At the industrial scale, both pure hydrogen combustion and hydrogen injection into natural gas streams were tested in a dryer system with burner capacities up to ~700 kW. In addition, a 160 kW natural gas burner from a tunnel kiln was successfully operated with hydrogen. Overall, the results demonstrate that hydrogen can effectively replace natural gas in clay brick firing without compromising product quality, highlighting its strong potential to reduce carbon emissions in ceramic manufacturing processes. However, further research is required at both pilot and industrial scales.

Valorization of Heterogeneous Waste into Carbon-Rich Solid Residue

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Keywords: Solid Recovered Fuel (SRF), Co-gasification, Solid Residue Valorization, Slagging Mitigation, Circular Economy

Abstract

This study investigates the thermochemical upcycling of complex Solid Recovered Fuel (SRF) into high value carbon-rich solid residue through a strategic wood biomass enrichment

approach. Utilizing a sliding-bed pilot-scale gasification system, the research addresses the fundamental barriers to the Waste-to-Material (WtM) pathway, specifically the challenges of carbon instability and ash slagging common in plastic-rich feedstocks. By operating within a controlled thermal window, the process achieves high thermochemical efficiency, successfully converting the high-energy solid feedstock (>20 MJ/kg) into a viable industrial syngas (5 MJ/m³) while simultaneously preserving a high-carbon solid residue useful in diverse applications. Chemical analysis shows that mixing the wood with SRF creates a heat-resistant mineral environment, which prevents the ash from melting and clogging the pores of the solid residues. Furthermore, the integration of vortex-induced gas-phase dynamics significantly mitigates particulate emissions and enhances syngas quality through in-situ thermochemical conversion. The resulting carbon residue contains 69.71% carbon and exhibits a near-neutral pH, offering a sustainable alternative to traditional materials by eliminating the intensive chemical washing typically required in industrial post-treatment. These findings provide a scalable framework for transitioning from simple waste disposal to the production of predictable, high value carbon-rich solid residue, supporting the global shift toward a functional circular economy.

Digital Fertiliser Product Passport: From Regional Waste Streams to EU-Compliant Fertilisers in the V4

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Keywords: Organo-mineral fertilisers, nutrient recovery, EU Fertilising Products Regulation 2019/1009, GIS mapping, waste streams, circular economy, digital product passport, Visegrad region

Abstract

The Visegrad region generates over one million tonnes of nutrient-rich residues annually - sewage sludge, digestate, agri-food processing by-products, and biomass ash - the majority of which remain unrecovered as agricultural inputs. EU Fertilising Products Regulation 2019/1009, applicable since July 2022, establishes compliant pathways for CE-marked organo-mineral fertilisers derived from such secondary raw materials. The conversion of these streams into certified products is systematically hindered by fragmented national data infrastructures, absent cross-border matchmaking mechanisms, and the lack of standardised traceability instruments. This presentation reports on V4-BIOWASTELINK (Visegrad Fund, 2026-2027), a consortium project addressing this gap across Poland, Czechia, and Hungary. A standardised open-access database and interactive GIS map of priority waste streams and key stakeholders is being developed to enable region-wide screening of feedstock availability, seasonality, and logistics. Structured industry engagement events co-located within established V4 conferences create direct matchmaking channels between waste producers, fertiliser manufacturers, and R&D institutions. A laboratory micro-pilot at WUST produces a small batch organo-mineral

granulate from Polish regional waste inputs and characterises it by ICP-OES, ICP-MS, and XRF, generating a replicable technical protocol. The digital fertiliser product passport concept - data-driven traceability of feedstock origin, processing history, and compliance status under EU FPR component material categories - is presented as a practical instrument supporting both market transparency and regulatory conformity. The V4 evidence base generated supports the development of a scalable regional waste-to-fertiliser model applicable beyond the project region.

LCA of Solid Recovered Fuels Production: Environmental Trade-Offs of Pelletisation and Biomass Addition

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Keywords: LCA, environmental impacts, solid recovered fuel, biomass, densification, transport

Abstract

Solid recovered fuel (SRF), produced from non-recyclable municipal and industrial waste fractions, represents a promising feedstock for thermochemical conversion technologies, including gasification. Besides conventional SRF, biomass-enriched SRF (SRFW) has been proposed to increase the renewable share of the fuel. However, additional processing steps, such as biomass drying and pelletisation, may significantly influence the overall environmental performance. This study evaluates the environmental impacts associated with the production and transportation of SRF and SRFW using Life cycle assessment (LCA). A comparative LCA was conducted for four production scenarios: non-pelletized SRF, pelletized SRF, non-pelletized SRFW containing 50 wt.% sawdust, and pelletized SRFW. The assessment included transportation of waste and biomass feedstocks to the production facility and transportation of the final fuel to a gasification facility, while the gasification process itself was excluded from the system boundaries.

The results showed that pelletized SRF exhibited the lowest overall environmental impacts among the evaluated scenarios. Although pelletisation increases electricity consumption during production, the higher energy density substantially reduces transport-related impacts, particularly over longer transport distances. Pelletisation becomes environmentally beneficial beyond transport distances of approximately 190 km for SRF and 210 km for SRFW. The inclusion of biomass did not improve the overall environmental performance, primarily due to the energy-intensive drying process required for sawdust.

The study demonstrates that fuel densification is an effective strategy for reducing environmental impacts associated with long-distance transport of SRF. Conversely, biomass addition should be carefully evaluated, as the environmental benefits of renewable content may

be offset by energy intensive pre-processing. The findings provide practical guidance for optimizing SRF production and logistics and support the deployment of gasification-based waste-to-energy systems by identifying environmentally preferable fuel conditioning strategies.

Effect of flame retardants on combustion, emission characteristics, and stability of flexible polyurethane foams

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Keywords: polyurethane foam, flame retardants, combustion, emissions, polycyclic aromatic hydrocarbons (PAHs)

Abstract

Flexible polyurethane (PU) foams are widely applied in the automotive, furniture, and construction industries due to their low density, mechanical flexibility, and favorable acoustic properties. However, their inherent flammability necessitates the incorporation of flame retardant (FR) additives to meet fire safety requirements. The presence of these additives may influence the foaming process, cellular structure, mechanical integrity, acoustic behavior, and thermal stability, particularly under long-term use and aging conditions.

In this study, three flame retardant additives with different mechanisms of action - tributyl phosphate (TBP), melamine (MEL), and magnesium hydroxide ($Mg(OH)_2$) - were systematically investigated in flexible open-cell polyurethane foams at concentrations of 1, 4, and 8 wt%.

Combustion behavior was analyzed using a Hőker Cső 350/900 electric resistance tube furnace equipped with a programmable temperature control system, enabling precise thermal conditions. Gas-phase products (CO_2, O_2, CO, SO_2, NO_x) were quantified using a Horiba PG-250 gas analyzer. Experiments were conducted at a constant air flow rate of 180 dm^3/h and temperatures of 600 °C, 750 °C, and 900 °C, using approximately 0.02 g samples.

The flue gas was passed through a quartz fiber filter to capture particulate matter, allowing subsequent analysis of particle morphology and composition, as well as the identification of polycyclic aromatic hydrocarbons (PAHs).

The combined evaluation of combustion, emission, and previously obtained mechanical and degradation data enables a comprehensive assessment of flame retardant performance. This integrated approach also considers environmental aspects and implications for thermal waste recovery processes.

Biochar production from fig-processing residues for circular environmental applications

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Keywords: Fig-processing residues; Biochar; Pyrolysis; Isoconversional kinetics; Life-cycle assessment

Abstract

Industrial fig processing generates seed-rich and skin-rich residues that remain underutilized as biochar precursors. This study treated fractionation as a process-design variable by comparing separately recovered fig seed and fig skin under matched pyrolysis conditions and multi-rate thermogravimetric analysis. Across a severity matrix of 350–500 °C with varied heating rates and holding times, biochar yield decreased from 30.3 to 24.52% for fig seed and from 32.0 to 27.73% for fig skin, with fig skin consistently retaining more solid under identical programmes. ATR-FTIR analysis revealed different carbonization pathways: seed-derived chars showed stronger attenuation of O-H and aliphatic C-H bands together with a more pronounced condensed/aromatic region, whereas skin-derived chars retained clearer oxygen-containing features. TG-DTG analysis at 5–40 °C min^{-1} showed contrasting devolatilization behavior, with fig seed dominated by a broad mid-temperature event and fig skin characterized by an early dominant peak followed by a secondary higher-temperature contribution. Gaussian DTG-stage partitioning converted these differences into quantitative descriptors, with fig skin retaining a persistent Stage I contribution (<260 °C; 27.21–35.54%) and fig seed developing a substantial Stage III fraction (≥400 °C; up to 52.17%). Isoconversional analysis showed higher and more conversion-sensitive apparent activation energies for fig seed (~107–327 kJ mol^{-1}) than for fig skin (~74–151 kJ mol^{-1}). DAEM analysis supported this contrast, while screening gate-to-gate LCA showed that midpoint burdens were governed mainly by programme-level electricity demand, with Program 3 giving the lowest burdens for both fractions. These results support a fraction-specific severity framework for targeted biochar production.

