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Contents

Harnessing structural complexity for hydrogen storage in multi-principal element alloys

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Keywords: high-entropy alloys; hydrogen storage; metal hydrides; lattice distortions; phase transformations

Abstract

A central task in advancing hydrogen technologies is the realization of storage systems that combine compactness, reversibility, and safety. Metal hydrides provide a viable pathway, yet their performance hinges on how atomic-scale features shape sorption thermodynamics and kinetics. Here we address this challenge using multi-principal-element alloys designed to incorporate lattice distortions and compositional complexity as tuning parameters. Five equiatomic high-entropy alloys, belonging to the class of multi-principal element alloys, were synthesized by arc melting and processed into fine powders. Their hydrogen interactions were studied through in-situ diffraction, volumetric sorption measurements, and ex-situ structural characterization. This integrated approach enabled direct monitoring of transformations under hydrogen exposure.

Our observations reveal that hydrogen uptake induces pronounced structural rearrangements. Parent BCC solid solutions evolve into hydrogen-rich distorted hydride phases, while intermediate concentrations stabilize mixed states. In-situ diffraction clarified decomposition pathways during desorption, showing that the balance between hydrogen-poor and hydrogen-rich domains is sensitive to both composition and experimental conditions. These findings identify lattice strain as a decisive factor in controlling the reversibility of hydrogen accommodation.

Instead of focusing on individual alloy compositions, this work outlines a conceptual design strategy in which compositional complexity provides a flexible platform for engineering hydrogen storage functionality. By linking structural phenomena with sorption behavior, the study demonstrates how thermodynamics and kinetics can be optimized through alloy design. This framework supports the development of hydride systems that meet the practical requirements of hydrogen-based energy applications, contributing to the broader transition to sustainable energy infrastructures.

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Theoretical and Numerical Investigation of the Effect of Blade Clearance on Heat Transfer and Pressure Drop in Rotary Air Preheaters

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Keywords: LUVO; air preheater; heat recovery; CFD; flue gas; thermal power plant

Abstract

In thermal power plants, flue gas waste heat recovery is crucial for increasing energy efficiency and reducing operating costs. Rotary-type low-temperature air preheaters (LUVOs), commonly used for this purpose, contribute to the overall energy performance of the system by transferring heat between the flue gas and combustion air. However, during long-term operation in these systems, soot, ash, and particulate matter accumulate on the fin surfaces. This accumulation narrows the air and gas passageways, increasing pressure loss and limiting heat transfer, reducing the system's thermal efficiency.

The primary objective of this study is to analyze the fouling effect in LUVO systems in detail through theoretical and numerical calculations, and to demonstrate the impact of different fin geometries and fin span ratios on fouling-induced efficiency losses. In this context, models with different fin spans were created for both clean (ideal) and fouled (deposition-accumulated) surface conditions, and the temperature distribution, total heat transfer, and pressure drop values during flue gas flow were comparatively investigated.

Analysis results indicate that fin geometries with wider spans and lower surface density are more resistant to fouling; conversely, narrow-span structures, despite initially offering high heat transfer performance, quickly suffer significant efficiency losses. Furthermore, it was determined that fouling formation significantly reduces overall heat transfer by creating an additional thermal resistance layer on the surface. These findings will contribute to both new system design and improved maintenance strategies for existing systems.

Advances in Bioenergy and Biofuel for Circular Economy and Sustainability

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Keywords: bioenergy; biofuel; thermochemical conversion; biochar; circular economy