Membrane technologies in hydrogen energy

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Abstract

Nowadays, most of the industrial hydrogen manufacture is linked to the natural gas steam reforming reaction plants, responsible for massive emissions of CO2 and further harmful compounds in the ambient. The European Green Deal is supporting measures to create a future hydrogen energy infrastructure under the net-zero CO2 emissions strategy, based on the principles of the process intensification and circularity as well. In the transition from a carbon-based to a sustainable hydrogen economy, the European Clean Hydrogen Alliance is promoting research and innovative technologies for the decarbonised hydrogen generation through the exploitation of biogas, as a renewable source, which constitutes an option with respect to the natural gas utilisation. Membrane and membrane reactors technologies may play a strategic role in the field of the net zero CO2 emissions strategy development, as they constitute an intensified solution presenting several benefits over the conventional processes to generate low impact carbon emissions hydrogen through biogas reforming.

This work deals with the potential and perspectives of advanced membrane solutions to generate and purify hydrogen with the intent of meeting the strict targets of the European Clean Hydrogen Alliance under the Strategic Research and Innovation Agenda 2021-2027. Furthermore, a pioneeristic design and development of an electrically-driven foam structured membrane reactor will be presented, outlining the benefits of an electricity-to-heat (Joule heating) assisted membrane reactor in terms of depletion of collateral CO2 emissions (conventionally due to the fossil fuel combustion heating), and higher energy efficiency over other competing technologies.

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Magnetic Stabilization of an Atmospheric-Pressure DC-Excited Plasma

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Keywords: Gas Reforming, Magnetic Stabilisation, Plasma, Vortex Discharge

Abstract

Non-thermal plasmas (NTPs) are widely explored for gas reforming because energetic electrons drive selective chemistry under non equilibrium conditions, enabling high reactivity without heating the entire bulk gas to thermal reforming temperatures. For practical implementation, NTP reactors often operate at atmospheric pressure, where discharge stability can be disturbed by local hotspots, plasma wall interactions, and ionisation-driven instabilities. Vortex (swirl) flow can enhance gas-plasma interaction by increasing mixing and residence time, but it introduces additional hydrodynamic complexity. Magnetic stabilization provides a contactless means of control: a current-carrying plasma in an imposed magnetic field experiences a Lorentz force that influences discharge motion and shape. In this paper, we investigate whether magnetic fields of the order of mT, produced by permanent magnets, can steer and stabilize a non-self-sustained DC vortex discharge.

Advances in Low-Temperature Biochar Production for Circularity and Sustainability

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Keywords: Low-temperature biochar, torrefaction, carbon-neutral; carbon-negative; circularity

Abstract

The continuous surge in carbon emissions from burning fossil fuels is unequivocally linked to the escalating challenges of climate change. The urgent need to transition towards a net-zero emissions paradigm becomes increasingly apparent for sustainability. Bioenergy plays a crucial role in developing renewable energies. Unlike solar and wind energy, which primarily serve power generation, the primary purpose of bioenergy is to produce biofuels to replace fossil fuels. This means biofuel is more flexible to be applied in various sectors. However, biomass possesses several disadvantages: hygroscopic and biodegradable, high moisture content, low calorific value, poor grindability, large volume or low bulk density, and low homogeneity. The aforementioned biomass properties can be greatly improved after torrefaction. Torrefaction is a biomass pretreatment and thermochemical conversion process that upgrades biomass and produces low-temperature biochar, making a coal-like solid biofuel. The produced biochar is a carbon-neutral fuel because its combustion produces no net carbon emissions. Moreover, biochar is a stable form of carbon that resists decomposition over extended periods. It can be used as a sustainable material for soil amendment, polymer blending, and architectural coating to achieve carbon negativity, decarbonization, circular economy, and sustainability. This study addresses the transformation of biomass properties and the biochar characteristics resulting from torrefaction. The biochar applications for carbon-neutral fuel and carbon-negative materials to achieve decarbonization, circularity, and sustainability will also be illustrated.

Smart Green Machining Technology and Stability Analysis for Carbon Fiber Reinforced Polymer

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Keywords: CFRP Machining, Stability Lobe Diagram, Green Manufacturing, Machine Learning, Energy Efficiency.

Abstract

Carbon Fiber Reinforced Polymer (CFRP) has become a pivotal material in aerospace and space industries due to its high strength-to-weight ratio. However, its anisotropic and non-homogeneous characteristics lead to significant machining challenges, including delamination, tool breakage, and high energy consumption due to low yields. This study proposes a comprehensive smart green machining framework for CFRP. First, a mechanistic cutting force model and a load-dependent energy consumption model are established for multi-directional

CFRP laminates, considering fiber orientation and instantaneous cutting area. To bridge the gap between simulation and practice, a Digital Twin environment is developed using Siemens Run My Virtual Machine (RMVM) to analyze dynamic stability. A novel 4D Stability Lobe Diagram (SLD) is introduced, integrating Material Removal Rate (MRR) with axial and radial depth of cut to identify optimal processing windows. Furthermore, machine learning models are employed for multi-objective optimization, targeting the simultaneous suppression of chatter, improvement of surface quality, and reduction of carbon emissions. Results indicate that the Digital Twin platform can predict axial feed load and energy consumption with an error of less than 8%. The 4D SLD enables the maximization of MRR while ensuring a stable cutting zone, effectively preventing CFRP delamination. This research provides a robust theoretical and practical foundation for sustainable high-precision manufacturing, significantly reducing material waste and carbon footprints in advanced composite processing.

Prospects for Reclaiming Valuable Metals from Biomass-Derived Ashes

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Keywords: Biomass-derived ash, metal recovery, gold, rare earth elements

Abstract

Reclaiming high-value metals from secondary resources is gaining increasing attention due to growing industrial demand and the gradual depletion of primary mineral deposits. This research investigates the feasibility of concentrating valuable metals through biomass incineration followed by multi-step ash leaching, using woody biomass collected from a brownfield location. The initial biomass contained low concentrations of target metals (<0.05 mg/kg Au, <0.5 mg/kg Ag, and <0.5 mg/kg Nd) and was combusted in a fixed-grate pilot-scale boiler. The resulting ashes were subjected to a sequential three-step leaching procedure, including water extraction, acidic leaching with 10% HCl, and alkaline treatment using 5% NaOH, to enhance metal enrichment. The analyses revealed significant increases in metal concentrations: leached bottom ash contained 12.1 mg/kg Au, 14.2 mg/kg Ag, and 54.9 mg/kg Nd; leached after-heat exchanger ash showed 21.5 mg/kg Ag and 20 mg/kg Nd; while leached deposited ash exhibited 12.6 mg/kg Au, 13.1 mg/kg Ag, and 11.7 mg/kg Nd. SEM-EDS characterization indicated that gold occurred as highly pure (>98%) discrete particles in bottom ash, as well as fine pure particles in after-heat-exchanger ash, whereas in fly and deposited ash, it appeared in compound forms. Silver was incorporated within solid matrices in bottom ash and formed coatings on fly ash particle surfaces. Rare earth elements (REEs) exhibited varied associations: praseodymium, neodymium, and cerium were found in compound phases in bottom ash, while erbium appeared as individual particles; in after-heat exchanger ash, praseodymium, neodymium, and erbium were incorporated within solid phases. Overall, the findings highlight the potential of biomass-derived ash as an alternative source for extracting

valuable metals, presenting a viable pathway for reclaiming critical materials from unconventional resources.

LaNi5 Metal Hydride as a Catalyst for Toluene Hydrogenation

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Abstract

Metal hydrides have attracted significant attention as safe and efficient hydrogen storage media, while liquid organic hydrogen carriers (LOHCs) offer a practical route for hydrogen transport and utilization. In this study, we explore the multifunctional role of $LaNi_5$ metal hydride in the hydrogenation of toluene to methylcyclohexane (MCH), focusing on its simultaneous function as both a hydrogen storage medium and a catalytic material. Hydrogenation experiments were conducted under moderate conditions (348–393 K, 3 MPa H_2), where $LaNi_5$ exhibited markedly enhanced catalytic performance compared to pure nickel. Near-complete conversion of toluene was achieved at elevated temperatures, indicating highly efficient hydrogenation behavior. Pressure–composition–temperature (PCT) analysis revealed that $LaNi_5$ releases stored hydrogen under reaction conditions, suggesting that internally stored atomic hydrogen actively participates in the reaction. The results demonstrate that metal hydrides can serve as integrated functional materials that couple hydrogen storage with catalytic conversion. This dual functionality provides a promising strategy for simplifying LOHC systems and enhancing the efficiency of hydrogen storage and transport technologies.

Characterization of Ti-containing HEA as Emerging Materials for Solid-State Hydrogen Storage

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Keywords: High entropy alloys, hydrogen storage

Abstract

Hydrogen is considered a promising energy carrier due to its high specific energy and environmentally benign combustion. However, efficient, safe, and energy-effective storage remains a key challenge. Solid-state hydrogen storage in metal-based materials offers an attractive alternative to compressed or liquid hydrogen, motivating the development of alloys capable of reversible hydrogen absorption under moderate conditions. In this context, high entropy alloys (HEAs) containing titanium have attracted increasing attention due to their structural stability and strong affinity for hydrogen. HEAs, especially those composed of refractory elements, are of particular interest as they tend to form body-centered cubic (BCC) solid solutions that can accommodate significant amounts of hydrogen. The severe lattice distortion inherent to multicomponent systems may strongly influence hydrogen diffusion, phase stability, and hydride formation mechanisms. In this study, gas-atomized Ti-containing Within these studies HEA powders were investigated with respect to their hydrogen storage behavior and structural evolution upon hydrogenation. The powders were characterized in the as-atomized state and after hydrogen exposure using scanning electron microscopy (SEM), X ray diffraction (XRD), and laser diffraction particle size analysis. The as-received materials exhibited predominantly spherical particle morphology and a mainly BCC solid solution structure. Initial hydrogen sorption measurements revealed limited or no hydrogen uptake, indicating surface passivation effects, most likely related to stable oxide layers. After applying an activation procedure, the alloys demonstrated the ability to absorb hydrogen, with measurable storage capacity. Hydrogenation induced pronounced microstructural changes, including particle cracking associated with lattice expansion, while the overall particle size distribution remained largely unchanged. XRD analysis after hydrogen exposure revealed clear modifications of the diffraction patterns, suggesting lattice distortion and the formation of hydride-related phases. These results highlight the capability of Ti-containing high-entropy alloys to undergo hydrogen absorption accompanied by significant structural evolution. The study provides insight into hydrogen–metal interactions in Ti-based HEAs and underlines their potential for further development as solid-state hydrogen storage materials, with particular emphasis on phase stability, reversibility, and cyclic performance.

Acknowledgement

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Optimizing reversible hydrogen storage capacity and activation characteristics in TiFe-based alloys by oxygen addition

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Keywords: Hydrogen storage alloys, TiFe alloy, Oxygen alloying activation, hydrogen diffusion

Abstract

TiFe alloy is a representative room-temperature hydrogen storage material that offers advantages such as excellent reversibility, cost-effectiveness, stability, and decent hydrogen storage capacity. Howeverm it suffers from the drawback of difficult activation (initial hydrogenation). In the ternary Ti–Fe–O system, there exists a unique compositional range that forms a ternary phase denoted as Ti4Fe2+xOy. Unlike typical A2B-type phases such as Ti2Ni and Ti2Co, the Ti2Fe phase requires a critical amount of O doping to stabilize its structure, forming an O-stabilized intermetallic compound. This phase, often referred to as the τ phase in the phase diagram, have a stable Fd-3m crystal structure even when the composition deviates significantly from the stoichiometric $Ti_4Fe_2O_{0.7}$, either through an increase in Fe content or a decrease in O content. Although it is widely recognized that even traces of O in TiFe leads to the formation of the τ phase in the TiFe matrix, its effect on the hydrogenation behavior of TiFe remains controversial in the literature. Furthermore, the intrinsic hydrogenation behavior of the τ phase itself has not been systematically investigated. In this study, bulk Ti–Fe–O alloys were synthesized via arc melting to elucidate the relationship between τ phase composition, H storage capacity, hydrogenation kinetics, and structural characteristics. The crystal structure of the τ phase was precisely determined using precession 3D electron diffraction. DFT calculations were performed to evaluate the formation energies of six different H interstitial sites and the H diffusion pathways as a function of structural variations. Our results demonstrate that both the H storage capacity and kinetics of the τ phase are strongly dependent on the amount of O vacancies. In particular, the presence of O vacancies significantly reduces the diffusion activation energy between reversible and irreversible H sites, enabling rapid H uptake even under extremely low H2 pressures. Finally, we demonstrate how the hydrogenation properties of the TiFe alloys such as capacity and activation conditions can be optimized through the formation of TiFe+τ dual-phase microstructures.

Analysis of a novel three-stage cold-start strategy and heat transfer mechanism of Metal-Supported Solid Oxide Electrolysis Cell system

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Keywords: Metal-Supported Solid Oxide Electrolysis Cell, thermal management, three stage, cold-start strategy, preheating

Abstract

This study introduces a comprehensive dynamic model of a Metal-Supported Solid Oxide Electrolysis Cell (MS-SOEC) system, which integrates a metal-supported stack, evaporator, heat exchanger, and dedicated thermal management components. To address thermal stress challenges during activation, a novel three-stage cold-start strategy is proposed to efficiently transition the system from 303.15 K to its operating temperature of 873.15 K. By strategically utilizing internal reaction heat during the second stage, this approach reduces total preheating time by 46 minutes and improves startup efficiency by 27.7% compared to traditional external heating methods. The strategy effectively prevents thermal shock by keeping peak conduction heat transfer below 7000 W. System regulation is implemented through a dual-side PID control architecture that maintains a constant ramp rate of 2 K/s. The success of this integration is demonstrated by a significant decrease in heater control signals—from an initial peak of 14,200 to steady-state values of 300 (fuel-side) and 100 (air-side). These results highlight the high thermal recuperation efficiency of the heat exchanger, which greatly reduces external power consumption once steady-state operation is established.

Advanced mathematical model for heat exchange in CFB boiler ash cooler

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Keywords: Ash cooler, heat exchange, CFB boiler, numerical modelling

Abstract

One of the attractive features of circulating fluidized bed (CFB) boilers is their ability to burn low-quality lignite. However, low-grade fossil fuels contain significant amounts of minerals; therefore, their ash content often reaches up to 30%. Maintaining stable fluidization conditions inside a CFB boiler requires keeping the total circulating mass constant. Thus, the continuous removal of excess ash from the combustion chamber is crucial for stable operation. For this reason, a single screw ash cooler (SSAC) is a key auxiliary device in any CFB boiler unit. The primary task of an ash cooler is to remove excess circulating mass and cool it down before transport to a storage site. An effective cooling process requires a precise mathematical model that accurately predicts the amount of bottom ash removed and its final temperature at the outlet of the heat exchanger. This paper presents an advanced 1D model of the thermal and flow processes occurring in an SSAC, accounting for the dynamic movement of the ash mass inside the device. The numerical results were validated against experimental measurements from a full-scale CFB boiler. The main features and objectives of the advanced (dynamic) model are:

• Operating conditions: CFB boilers force SSACs to operate with varying levels of ash filling. The ash filling characteristic is an individual curve for each SSAC, derived from experimental data.

• Heat transfer mechanism: A key element of the mathematical model is the Schlünder model, which defines the heat transfer coefficient for ash by considering the local dynamic mixing process. Numerical results verify that the mixing model correctly predicts local heat transfer coefficients, confirming that this parameter plays a crucial role in the overall heat exchange process.

• Dynamic movement: Ash movement inside the cooler involves complex displacement, including both translational and rotational motion. This advanced (dynamic) approach to heat exchange is more consistent with experimental data than the previously used static model.

Modelling a biomass gasification installation for use in hybrid renewable energy sources

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Keywords: Biomass gasification; hybrid RES; thermodynamic equilibrium modelling; literature-based validation

Abstract

The research aims to present the modelling capabilities of downdraft biomass gasification installations designed to cooperate with other renewable energy sources (RES). The study identifies key areas for modelling such systems, which must include the operation of the system at both maximum output and variable load conditions resulting from the load of weather-dependent energy sources. The author believes that modelling gasifiers for use in hybrid systems has been insufficiently explored in the existing scientific literature. This research examines three system modelling methods based on chemical reactions, thermodynamic properties and transformations, but does not include reaction dynamics or CFD modelling. This results from the purpose of this modelling – to analyse the entire hybrid RES system. The following models are analyzed:

1) a single-component model based on minimizing Gibbs free energy with specified thermodynamic parameters;

2) a single component-based model using the NASA CEA (Chemical Equilibrium with Applications) thermodynamic equations and the water-gas shift reaction equations;

and 3) a three-zone model in which each zone (drying and pyrolysis, combustion, and reduction) is modeled separately using appropriate components based on minimizing Gibbs free energy and water gas shift reactions. The models have been developed based on literature experimental data regarding gasification process parameters (temperature, pressure, air ratio, process efficiency) and syngas parameters (chemical composition, calorific value) at both nominal output and part-load. To best match the models to the experimental data, unmeasured parameter values have been selected using a genetic optimisation algorithm. Next, the modelling methods in terms of their fit to experimental data are compared, and the advantages

and disadvantages of each solution are identified. Conclusions from the analysis are presented, along with limitations of the research and further research directions. The results and research conclusions can be used to develop hybrid renewable energy systems that use a biomass gasification system in cooperation with other RES. Focusing on modelling only the process effects (process efficiency, syngas properties, and energy balance) accelerates calculations, and the models can be used in comprehensive analyses of hybrid installations. Examples of such applications include feasibility studies and techno-economic analyses of the hybrid system's profitability.

New materials for electrochemical and chemical energy conversion and storage

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Keywords: Hydrogen energy, high-temperature fuel cells, supercapacitors, methanation catalysts, solid-state hydrogen storage

Abstract

Hydrogen is widely recognized as a promising energy carrier due to its high specific energy and environmentally benign utilization. However, its efficient conversion and safe, high-density storage remain critical challenges limiting broader implementation. Addressing these issues requires the development of advanced materials tailored for both energy conversion and storage technologies.

In the field of electrochemical and chemical energy conversion, particular attention is devoted to high-temperature fuel cells, including molten carbonate fuel cells (MCFC) and hybrid SOFC–MCFC systems. These technologies offer high efficiency and fuel flexibility, but their performance strongly depends on the stability and activity of electrode and electrolyte materials under harsh operating conditions. In parallel, the development of 3D-printed catalysts for methanation enables optimized architectures with enhanced surface area, controlled porosity, and improved mass and heat transport, supporting efficient catalytic conversion of hydrogen and carbon dioxide into synthetic fuels.

For hydrogen storage, solid-state approaches based on advanced materials provide a safer alternative to conventional compressed or liquefied systems. Gas-atomized Ti-containing alloys were investigated in terms of hydrogen absorption and structural evolution. The powders exhibited spherical morphology and a predominantly BCC structure. Initial hydrogen uptake was limited due to surface passivation, but activation enabled measurable storage capacity. Hydrogenation induced lattice expansion, particle cracking, and structural changes, as confirmed by SEM and XRD.