Abstract

The development of bioenergy and biofuel technologies has attracted a great deal of attention and has made remarkable progress over the past several decades. The application of bioenergy and biofuel can lessen fossil (nonrenewable) fuel consumption, abate greenhouse gas (GHG) emissions, and mitigate global warming and climate change. In particular, when bioenergy and biofuel are generated from wastes, such as agricultural wastes, sludge, food waste, etc., these wastes are recovered and valorized, thereby achieving a circular economy. This is conducive to resource and environmental sustainability. Academic research in bioenergy and biofuel fuels plays a vital role in their application in the industry. This talk will introduce the development of bioenergy and biofuel through various thermochemical or chemical conversion processes. For produced biofuels, three-phase products will be elaborated. The characteristics of produced bio-oil, syngas, and biochar from pyrolysis, liquefaction, gasification, and torrefaction will be illustrated. The pretreatment technique for bioethanol production from lignocellulosic and algal biomass will also be underlined. The development of evolutionary computation for bioenergy and biofuel system optimization in recent years will be outlined. In addition to bioenergy and biofuel creation, recent efforts in bioenergy system integration to achieve energy saving and storage will also be addressed.

Experimental and numerical analysis of hydrogen combustion in a high-pressure oxygen-CO_2 environment. Design and performance of a combustion chamber

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Keywords: hydrogen; supercritical CO_2

Abstract

The oxy-combustion of hydrogen with high CO_2 dilution is a key technology in supercritical-CO_2 (sCO_2) power cycles, such as the Allam cycle, which is already in operation in zero-emission power plants with carbon capture. These cycles are known for their high efficiency and offer a promising approach to CO_2 capture. However, there is a lack of data on hydrogen oxy-combustion under high-pressure conditions with high CO_2 concentrations.

A major challenge in this technology is the optimization of gas and oxidizer injection strategies to ensure stable combustion and maintain a constant flue gas outlet temperature, which is crucial for gas turbine operation. The oxidizer consists of a high-pressure mixture of oxygen and CO_2, and the significant density difference between hydrogen and CO_2 complicates the mixing process. As a result, maintaining stable combustion in an oxy atmosphere with over 70% CO_2 at high pressure requires both experimental and numerical investigations.

The existing knowledge on combustion kinetics in CO_2-rich environments is mostly limited to low pressures and low CO_2 concentrations, which do not align with the operating conditions of sCO_2 turbines. To bridge this gap, experimental and numerical studies on hydrogen oxy-combustion with high CO_2 concentrations were conducted.

Numerical simulations were performed using both a global reaction model and a detailed radical mechanism to assess the combustion process. Experimentally, a custom-designed multi-hole injection burner was developed for testing. The burner featured an annular arrangement of 12 holes, each 2 mm in diameter, with six holes alternately designated for hydrogen and the oxidizer.

Numerical modeling helped evaluate the mixing and combustion characteristics under extreme pressure conditions, while experimental studies analyzed the effect of varying CO_2 concentrations, including an additional cooling CO_2 stream. In most tested scenarios, stable flame propagation was successfully achieved, providing valuable insights into the feasibility of hydrogen oxy-combustion under high pressure, high-CO_2 conditions.

Design and Numerical Investigation of a Novel Heat Exchanger for Adsorption Bed Applications

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Keywords: adsorption chiller; heat exchanger design; porous media modelling; dynamic simulation; adsorption/desorption process; sustainable cooling

Abstract

The efficiency of heat and mass transfer within adsorption beds plays a critical role in determining the duration of adsorption/desorption cycles and the overall cooling performance of adsorption chillers. Existing plate and fin-tube heat exchanger configurations, although widely used due to their simplicity and low manufacturing cost, are limited by insufficient heat transfer with the adsorbent material and an excessive proportion of structural metal mass relative to the sorbent volume.

This work presents the concept and numerical modeling of a novel heat exchanger design intended to improve thermal efficiency within adsorption beds. A three-dimensional periodic model was developed in ANSYS Fluent, utilizing User-Defined Functions (UDFs) to dynamically model heat and mass transfer, based on the Dubinin Astakhov (D-A) equilibrium model and the Linear Driving Force (LDF) kinetic model.

The research investigates how heat exchanger geometry, material selection, and manufacturing methods, including additive manufacturing, could enhance heat transfer rates while reducing the structural mass. Different design configurations are analyzed to explore their impact on the thermal and sorption behavior of the bed.