Complementary material concepts, including multicomponent alloys and highly porous structures, are also considered for hydrogen storage due to their tunable properties and potential for improved performance.

The presented results highlight the potential of advanced materials for integrated energy systems, with emphasis on structure-property relationships governing hydrogen interactions, catalytic activity, and long-term stability. These insights support the development of efficient, reversible, and scalable energy conversion and storage technologies.

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Potential of plasma-based processes as a demand side response for flexible electrified industry

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Keywords: Plasma, gasification, pyrolysis, demand side response, flexible energy systems.

Abstract

Energy systems are currently struggling to maintain a stable supply with the increasing installed power of intermittent renewable energy sources. By the end of 2025, the installed power of solar, wind onshore, and wind offshore connected to the grid in the EU reached 309, 195, and 21 GW, respectively. Among the fossil fuels, installed power was 190 GW for natural gas, 50 for hard coal, and 37 for lignite. This requires extensive energy storage and improved flexibility of the energy sources and the grid. However, the current trend of electrification of industry will increase those needs further if accompanied by further growth of solar and wind. A Demand Side Response (DSR) is considered an additional way to increase the flexibility of modern energy systems, with the electrification of various branches of industry at the same time. DSR is based on the ability of the electricity consumers to temporarily reduce, increase or shift their electricity consumption in reaction to available power in the grid and its fluctuations. Processes based on plasma technology are ideal consumers, in terms of flexibility, as the generation of plasma can be switched on and off extremely quickly. The novel approach investigated in this work provides an overview of different plasma-based technologies capable of flexible operation as DSR, providing useful products along with flexible service to the energy grid. This includes plasma novel applications of plasma in the energy sector, biorefineries, and the production of materials. The work assesses the potential of technologies such as plasma gasification (using microwave and DC plasma torches), plasma-assisted combustion, as well as various technologies with potential in different industrial sectors, such as the production of

chemicals, fertilisers, and metallurgy. Moreover, the current state-of-the-art of the capacity markets is outlined, identifying possible revenue streams related to DSR operation of plasma processes.

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Biochar-templated modification of photocatalyst structural properties

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Keywords: Biochar templating, TiO2-biochar composite, TiO2 morphology control, Micropollutants degradation,

Abstract

The growing contamination of wastewater by pharmaceutical micropollutants represents a significant environmental challenge, as conventional biological treatment stages in wastewater treatment plants are unable to effectively remove these substances. Therefore, the development of efficient and environmentally friendly technologies for their degradation remains a highly relevant topic. One of the promising methods is heterogeneous photocatalysis utilizing titanium dioxide (TiO2). The aim of this work was to develop an effective TiO2-based photocatalytic material using biochar as a structural template to control the properties of the photocatalyst.

TiO2 was prepared via the sol-gel method in the presence of wood chip biochar. During preparation, the biochar provided its structure for the crystallization of TiO2 and significantly influenced the final morphology and specific surface area of the material. Subsequent calcination led to the removal of the biochar; however, its template effect was preserved in the structure of the resulting TiO2. This approach allows for the targeted modification of the photocatalyst structure without the presence of a carbonaceous component in the final material.

The prepared materials were tested in the photocatalytic degradation of pharmaceutical micropollutants (acetaminophen, diclofenac, sulfamethoxazole, and tramadol) in model aqueous solutions under UV-A LED radiation at a wavelength of 365 nm. The results demonstrated a significant effect of the biochar templating action on the structural properties of TiO2 and, consequently, on its photocatalytic activity. For the optimally prepared material, the degradation efficiency of the model micropollutant was achieved of up to 97%. These results

confirm the potential of biochar as an effective tool for controlling the structure of TiO2 and increasing its photocatalytic efficiency in advanced water treatment.

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Real-Time Optimization of Dual-Fuel ICE Performance Using Fuzzy Logic and Grey Wolf Optimization

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Keywords: Hydrogen energy, internal combustion engine, fuzzy logic control, Grey Wolf Optimizer.

Abstract

As global warming and air pollution become increasingly severe, internal combustion engine (ICE) vehicles—still the dominant transportation power source—are under growing scrutiny due to their high carbon and pollutant emissions. Although electric and fuel cell vehicles are considered future trends, incomplete infrastructure and the continued prevalence of ICEs make full replacement unlikely in the short term. Therefore, improving the energy efficiency of existing ICEs while reducing emissions has become a critical challenge during the energy transition period. This study proposes and validates a hydrogen–gasoline dual-fuel combustion system based on a four-input fuzzy logic controller (FLC-4in) integrated with the Grey Wolf Optimizer (GWO), aiming to achieve an optimal trade-off between energy savings, emission reduction, and cost-effectiveness. A high-fidelity simulation model was developed in MATLAB/Simulink, incorporating vehicle dynamics, FTP-75 driving cycle tracking, engine combustion and emissions, and fuel and carbon cost calculations, solved using a fixed-step ODE4 method (0.1 s). Five control strategies—pure gasoline, FLC-2in, FLC-3in, FLC-4in, and FLC-4in-GWO—were evaluated. Results show that FLC-4in-GWO reduces peak gasoline consumption from 1.8 g/s to 0.4–0.7 g/s, CO_2 emissions from 5.9 g/s to 2.39 g/s, and NOx emissions from 6.5×10^{-3} g/s to 2.8×10^{-3} g/s, with smoother emission profiles under idle and low-load conditions. Cumulatively, gasoline consumption decreases by approximately 50% (399.24 L to 198.74 L), CO_2 emissions by over 50% (1266.4 g to 630.41 g), and NOx by about 40%. Although hydrogen and carbon costs increase slightly, cost per distance remains more economical than conventional control. A real-time feasible GWO update (1 s interval) with dynamic weighting ensures convergence and stability, maintaining speed tracking error within ±0.5 km/h and torque delay below 0.05 s. This study demonstrates a practical and scalable approach for future ECU implementation and real-world deployment.

Biomass processing technology with the addition of binders for energy use

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Keywords: Biomass, pelletization, pellets, binders, torrefaction

Abstract

The research focuses on biomass processing technologies for energy purposes with the addition of organic and inorganic binders in various proportions (2 and 15%). Pelletization and torrefaction technologies are used for biomass processing. Pellet samples before and after torrefaction are subjected to evaluation of mechanical-physical and thermochemical properties in order to assess the influence of the substances used and process conditions on the resulting fuel quality. By optimally choosing the content and type of binder in the mixture for pellet production, it is possible to achieve high-quality properties of pellets before and after torrefaction while maintaining the efficiency of the production process. The torrefaction took place at a temperature of 250 °C in a nitrogen atmosphere and the residence time in the reactor was 2 hours. The solid residue content of the individual samples ranged from 42 to 59%, with the lowest value belonging to the 15% carboxymethylcellulose sample (41.6%) and the highest solid residue being recorded for the 2% calcium carbonate sample (59.4%). The anhydrous weight loss (AWL) values for the individual samples ranged from approximately 40 to 58%. The expected relationship can be observed from the solid residue yield data and AWL values. Higher weight loss corresponds to lower solid product content after torrefaction. For example, the 15% starch sample had a solid residue content of 46.7%, which corresponds to a weight loss of approximately 53%, which is in good agreement with the AWL value. Pellets before torrefaction were burned in a fluidized bed boiler with a stationary fluidized bed and emissions in the flue gases were detected. The analysis showed that, for example, with the addition of lignosulfonate, the amount of sulfur increases quite significantly. From the overall assessment, pellet samples that contained a lower content achieved better results, with the best results before and after torrefaction being achieved by samples 2% magnesium carbonate, 2% calcium carbonate and 2% starch. From a technological and economic point of view, this is a significant benefit, because it allows for a reduction in the consumption of binders in the production of pellets without a negative impact on their properties.

Enhanced initial hydrogenation of TiFe-based hydrogen storage alloys

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Abstract

AB-type TiFe alloys can be produced at a relatively low cost and can be handled with a low risk of fire, making them promising candidates as next-generation hydrogen storage materials. A TiFe hydrogen storage alloy can absorb up to 1.9 wt% hydrogen by forming TiFeH and subsequently TiFeH2 at room temperature. However, the presence of dense oxide layers on the TiFe phase with the BCC structure hinders the initial hydrogenation of these types of alloys and necessitates repeated pressurization with H2 at a high temperature of approximately 450 ℃ for initial hydrogenation. In this study, the evolution of hydrogen absorption on TiFe-based alloys containing approximately 0, 2, 5, and 6 at% C and hydrogen desorption from these alloys were investigated, including analysis of the pressure-composition-isotherm (PCI) curves and long-term hydrogen sorption cycles. Focus is placed on the influence of C addition on the initial hydrogenation of the alloys, and the mechanism of initial hydrogenation is discussed. In addition, we will investigate the effect of Ce addition on the initial hydrogenation of TiFeV alloys.

Industrial Paper Cores: Energy Potential or Technological Risk? A Comprehensive Evaluation for Thermochemical Conversion

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Keywords: Industrial paper cores; thermochemical conversion; analytical pyrolysis; ash mineralogy; condensable organic products

Abstract

Industrial paper cores generated during paper-yarn production are commonly treated as predominantly cellulosic residues and may therefore be considered for energy recovery. Their recycled-paper matrix, mineral fillers, and heterogeneous organic composition may, however, influence thermal conversion, ash behaviour, and the formation of condensable products.

This study presents an integrated evaluation of eight industrial paper cores, designated TENDON 1–8 (T1–T8), linking feedstock characteristics with thermal behaviour and organic conversion products. The materials were examined by scanning electron microscopy and characterised in terms of higher heating value, ash content, elemental composition, and the elemental and mineralogical composition of the ash, including Rietveld refinement. Thermal behaviour was assessed by thermogravimetry, differential scanning calorimetry, and derivative thermogravimetry. Thermally releasable and conversion-derived organic compounds were investigated using sorption-tube thermal desorption GC/MS, direct-pyrolysis GC/MS, and controlled thermochemical conversion.

Higher heating values ranged from 12.7 to 15.2 MJ kg^{-1}, while ash contents varied between 9.4 and 17.4 wt.%. The elemental composition was characteristic of cellulosic materials, whereas the ash was calcium-dominated, with Ca concentrations reaching 52 wt.%. Calcite, dolomite, quartz, hematite, albite, and sanidine were identified among the crystalline phases. Representative cores exhibited comparable primary decomposition, but T8 showed a distinct secondary oxidation event in air, indicating differences in organic-matrix composition that were corroborated by Py-GC/MS. In total, 304 organic compounds were identified and classified into seven principal formation mechanisms: biomass degradation (75 compounds), hydrogenation/dehydrogenation (46), side-chain scission (47), random scission (45), dehydration (32), cyclisation (31), and other reactions (28).

Despite their appreciable energy potential, thermochemical conversion resulted in the accumulation of liquid organic condensate within and around the reactor, with condensable products escaping from the system. The study therefore demonstrates that fuel suitability cannot be inferred from calorific value alone. Industrial paper cores constitute a promising secondary energy resource, but further process optimisation is required to control condensable products and achieve stable, clean, and environmentally acceptable energy recovery.

Multi-criteria development of lightweight hemp-shive composite panels incorporating gasified wood pellets for sustainable construction products

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Keywords: Hemp shives; Gasified wood pellets; Sustainable construction products; Lightweight bio-based panels.

Abstract

The construction sector requires new low-carbon construction products capable of reducing embodied energy, improving thermal performance and supporting circular material use. This need is reinforced by the European Construction Products Regulation, which reinforces the role of environmental sustainability performance in construction product assessment. In this context, bio-based panels made from forest and agricultural residues represent a promising way for insulation, internal lining and non-load-bearing construction applications, provided that their thermal, fire and mechanical behaviour is considered and assessed within the design formulation.

This study developed lightweight hemp-shive composite panels incorporating raw hemp shives, gasified wood pellets, melamine–urea–formaldehyde resin and ammonium polyphosphate (APP). A Taguchi L9 design varied gasified wood pellets from 5 to 15 wt.%, resin from 8 to 16 wt.% and flame retardant from 3 to 7 wt.%, with a target density of approximately 300 kg/m³. The panels were evaluated by guarded hot plate thermal conductivity, cone calorimetry at 50 kW/m², dynamic mechanical analysis, from 20 °C to 220 °C at 2 K/min under nitrogen, and three-point bending. Thermal conductivity ranged from 62.33 to 66.77 mW/(m·K), with the best value obtained for the formulation containing 10 wt.% gasified wood pellets, 12 wt.% resin and 7 wt.% ammonium polyphosphate. Cone calorimetry showed peak heat release rates between 64.44 and 116.56 kW/m², with the lowest first peak obtained for 10 wt.% gasified wood pellets, 16 wt.% resin and 3 wt.% flame retardant. Multi-response optimisation selected the formulation with 10 wt.% gasified wood pellets, 8 wt.% resin and 5 wt.% APP as the best performing formulation under the combined desirability criteria. The final three-point bending validation gave an average modulus of elasticity of 10.17 MPa and bending strength of 0.63 MPa, indicating suitability for lightweight insulation and finishing non-load-bearing panels.

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Experimental Comparison of Single-Acting and Double-Acting Rotary Vane Expanders in Organic Rankine Cycle Systems

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Keywords: Organic Rankine cycle (ORC), rotary vane expander, single-acting, double-acting, isentropic efficiency

Abstract

Efficient recovery of low-grade waste heat from industrial processes is crucial for energy sustainability. The organic Rankine cycle (ORC) is well suited for low-grade waste heat recovery, where expander performance plays a critical role in system efficiency and cost. Rotary vane expanders (RVEs) have been widely adopted because of their structural simplicity and operational reliability. Among existing RVE configurations, single-acting RVEs (SRVEs) represent the conventional design, whereas double-acting RVEs (DRVEs) have been introduced to improve power density. However, experimental comparisons between SRVEs and DRVEs under identical conditions are still lacking at the micro-scale, and the impact of DRVEs' increased structural complexity on permeability and mechanical losses has not been fully clarified.

To address this gap, this study presents a comparative experimental investigation of prototype SRVEs and DRVEs under identical operating conditions in a 2 kW ORC experimental test rig. R134a was used as the working fluid, and experiments were conducted at a given heat source temperature of 95℃, a fixed rotational speed of 900 rpm and a cold source temperature of 20℃. Thermodynamic performance and internal flow characteristics were evaluated in terms of isentropic efficiency, net efficiency, and permeability as an indicator of internal leakage severity.

Results show that both expanders improve with increasing pressure ratio, but the SRVE exhibits more stable trends in isentropic and net efficiencies. In contrast, the DRVE shows higher permeability, mainly due to its larger number of vane slots combined with back-pressure

slot design, which facilitates vane extension but also creates additional flow passages. As pressure ratio increases, the performance of the DRVE deteriorates slightly because of increased mechanical friction losses caused by the greater number of vanes. Under the tested conditions, the SRVE achieved a maximum power output of 815 W, a maximum net efficiency of 2.82%, and a maximum isentropic efficiency of 31.9%, whereas the corresponding values for the DRVE were 770 W, 2.66%, and 30.3%, respectively.

Finally, the comparison demonstrates that, under identical ORC operating conditions, the SRVE outperforms the DRVE in operational stability and net efficiency, while maintaining lower permeability. The results indicate that the expected advantage of the double-acting configuration is offset by increased permeability and friction losses, highlighting permeability reduction and friction control as key design priorities for future micro-scale RVE development.

Use of algae-derived biochar for soil amendment

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Keywords: Macroalgae, Seaweed, Soil carbon, Bioremediation, Soil amendments

Abstract

The cold seas of the Western Cape Province (South Africa) have an abundant supply of macroalgae due to their rapid growth rate. When floated out of the sea, algae cover local beaches, making them uncomfortable for visitors. Despite the abundance, the use of algae in South Africa is limited. Marine macroalgae are a viable source of biomass that can be converted into biochar for soil amendment via slow pyrolysis. Two different carbonisation temperatures (720 °C and 450 °C) were chosen to produce biochar from marine algae “Eclonia Maxima” at the heating rates of 15.8°C/min and soak times of 90 minutes. The biochar yield at lower temperatures averaged 60.4wt%, whereas the yield of biochar at higher temperatures averaged 41.3wt%. The BET surface area of biochar pyrolysed at 720°C and 450°C was 304$m2$/g and 18$m2$/g, respectively. An elemental analysis revealed that pyrolysis at 720°C provided higher percentages of nitrogen (3.54%) compared to the temperature of 450°C (1.57% nitrogen). To test the efficiency of biochar, growth trials on “Microgreen“seeds were performed with store-bought nutrient soil with and without biochar and a commercial fertilizer added. While the growth rate (expressed as an increase in the crop mass and its height) in fertilized soil initially surpassed that in biochar-treated soil, the rates eventually equalized; ultimately, crop growth on the biochar-amended soil proved fastest, driven by moisture retention within the biochar's porous structure and the gradual release of that moisture along with the nutrients contained in

the biochar. After 12 weeks of growth, the 720 °C biochar contributed to the greatest growth compared to the fertiliser-amended pots and plants in pots with soil without any addition.

Advanced Waste-to-Energy and Material Recovery Technology Using SRF Pellets for Low-Oxygen Pyrolysis Processes

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Keywords: Solid Recovered Fuel; SRF pellets; low-oxygen pyrolysis; syngas; material recovery; circular economy

Abstract

The growing volume of residual industrial and municipal waste, together with stricter landfill reduction targets and increasing demand for secondary raw materials, creates a need for integrated technologies that combine energy recovery with material valorisation. This work presents an advanced waste-to energy and material recovery concept based on the use of Solid Recovered Fuel (SRF) pellets as a controlled feedstock for low-oxygen pyrolysis processes.

The proposed approach integrates mechanical pre-treatment of non-hazardous waste, SRF pelletisation, thermal decomposition and downstream treatment of liquid process streams. In contrast to commonly used SRF flakes, pelletised SRF provides higher bulk density, more stable dosing behaviour and improved handling properties. The method is based on compacting SRF flakes into pellets with a typical diameter of 6 – 10 mm and length of 10 – 30 mm, increasing bulk density from approx. 130 kg.m-3 for flakes to approx. 455 – 650 kg.m-3 for pellets. This compaction reduces the volume of air voids in the input material and, according to the presented calculation, decreases oxygen ingress into the pyrolysis process by 39.8–63.5 %.

The reduction of oxygen availability is significant for improving the stability and quality of reductive pyrolysis. Lower oxygen ingress limits unwanted oxidation reactions, supports higher shares of energy rich gaseous components such as hydrogen and methane, reduces the formation of carbon oxides, improves the quality of liquid hydrocarbon fractions and helps preserve the carbonaceous value of the solid residue. The resulting output streams include syngas suitable for heat or electricity production, liquid hydrocarbon fractions, and a solid carbon-rich product containing ash and inorganic residues with potential for further industrial use.