The study aims to establish new design strategies for adsorption bed heat exchangers, supporting the development of more efficient and sustainable cooling systems.

Management of corn silage and tomato residue silage through hydrothermal carbonization process

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Keywords: agricultural biomass; hydrothermal carbonization; hydrochar; process water

Abstract

Corn is primarily grown in Poland and globally for consumption purposes. Corn silage has found applications mainly as animal forage and as a raw material in agricultural biogas plants. Tomato residue refer to the above-ground parts of the plant, primarily stems and leaves, which are treated as waste. The possibility for utilizing these materials is the process of hydrothermal carbonization (HTC). The HTC process is conducted in a special reactor at high temperature and under autogenous pressure. As a result of this process, three products are obtained: process water, hydrochar, and a gaseous phase. Hydrochar exhibits properties similar to lignite, while the process water contains salts and elements such as phosphorus, nitrogen, and potassium. In this study the HTC process was conducted at 190 and 210 °C for 0.5 and 2 h. Hydrochar was then examined for its fuel properties - the ultimate analysis and higher heating values were determined. The process water was assessed for its potential use as liquid fertilizer. For the analysis the spectrophotometer was used to investigate the phosphorous compounds and nitrogen content. The results showed that corn silage is characterized by better fuel properties than tomato residue silage. However, the process water produced from tomato silage has higher phosphorous and nitrogen content. The properties of products obtained in the HTC process are influenced by the residence time and temperature of the process.

Coated Adsorption Beds for Enhanced Heat Transfer in Adsorption Cooling Systems

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Keywords: conductive binders; composite sorbents; adsorption cooling; sorption capacity; heat transfer

Abstract

The increasing demand for sustainable cooling technologies encourages the development of solutions capable of utilizing low-grade heat sources. Among them, adsorption chillers, which can be driven by waste heat or solar thermal energy in the 50–90 °C temperature range, offer an environmentally friendly alternative to conventional vapor-compression systems. However, broader implementation is hindered by relatively low coefficient of performance (COP), primarily due to limited heat transfer within the adsorbent bed.

This study investigates the impact of thermally conductive binders on the performance of composite adsorbent beds. A selection of binder materials with inherently different chemical bases including epoxy resins, polyurethane resins, polyvinyl alcohol (PVA), and cellulose derivatives were modified with metallic and carbon-based modifiers to enhance thermal conductivity while preserving sorption characteristics. The binders were applied to wide- and narrow-pore silica gels in a controlled multi-step fabrication process aimed at achieving optimal thickness, porosity, and adhesion.

The influence of the modified binders on key thermophysical and sorption parameters was assessed through a comprehensive set of measurements. Thermal diffusivity and conductivity were determined using the laser flash analysis (LFA) method across a range of temperatures. Simultaneously, differential scanning calorimetry (DSC) was employed to assess specific heat capacity, while vacuum-based gravimetric sorption (DVS) experiments enabled the evaluation of equilibrium capacity and sorption kinetics. Additionally, structural analyses of the composite samples were conducted using a metallurgical microscope and the thermal stability of the binders was further examined via thermogravimetric analysis (TGA).

The results demonstrate that by incorporating thermally conductive binders into silica gel-based composite beds, it is possible to improve the effective thermal conductivity of the adsorbent layer by up to 180%, with a few percent loss in adsorption performance, compared to loose-packed sorbent granules. This approach offers a promising pathway to reduce cycle times and improve the overall efficiency of adsorption chillers, particularly in systems recovering waste heat.

Factors affecting mercury emissions from residential solid fuel boilers

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Keywords: residential boilers; solid fuel boilers; emission; mercury

Abstract

The use of solid fuels results in mercury emissions. This is related to the high volatility of mercury, which is released into the flue gas in the boiler. Residential boilers, in contrast to industrial boilers, are not equipped with flue gas cleaning system. Furthermore, power plants must meet mercury emission standards, resulting in lower emissions from this source. Thus, the contribution of the municipal sector to global mercury emissions is increasing. This may lead to the introduction of emission regulations in the future. To address this issue, the factors affecting mercury emissions from residential solid fuel boilers and the possibility of its decrease are presented in the paper.

Annual mercury emissions (heating season) from residential solid fuel boilers were assessed. Boilers of different classes supplied with hard coal or biomass pellets were analyzed. Fuel and solid by-products of combustion were sampled: bottom ash, heat exchanger deposits, and soot collected from the chimney. The mass of by-products and mercury content were determined.

Between 39 and 99% of the mercury contained in the fuel was emitted into the atmosphere. The amount of mercury emitted was determined by both the mercury content in the fuel and the amount of mercury adsorbed in the solid by-products. Mercury was mainly absorbed by soot (up to 57%), where up to 17514 µg/kg was recorded. Paradoxically, in the case of high-class boilers, where the combustion process is more efficient, mercury emissions will increase.

Practically, the only effective method to reduce mercury emissions from residential boilers is to use fuels with the lowest possible mercury content. Wood and wood pellets are preferred. However, in the case of using waste biomass, mercury emissions can be significant and even higher than those of coal (e.g., tree leaves). The removal of mercury from this type of biomass can be performed by the torrefaction process. In some cases, it allows for the removal of up to 100% mercury. The use of torrefied biomass will successfully reduce mercury emissions from the residential sector to a minimum.

Biowaste and the circular economy: some significant examples based on hydrothermal, biochemical and extraction processes

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Keywords: circular bioeconomy; biomass; biorefinery; hydrothermal processes; process integration

Abstract

The presentation will illustrate the research activities of the "Green Processes Engineering" group at the University of Trento - Northern Italy.

The main technologies under study will be illustrated first: hydrothermal technologies (hydrothermal carbonization in primis, but also thermal hydrolysis, hydrothermal liquefaction, gasification in supercritical water) and extraction with supercritical CO_2. The other technologies in use will follow: extraction with subcritical water and with solvent at atmospheric pressure, pyrolytic and activation processes, biological processes such as anaerobic digestion and composting.

The group's research projects will then be illustrated, from the most innovative to those on which work has been carried out for the longest time. These projects all show a common characteristic: the search for new process paths to enhance residual biomass and organic waste, to give them a new life.

And so:

- Waste bioplastics (which end up in organic waste, but which cause problems to anaerobic digestion plants) which can be transformed for the recovery of biomethane, or to convert them into carbon micro particles (and carbon black?).
- Fish (namely, trout) processing waste transformed into fish proteins, fish oil, and omega-3 concentrates.
- Tomato processing waste from the production of tomato sauce from which to extract lycopene and bioactive compounds.
- Enhancement of apple juice production waste for fertilizer productions.
- Grape marc valorization through recovery of grape seed oil, polyphenolic compounds, and fibers.
- Manure treatment and valorization for nutrient-enriched biochars, phosphorous recovery, biogas production.

- Intensification of the OFMSW treatment by integrating anaerobic digestion, hydrothermal carbonization and composting.
- Integration of hydrothermal technologies in wastewater treatment plants.

Fire behaviour of Twisted Pair communication cables

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Keywords: communication cable; fire load; conical calorimeter; heat of combustion; heat release rate

Abstract

Twisted Pair cables, either in unshielded version (UTP cables) or with some variant of shielding (F/UTP, S/FTP, etc.), are used as a basic building element of universal (structured) cabling in buildings. The most common use of this cabling is for data transmission in computer networks and for telephone networks in buildings, but it is also used for other data transmissions and analogue signal transmissions. With the more widespread use of electronics, universal cabling is appearing not only in amenity buildings, manufacturing facilities, medical facilities, etc., but also in new single-family homes and apartments. The extent of this cabling in buildings has increased significantly compared to the past. Although Twisted Pair cables do not pose the same f ire risk as power conductors, they can contribute significantly to the development of a f ire due to the material composition of the insulation of the individual cores and sheath.