The significance of the presented technology lies in its integrated circular economy approach: residual waste is transformed into certified fuel, gaseous energy carriers, liquid products, carbon-rich solids and treated process water. The concept therefore provides a pathway for reducing landfill dependency, improving energy recovery, supporting material recovery and addressing legislative barriers associated with the transition from waste treatment to secondary resource utilisation.

Torrefied Biomass and Anaerobic Digestion Synergy

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Keywords: Torrefied biomass, Anaerobic digestion, Methane production, Oxytree, Hydrolysis kinetics

Abstract

Anaerobic digestion is a promising technology for renewable methane production; however, its efficiency can be limited by slow hydrolysis, process instability, and inhibitory compounds released during the degradation of organic wastes. The addition of torrefied biomass has gained attention as a strategy to improve digestion performance due to its porous structure, surface functional groups, buffering capacity, and potential role as a microbial support material. In this study, Oxytree biomass was torrefied and evaluated as an additive in the anaerobic digestion of chicken manure. The aim was to determine how the severity of torrefaction affects methane production, hydrolysis kinetics, lag phase, and overall digestion performance.

Torrefied Oxytree biomass produced at 220 °C and 270 °C was tested at different torrefied biomass-to substrate ratios of 0.1, 0.2, 0.4, 0.8, 1.2, 2.4, and 4.8 g VS torrefied biomass/g VS substrate under mesophilic conditions for 60 days. Methane production was evaluated using modified Gompertz and first-order kinetic models. The results showed that the effect of torrefied biomass strongly depended on torrefaction temperature. The 220 °C torrefied Oxytree biomass showed the most beneficial performance, increasing the hydrolysis rate constant from 0.05 d^{-1} in the control to an average of 0.0657 d^{-1} and reducing the lag phase by approximately 49%. This indicated faster microbial adaptation and improved degradation of organic matter. The ultimate methane potential was also higher than the control, confirming that mildly torrefied Oxytree biomass can enhance both digestion kinetics and methane yield. In contrast, 270 °C torrefied Oxytree biomass increased the hydrolysis rate more strongly, reaching an average k value of 0.0800 d^{-1}, but caused a longer lag phase and lower ultimate methane potential compared with 220 °C torrefied Oxytree biomass.

The improved performance of 220 °C torrefied Oxytree biomass was attributed to its milder carbonization degree, remaining oxygenated functional groups, buffering effect, and possible support for microbial attachment. Effluent pH remained within the suitable range for methanogenic activity, while increased ammonium nitrogen suggested enhanced organic nitrogen conversion rather than ammonia inhibition. Overall, the study demonstrates that torrefied biomass and anaerobic digestion can act synergistically within an optimized process window. Mildly torrefied Oxytree biomass, especially at 220 °C, showed the highest potential

for biogas applications by accelerating hydrolysis, shortening adaptation time, and improving methane production.

Comparative Analysis of Pyrolysis and Gasification of Olive Stones: Biochar, Syngas and Bio-oil Characterization

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Keywords: Olive stones; pyrolysis; gasification; biochar; bio-oil; syngas

Abstract

Olive stones are an abundant agro-industrial residue with promising potential for energy recovery and material valorisation through thermochemical conversion. This study investigates the pyrolysis and gasification of olive stones, with a focus on the characterization of the resulting biochar, bio-oil and syngas. Pyrolysis experiments were performed in a batch reactor at 300, 400 and 500 °C, while gasification was carried out in a pilot-scale fluidized bed gasifier operated within the BIO2CHP facility. The obtained products were analysed using thermogravimetric analysis, proximate analysis, X-ray fluorescence spectroscopy, GC–MS analysis of bio-oil and syngas composition analysis.

The results showed that pyrolysis temperature strongly influenced product distribution. At 300 °C, biochar was the dominant product, reaching 72.6 wt.%, whereas at 400 and 500 °C the process favoured liquid product formation, with bio-oil yields of 50.8 and 51.2 wt.%, respectively. The gas yield increased with temperature, reaching 22.2 wt.% at 500 °C. Thermogravimetric analysis indicated multi-stage degradation typical of lignocellulosic biomass, with the main decomposition occurring between approximately 250 and 380 °C. XRF analysis showed moderate enrichment of calcium and potassium in pyrolysis-derived biochars, while gasification-derived biochar exhibited substantially higher mineral concentrations, suggesting ash enrichment and possible interactions with the fluidized-bed material. GC–MS analysis revealed that increasing pyrolysis temperature reduced furanic and acidic compounds in the bio-oil, while increasing the relative share of phenolic derivatives. Syngas analysis showed that air gasification produced nitrogen-diluted gas, with hydrogen reaching up to 15.53% and methane up to 6.42%.

Overall, the study confirms that olive stones are suitable feedstock for thermochemical conversion. The obtained results highlight the importance of process conditions in determining

product distribution and quality, supporting further development of olive-stone-based bioenergy and bio-based material applications.

Characterization of the Thermal Conductivity of Materials in Energy and Thermal Management Applications

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Keywords: Lithium-ion batteries, thermal conductivity, anisotropy, specific heat capacity, thermal management, thermal interface material

Abstract

Accurate characterization of thermal conductivity is essential for understanding heat transport in lithium-ion batteries and for thermal-management design. Single-sided Transient Plane Source (TPS) measurements combined with anisotropy analysis enable directional thermal conductivity characterization of intact battery cells. The method resolves in-plane and through-plane thermal conductivity in pouch cells and in 18650 and 21700 cylindrical cells. While thermal conductivity is the primary focus, the TPS Cp Utility additionally determines the specific heat capacity of intact pouch and cylindrical cells, providing a complementary thermophysical parameter alongside thermal conductivity for thermal modelling and thermal management design.

At the module and pack level, thermal performance is also influenced by adhesive and interface layers that connect battery cells and affect heat transfer through the assembly. The TPS Thin Films Utility characterizes thin pressure-sensitive adhesive films used in electric vehicle (EV) battery modules. Modified Transient Plane Source (MTPS) measurements characterize thermally conductive adhesives in both uncured and cured states, providing rapid feedback for formulation development and supporting evaluation of cured performance. MTPS also characterizes self-adhesive thermal interface tapes used for cell-to-cell, cell-array-to-cold-plate, cell-to-side-plate, and temperature-sensor mounting in EV battery systems. Collectively, these methods provide complementary capabilities for characterizing thermal conductivity across battery cells and surrounding thermal management materials, while specific heat capacity measurements provide additional information where required for more complete thermal modelling and system design.

A Computational Model for the Design and Optimization of Convergent and Laval Nozzles

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Keywords: Laval nozzle, Computational model, Nozzle optimization, Method of Characteristics, Engineering Equation Solver (EES)

Abstract

The design of convergent and Laval nozzles for compressible fluid flow represents a complex engineering task that requires simultaneous consideration of the thermodynamic properties of the working fluid, operating conditions, and nozzle geometry. Although specialized numerical tools are available for this purpose, their integration and practical application in engineering design are often time-consuming.

The computational model was developed to support the design of nozzles for experimental investigations of supersonic compressible flow. This contribution presents the model, developed as part of the author's ongoing habilitation research, which automates the design of both convergent and Laval nozzles for compressible fluid flow. The model was implemented in the Engineering Equation Solver (EES) environment and currently supports calculations for air and steam. Based on specified boundary conditions, including inlet and outlet pressure, temperature, mass flow rate, and nozzle isentropic efficiency, the model evaluates the flow regime, automatically selects the appropriate nozzle configuration, and performs both thermodynamic and preliminary geometric design. The outputs include comprehensive tables, h–s diagrams, dimensioned geometric drawings, and data files suitable for further processing.

For Laval nozzles, the computational model is complemented by a dedicated optimization application developed in MATLAB. This application combines Hermite cubic interpolation for the design of the convergent section with the Method of Characteristics (MOC) for the design of the divergent section. The resulting geometry is aerodynamically optimized and can be directly exported to CAD software for subsequent CFD simulations and experimental validation.

The proposed model represents a versatile engineering tool that significantly simplifies and accelerates the design of convergent and Laval nozzles while providing an integrated platform for numerical optimization, CAD modelling, CFD simulations, and experimental verification.

Heavy Metal Adsorption by CO_2 – and CO_2–Steam-Activated Food Industry Waste Biochars

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Keywords: Wastewater Treatment, Biochar, Food Industry Waste, Heavy metal removal

Abstract

Food industry residues can serve not only as renewable feedstocks for thermochemical conversion but also as precursors of functional carbon-based materials for water remediation. In this work, biochars obtained from sunflower husks, buckwheat husks, and cherry stones were produced by gasification at 900 °C under CO2 and CO2-steam atmospheres and assessed for the removal of Cu(II) and Ni(II) ions from aqueous solutions. The study focused on how feedstock-dependent ash composition and gasification atmosphere affect pore development, mineral leaching, pH evolution, and the apparent adsorption behaviour of the obtained biochars.

The investigated materials represented two distinct mineral systems: K-rich sunflower and buckwheat husk biochars, with K2O contents of 48.09 and 50.06 wt.%, respectively, and Ca–P-rich cherry stone biochar, containing 22.85 wt.% CaO and 31.48 wt.% P2O5. The activation atmosphere strongly modified both the carbon matrix and mineral phase behaviour. CO2 gasification promoted higher carbonisation and mineral stabilisation, whereas CO2-steam gasification enhanced textural development, increasing BET surface area up to approximately 800 m2/g and increasing the accessibility of ash-derived alkaline species. The highest alkalinity was observed for steam-activated sunflower husk biochar, which reached pH 9.73 and released 83.8 mg/dm3 of potassium. In contrast, CO2 treatment reduced the alkalinity of cherry stone biochar from pH 9.18 to 7.52, indicating carbonation and stabilisation of Ca-containing phases.