This paper focuses on the assessment of the fire performance of Category 5 and 6 Twisted Pair cables, primarily through calorimetric methods, as key characteristics describing the behaviour of materials in fire.

Novel Composite Materials for Adsorption Chillers Powered by Low-Temperature Heat

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Keywords: adsorption chiller; low-temperature heat; composite sorbent materials; silica gel–salt composites; sustainable cooling technologies

Abstract

The research presented in this work focuses on the development of new composite sorption materials for adsorption chillers powered by low-temperature heat sources. The main objective is to enhance the performance parameters of adsorption cooling systems while simultaneously reducing their overall weight and dimensions. To achieve this, silica gel is employed as the base sorbent material, modified through the incorporation of selected inorganic salts.

The scope of the study includes a systematic evaluation of the fundamental properties of silica gels, followed by the design and optimization of impregnation techniques aimed at maximizing sorption capacity, thermal conductivity, and mechanical stability of the composite materials. Special emphasis is placed on identifying the most effective impregnation methods to ensure uniform salt distribution within the porous structure of silica gel, thereby enhancing the material's overall adsorption–desorption performance.

The research methodology involves the preparation of various silica gel–salt composites, experimental verification of their structural and sorption properties, and a comparative assessment of their performance relative to pure silica gel. By tailoring the composition and processing techniques, the project aims to achieve a significant improvement in both the cooling efficiency and the compactness of adsorption chillers.

Ultimately, the expected outcome of this work is the development of advanced composite materials that not only expand the applicability of adsorption-based cooling systems to low-grade thermal energy sources but also contribute to sustainable energy management and reduction of greenhouse gas emissions through the use of environmentally friendly cooling technologies.

Acknowledgment:

This research project was supported by the program „Excellence initiative – research university" for the AGH University of Krakow.

Optimization of Artificial Neural Network Parameters for Modeling Flue Gas Composition from Woodstove Combustion of Beech Wood and Briquettes

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Keywords: artificial neural networks; wood combustion; flue gas emissions; model optimization; biomass fuels; low-emission heating

Abstract

Efficient and environmentally responsible wood combustion remains a key challenge in domestic heating. This study focuses on the development and optimization of artificial neural network (ANN) models to predict flue gas composition based on the operational parameters of a woodstove during combustion of two biomass types: beech wood and commercial wood briquettes. Experimental data were collected under controlled conditions, with variations in air supply, fuel load, and combustion phase, enabling high-resolution tracking of CO, CO_2, O_2, and NO_x emissions.

Multiple ANN architectures were tested, including multilayer perceptrons (MLPs) with varying numbers of hidden layers and neurons, trained using backpropagation and Adam optimization. Key performance metrics such as mean squared error (MSE), R^2 score, and generalization ability were analyzed to identify the most effective network configurations for both fuel types.

The results indicate that optimal network architectures differ depending on the biomass type, highlighting the need for fuel-specific modeling strategies. For briquettes, simpler architectures yielded sufficient accuracy due to more stable combustion characteristics. In contrast, beech wood combustion—being more dynamic—required deeper networks with regularization techniques to avoid overfitting. Sensitivity analysis revealed air flow rate and combustion phase as the most influential predictors.

This research demonstrates the potential of ANN-based models in real-time combustion diagnostics and control, contributing to more efficient and cleaner use of biomass fuels. The f indings support future integration of intelligent control systems in residential heating devices, aligned with low-emission strategies and energy efficiency standards.

Performance analysis of mixed fuels in low and medium-temperature SOFC

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Keywords: MS-SOFC; partial differential equations; water-to-carbon ratio

Abstract

In this novel study, the mass transfer and energy balance equations for the metal supported layer solid oxide fuel cell model (MS-SOFC Model) and the steam reforming model (Steam Methane Reformer Model) are described using partial differential equations. In the context of MS-SOFC, the primary focus is on achieving low temperature operation at 600°C and enhancing current density. Lowering the temperature increases the voltage loss due to polarization, leading to a decrease in current density. Therefore, it is crucial to improve the conductivity of the materials and reduce their thickness. This approach allows for the optimization of current density, temperature distribution, voltage, and other cell reaction mechanisms. The peak power density using pure hydrogen fuel is 0.24201 W cm . The highest peak power density for the hybrid fuel, at a water-to-carbon ratio of 2 and a methane vapor reforming reaction rate of 100%, was 4.793% lower than that of the pure hydrogen fuel.

Thermochemical conversion of food waste toward production of new porous materials

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Keywords: activated carbon; waste biomass; gasification; circular economy; adsorption

Abstract

According to the UNEP Food Waste Index Report 2024, about 1.05 billion tonnes of food were wasted globally in 2022, posing serious environmental, economic, and social challenges. This large amount of organic waste represents not only a loss of valuable resources but in further perspective a potential feedstock for renewable energy and material recovery. Through thermochemical processes such as pyrolysis or gasification, food waste can be converted into hydrogen-rich syngas and porous carbonaceous materials (char), offering a sustainable pathway for waste valorization and contributing to circular economy goals. This study explores a potential pathway for converting food waste into valuable products through gasification, especially high-porosity char suitable for heavy metal capture in water treatment technologies.

In this study gasification experiments were performed on four samples of crop residues and by-products from food processing using a fixed-bed laboratory setup at 900 °C under a CO_2 atmosphere. The primary aim was to examine how feedstock properties influence char and syngas yields. To characterize the gasification products, elemental analysis (C, H, and N content) of the raw materials and resulting chars was performed, along with gas chromatography (GC) for syngas composition analysis.

Chars produced through gasification of biomass are effective adsorbents for the removal of heavy metals from wastewater. Their high surface area, porous structure, and surface functional groups enable strong interactions with metal ions. The efficiency of metal adsorption depends on various factors, including the feedstock type, gasification conditions, pH of the solution, contact time, and initial metal concentration. Heavy metals adsorption tests were performed for zinc (Zn), chromium (Cr), copper (Cu), and nickel (Ni) ions in water using UV/VIS method. Obtained results shows that chars derived from agricultural residues such as sunflower hulls, buckwheat hulls, and tomato stems show promising potential as low-cost, sustainable adsorbents for heavy metal remediation in contaminated water systems.

Acknowledgment:

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The Importance of Sorption Technologies for the Energy Transition

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Keywords: sorption; CO_2 separation; H_2 storage

Abstract

Sorption technologies are of central importance for the energy transition, as they reveal efficient ways to store energy, removing pollutants from gaseous energy sources or optimize thermal systems. These technologies help to make renewable energies more usable and increase energy efficiency in various applications. The role of sorption technologies will be explained in the lecture using a number of examples. CO_2 gas purification and capture with special sorbents can remove CO_2 from industrial processes or air, which is pivotal for reducing greenhouse gas emissions. This CO_2 capture technology makes it possible to use the captured CO_2 later for industrial purposes or for storage. Another example is the circular economy of hydrogen, which is closely linked to the use of CO_2 (see Fig. 1). Hydrogen plays a key role in the energy transition, but its storage is a technical challenge. Sorbents such as systems based on solid materials, e.g. metal hydrides, enable efficient and safe hydrogen storage, proving to be crucial for mobile and stationary applications. Liquid storage systems such as NH_3, for example, can make use of existing infrastructure (e.g. transportation by ship). However, ammonia decomposition for the release and utilization of hydrogen is associated with gas purification steps. The advantages and disadvantages of the potentially applicable sorption processes will be presented and discussed during the lecture.