Cu(II) removal was governed by a combination of adsorption and precipitation-related processes. The highest apparent Cu(II) uptake reached approximately 67 mg/g under strongly alkaline conditions, particularly for steam-activated sunflower husk biochar. The occurrence of blue precipitates and the contribution of Ca, Mg, carbonate, and hydroxide-related phases indicated that Cu(II) immobilisation cannot be interpreted solely as surface adsorption. Ni(II) removal was more closely related to porosity and surface accessibility, with maximum apparent capacities of 30–33 mg/g for CO2–steam-activated biochars. Isotherm analysis showed that the Freundlich model fitted most Ni(II) systems well, with R^2 values of 0.98-0.99, confirming

heterogeneous adsorption behaviour, although mineral-induced hydroxide retention may also contribute under alkaline conditions.

Overall, the results demonstrate that gasification-derived biochars from food industry residues can be tailored through activation atmosphere selection. However, for highly alkaline biochars, apparent metal removal capacities should be interpreted with caution due to simultaneous adsorption, precipitation, and mineral-driven retention mechanisms.

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Beyond Measurements: Interpreting Hidden Environmental Patterns with Machine Learning

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Keywords: Machine learning; environmental data analysis; environmental monitoring; VOC; chemometrics; pattern recognition; environmental informatics; interpretable AI

Abstract

Environmental monitoring systems generate continuously increasing volumes of data; however, the transformation of measurements into meaningful environmental understanding remains a major scientific challenge. Conventional approaches are typically focused on direct observations, descriptive statistics, and threshold-based interpretation, which often oversimplify the complexity of environmental processes and fail to capture hidden nonlinear relationships embedded in the data.

This work explores the role of machine learning as a tool not only for prediction, but also for the interpretation of hidden environmental patterns. The study discusses how data driven approaches can support the identification of latent structures, temporal dependencies, and multidimensional relationships that remain difficult to recognize using classical analytical methods alone. Particular attention is given to complex environmental signals associated with energy and atmospheric systems, including volatile organic compound (VOC) monitoring and process-related environmental datasets characterized by high variability and uncertainty.

The presented approach combines environmental measurements with chemometric analysis, descriptor-space representation, clustering methods, and machine learning techniques

to move beyond simple concentration-based interpretation toward pattern oriented environmental analytics. The study highlights the importance of contextual interpretation, validation strategy, and domain knowledge integration in avoiding misleading conclusions generated by purely statistical or black-box approaches.

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Predictive Analysis of Volatile Organic Compound Emissions in Process Gases Using Machine Learning Methods

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Keywords: Volatile organic compounds (VOC); machine learning; artificial neural networks; predictive modelling; process gas emissions; environmental monitoring

Abstract

Volatile organic compounds (VOCs) constitute a group of chemical substances emitted into the atmosphere as a result of technological processes occurring in industrial installations, including energy generation systems. Their presence is associated with significant environmental and health impacts, as they participate in photochemical reactions leading to the formation of tropospheric ozone and secondary organic aerosols, while many VOCs exhibit toxic properties. VOC emissions are characterized by high temporal variability and strong dependence on process parameters, which makes their characterization challenging using conventional measurement approaches. This study presents an approach combining analytical methods with artificial intelligence-based data analysis for the prediction of VOC emissions in process gases. The research was based on a laboratory-scale measurement system enabling VOC determination and continuous monitoring of emission variability over time. The acquired data were used to develop predictive models employing machine learning techniques, including artificial neural networks.

The developed models enabled the identification of relationships between process parameters and VOC emission levels, as well as the assessment of their predictive capability. The results demonstrate the significant potential of integrating measurement systems with machine learning methods for the analysis and prediction of emissions in energy and industrial systems.

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Research University programme, and by AGH University of Krakow under grant no. 501.00.210000.10000.

Design, Fabrication, and Performance Evaluation of a Portable Planar Proton Exchange Membrane Fuel Cell Employing Titanium Fiber Felt Current Collectors

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Keywords: Proton Exchange Membrane Fuel Cell; Planar Design; Air-breathing; Portable; Tita nium Fiber Felt

Abstract

This study aims to design and fabricate a planar, portable cathode-open Proton Exchange Membrane Fuel Cell (PEMFC) incorporating a titanium fiber felt current collector, and to assemble it into a multi-cell configuration for performance evaluation. In the initial stage, a cathode-open single cell equipped with a titanium fiber felt current collector was developed. The Taguchi method was employed to optimize the design of the titanium fiber felt current collector. The experimental configuration exhibiting the highest average power density was subsequently selected as the baseline for the multi-cell design. Various configurations, including different flow field designs (serpentine and parallel flow channels) and current collector materials (FR-4 and PCB), were integrated. Performance comparisons were conducted in terms of clamping force, compression ratio, polarization behavior, and operational stability. Finally, the system was scaled up to a 4-cell configuration, and its performance was further investigated and compared. The experimental results demonstrate that the parallel flow field outperforms the serpentine flow field in all evaluated aspects within the proposed planar cathode-open design. Regarding current collector materials, the FR-4 current collector exhibited superior performance compared to the PCB current collector in the 2-cell configuration. However, upon scaling up to the 4-cell system, the PCB current collector demonstrated enhanced performance, achieving a maximum power density of 79.9 mW/cm2. Throughout the scaling process, various design parameters were systematically introduced to evaluate their influence on power density performance. This study seeks to enhance the output performance of the fuel cell while identifying an optimal design for portable and lightweight applications, thereby promoting the broader adoption of green energy technologies in daily life.

Laser Diagnostics of Combustion and Flow Processes at the Department of Power Engineering

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Keywords: Laser diagnostics, combustion, LIF, BOS, reactive flows, hydrogen combustion, non intrusive, measurements

Abstract

The Department of Power Engineering at VSB – Technical University of Ostrava conducts experimental research focused on combustion processes, reactive flows, and advanced optical diagnostics. The laboratory infrastructure enables detailed investigations of flow fields, flame structure, species concentration, temperature distribution, and pollutant formation in conventional and alternative fuel combustion systems.

The research activities employ several state-of-the-art laser diagnostic techniques, including Laser Induced Fluorescence (LIF), Particle Image Velocimetry (PIV), Background Oriented Schlieren (BOS), Laser-Induced Incandescence (LII), Raman and Rayleigh scattering, chemiluminescence, and high speed imaging. These methods provide non-intrusive measurements of physical and chemical phenomena occurring in reacting flows. The integration of a newly acquired high-speed camera with three-dimensional tomographic BOS enables detailed investigation of rapidly evolving, asymmetric flame structures, including the development of local instabilities and transient flow features.

Current research topics focus on co-combustion of methane and hydrogen, with particular emphasis on the influence of hydrogen addition on NO formation as a function of mixture concentration and equivalence ratio. The research investigates individual NO formation mechanisms occurring both in the reaction zone and in the post-flame region, as well as the influence of hydrogen preferential diffusion and thermo-diffusive instabilities on local flame structure, flame front wrinkling, and NO production.

The presented abstract provides an overview of the available experimental facilities, diagnostic systems, and ongoing research projects, highlighting the capabilities of the department in the field of combustion and flow diagnostics.

Tailoring Medium-Entropy Alloys for Advanced Hydrogen Storage

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Keywords: Medium-entropy alloy, hydrogen storage, zirconium alloying, metal hydride, phase tailoring

Abstract

Medium-entropy alloys (MEAs) provide extensive compositional freedom for designing solid-state hydrogen storage materials, but their performance depends critically on phase constitution and hydride stability. This work demonstrates how minor zirconium additions tailor the structure and hydrogen sorption behaviour of the $(TiVNb)_{85}Cr_{15}$ system. Arc-melted alloys containing 1, 4 and 7 at.% Zr were examined by X-ray diffraction and scanning electron microscopy with energy-dispersive X-ray spectroscopy, while hydrogen absorption and desorption were evaluated by sorption and thermogravimetric measurements. All compositions remained multiphase, showing that Zr addition did not stabilise a single solid solution. Their microstructures comprised a dominant body-centred cubic phase (HEA_1), acting as the principal hydrogen absorber, together with minor HEA_2 and HEA_3 phases that significantly influenced the absorption/desorption response. The effect of Zr was strongly non monotonic. The alloy containing 4 at.% Zr, $(TiVNb)_{81}Cr_{15}Zr_4$, combined the easiest activation with the highest hydrogen uptake and the largest reversibly available fraction. It absorbed hydrogen at room temperature without additional activation processing and provided a reversible capacity of up to 0.74 wt.% H, corresponding to H/M = 0.46. Only 0.18 wt.% H remained strongly bound and was released during heating to 600 °C. In comparison, the low-temperature reversible capacities of the 1 and 7 at.% Zr alloys were only 0.04 and 0.19 wt.%, respectively. These results show that optimal hydrogen storage cannot be predicted from the concentration of a single alloying element alone. Instead, controlled minor element additions can be used to engineer multiphase architectures, tune hydride stability and balance activation, capacity and reversibility in advanced MEA-based storage materials.

Activated Carbon Preparation from Paper, Cardboard, Polystyrene and Refuse-Derived Fuel for Phenol Removal from Aqueous Solutions

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Abstract

Municipal solid waste (MSW) is an abundant resource, but its complexity limits direct valorisation. Refuse-derived fuel (RDF) and its main components provide more stable feedstocks for thermochemical conversion. In this study, chars from paper, cardboard, polystyrene (PS), and RDF were steam-activated at 800 °C and compared with earlier experiments at 900 °C. Syngas production and composition were analysed, and the activated carbons were tested for phenol adsorption. Higher activation temperature decreased char yield and shifted syngas composition toward higher CO and H_2 with lower CO_2. The pseudo-first-order (PFO) kinetic model was fitted to the adsorption data to estimate the time required for equilibrium. While the exact values differed slightly among samples, 20 h was sufficient for all activated carbons to reach equilibrium (R^2 = 0.94–0.98). Cardboard-derived material exhibited the highest uptake capacity, whereas paper-derived carbon showed the lowest. RDF-based activated carbon produced at 800 °C achieved a higher capacity (1.95 mg g^{-1}) than that obtained at 900 °C (1.34 mg g^{-1}). This difference may be associated with structural changes at elevated activation temperature, as suggested in the literature, where excessive burn-off can lead to reduced surface area and adsorption efficiency.

Bio-based fertilisers: from compositional characterisation to plant response

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Keywords: Meat and bone meal, alkaline hydrolysis, organo-mineral fertilisers, nutrient recovery, cucumber

Abstract

Demand for sustainable fertilisers and the need to reduce reliance on primary mineral resources have increased interest in nutrient recovery from organic by-products. This study

produced amino acid containing organo-mineral fertilisers from meat and bone meal (MBM), a material derived from animal by-products, and evaluated fertiliser composition, nutrient extractability, plant response, and the microbiological quality of the MBM feedstock. The feedstock contained 8.73% N, 36.3% C, 11.6% P2O5, and 13.7% CaO. Microbiological analysis showed <10 CFU/g of Escherichia coli and no detectable Salmonella spp. in 25 g.

Alkaline hydrolysis was applied to convert the protein-rich MBM into amino acid-containing hydrolysates for subsequent fertiliser production. To maximise amino acid release and identify suitable processing conditions, the process was optimised using Response Surface Methodology and a Box Behnken design. KOH concentration, temperature and the solid-to-liquid mass ratio were investigated as independent variables, with total amino acid content as the response. The highest experimentally determined amino acid content, 17,505±721 mg/kg, was obtained at 50% KOH, 100°C and a solid-to liquid ratio of 1:2. The model predicted optimum conditions of 50% KOH, 100°C and a 1:1 ratio, corresponding to 18,090 mg/kg. The hydrolysates contained amino acids, non-proteinogenic amino acids and short peptides, including arginine, proline, threonine, γ-aminobutyric acid and glutathione.

Two granular formulations were produced by neutralising the hydrolysate with phosphoric acid (F1) or sulphuric acid (F2), followed by granulation with peat and zinc lignosulfonate. F1 contained 12.4% P2O5 and 3.09% SO3, whereas F2 contained 4.51% P2O5 and 9.00% SO3. Nutrient-extraction tests showed nearly quantitative extraction of magnesium and sulphur in water and of phosphorus, manganese, and zinc in neutral ammonium citrate.

Plant response was assessed in a cucumber (Cucumis sativus L.) pot experiment. At 25% of the target N dose, F2-treated plants had a mean total root length of 910±266 cm versus 156±104 cm in the unfertilised control. At the full N dose, F1-treated plants produced 23.2±4.2 buds and flowers per plant, compared with 4.17±1.47 in the control and 14.3±5.0 with the commercial reference fertiliser. At that dose, F2-treated plants had the numerically highest mean root and shoot fresh masses (3.02±0.82 and 9.25±2.19 g, respectively). These results support the laboratory-scale feasibility of converting MBM into nutrient-rich organo-mineral fertilisers and warrant field evaluation.

Powering circularity in the V4 region: waste streams for energy and fertilisers

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Keywords: V4, circular economy, biowaste, nutrient recovery, energy, fertilisers

Abstract

Current geopolitical and economic challenges highlight the growing importance of raw material security and the need to diversify sources of materials that are essential for the functioning of European economies. This applies both to energy resources and to elements required for fertiliser production. In response to these challenges, within the BIOWASTELINK

project, funded by the International Visegrad Fund, researchers from Poland, Czechia, and Hungary are developing a joint platform for the identification and characterisation of regional biowaste streams with high potential for energy recovery and use as feedstocks for EU-compliant fertilisers across the V4 region. The methodology combines data from national statistical systems and relevant European Union databases. Harmonised information on waste origin, availability, composition, and current management will be integrated into a common database and visualised in Esri's ArcGIS Pro to map feedstock availability and nutrient valorisation potential.

Among EU Member States reporting 2024 data to Eurostat, urban wastewater treatment plants generated 556.59, 261.91, 218.58, and 55.48 thousand tonnes of sewage sludge on a dry matter basis in Poland, Hungary, Czechia, and Slovakia, respectively. These were the fourth-, sixth-, seventh-, and thirteenth highest reported values. The data illustrate the scale of the resource but do not by themselves demonstrate recovery potential. They therefore provide a basis for subsequent assessment of sludge composition, accessibility, current management, regulatory constraints, and technically feasible nutrient-recovery routes.

Beyond sewage sludge, the BIOWASTELINK platform will cover a broader range of biowaste streams, including agricultural residues, food-processing waste, digestates, and other biomass residues with potential applications in energy and fertiliser production. The GIS-based approach will enable the identification of regional hotspots characterised by high resource availability and favourable conditions for local valorisation. Ultimately, the developed platform is expected to facilitate cross-border knowledge exchange, support the identification of underutilised secondary resources, and provide a basis for the development of future regional waste-to-energy and waste-to-fertiliser initiatives.

Beyond Energy Storage: How Grid-Forming BESS Can Support Europe's Power System Stability

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Abstract

Battery Energy Storage Systems (BESS) are rapidly becoming an essential part of Europe's energy infrastructure. Until recently, their role has been primarily associated with energy shifting, peak shaving, renewable energy integration and ancillary services. However, as conventional synchronous generation is gradually replaced by inverter-based renewable energy sources, a new challenge is emerging: maintaining the stability and resilience of the power system.

This presentation explores the evolving role of BESS from energy storage assets to active contributors to power system stability. Particular attention is given to Grid-Forming technology and its potential to provide capabilities traditionally associated with synchronous generators, including fast frequency response, synthetic inertia, voltage support and system restoration.

The presentation will highlight why the transition from Grid-Following to Grid-Forming functionality is becoming increasingly relevant for European power systems and how this development may influence the technical requirements and design philosophy of future utility-scale BESS projects.

Hydrogen sorption characteristics of Cu-doped high-entropy alloys

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Keywords: hydrogen storage, high-entropy alloys, TiVNbCr, copper alloying, pressure–composition isotherms, activation behaviour

Abstract

TiVNbCr-based multicomponent alloys are promising candidates for solid-state hydrogen storage because they combine relatively high hydrogen uptake with broad compositional flexibility for tuning pressure–composition behaviour. In this study, the effect of Cu content was investigated by comparing two Ti–V–Nb–Cr–Cu alloys containing 2.5 at. % Cu (Label A) and 15 at. % Cu (Label E). The main objective was to evaluate how increasing the Cu concentration influences phase constitution, activation behaviour, experimentally accessible hydrogen content, and the pressure–composition response of the alloys.

The powders were produced by ultrasonic melt atomization and characterized using CALPHAD thermodynamic calculations, X-ray diffraction (XRD), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM–EDS), and particle-size analysis. CALPHAD calculations predicted complex multiphase equilibrium constitutions for both compositions, with a stronger tendency toward Cu-containing secondary phases at the higher Cu level. XRD confirmed composition-dependent phase complexity in the as-atomized powders. SEM observations showed predominantly spherical particles with closely comparable particle-size distributions for both alloys, while EDS mapping revealed no detectable Cu segregation at the micrometre scale in the as-atomized state. Nanoscale chemical partitioning, however, cannot be excluded by the present SEM–EDS measurements.

Hydrogen sorption measurements were performed using a Setaram GasPro HA volumetric analyser. Both alloys were activated at 350 °C under dynamic vacuum, but clearly different activation requirements were observed. Label A was activated after approximately 2 h without mechanical pre-treatment, whereas Label E required manual grinding followed by a substantially longer activation treatment of approximately 10 h. After activation, Label A

exhibited higher hydrogen uptake at all investigated kinetic-measurement temperatures. At 30 °C, the hydrogen content reached 2.64 wt.% for Label A compared with 1.80 wt.% for Label E; at 100 °C, the corresponding values were 2.10 and 1.21 wt.%, respectively.

Absorption pressure–composition isotherms were measured at 30 and 100 °C. Under the investigated PCT conditions, Label A reached maximum experimentally accessible hydrogen contents of 2.84 wt.% at 30 °C and 3.79 wt.% at 100 °C, while Label E reached 2.13 and 1.57 wt.%, respectively. Increasing the Cu content was associated with a systematic shift of the absorption pressure–composition response toward higher equilibrium pressures together with a reduction in accessible hydrogen uptake. This shift is consistent with reduced hydride stability, although quantitative thermodynamic parameters were not determined in the present study. Overall, the results demonstrate a composition-dependent trade-off between equilibrium-pressure tuning, accessible hydrogen-storage capacity, activation requirements, and phase complexity. Within the investigated compositions, the low-Cu alloy provides the more favourable practical balance between hydrogen uptake, activation behaviour, and pressure–composition response.

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