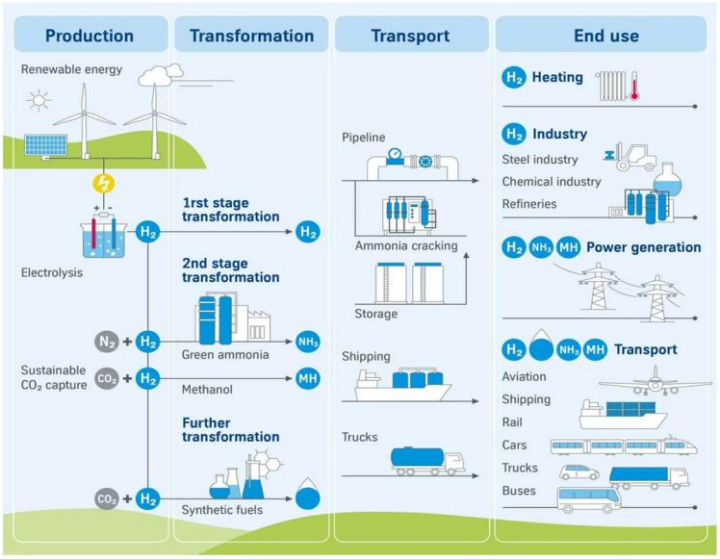

Fig. 1 Concept by thyssenkrupp Uhde GmbH for the production, transportation and use of ammonia as an energy source for hydrogen (taken from Ref. [1]).

[1]https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/gruenes-ammoniak-und sein-beitrag-zur-bewaeltigung-des-klimawandels.

Thin-layer drying kinetics of tomato waste for biorefinery purposes – an LCA perspective

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Keywords: drying; kinetics; tomato waste; biorefinery; LCA

Abstract

Tomato is an important fruit, with approximately 12 million tonnes processed each year considering agricultural sector worldwide [1]. Approximately 44% of this crop is produced in the Mediterranean region, which could be associated with approx. 2.4 million tonnes of processing waste [1]. Tomato waste has a signifficant potential in terms of its use as a feedstock in biorefineries and recovery of many valuable compounds, including oil, lycopene, and proteins. However, use of extraction processes for recovery of such compounds requires pre-drying, which is costly due to energy requirements and investments needed for the suitable process machinery. This work presents results of experimental study on kinetics of thin-layer drying, which could be used for optimisation of the size of required dryer. Among the thin-layer models, the modified Page model and Midilli model performed the best among all applied models, when it comes to fitting to experimental data, achieving the lowest root mean square error. Obtained kinetic data was used for estimating the size of a suitable thin film dryer, which enabled including capital goods within the scope of performed LCA, thus providing valuable insight on sustainability of such process. In terms of generating heat required for drying, different options were taken into account. Among the energy carriers, environmental performance of the natural gas has been compared with the use of biogas, produced by anaerobic digestion of a part of the feedstock.

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Efficiency Enhancement in Adsorption Chillers Through Glue Bed Application

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Keywords: adsorption chillers glue beds; thermal efficiency; heat transfer enhancement; sustainable cooling systems

Abstract

An adsorption chiller is a device used in industrial engineering applications to produce chilled and desalinated water by utilizing low-grade thermal energy as the primary input. Despite their potential for sustainable cooling, the adoption of adsorption chillers remains limited due to their relatively low coefficient of performance (COP). Attempts to enhance their efficiency often result in increased weight and size, which further restricts their widespread implementation. One of the key parameters influencing the performance of adsorption chillers is thermal resistance— particularly in the region between the adsorption bed and the heat exchanger surface. High thermal resistance in this area reduces the unit's energy transfer efficiency and overall performance. To address this issue, this study explores the use of adhesive-filled (glued) adsorption beds. By partially replacing the gaseous voids in the interstitial spaces of the bed with an adhesive material possessing lower thermal resistance, it is possible to enhance heat transfer between the adsorption bed and the fluid in the embedded pipe system. The reduced porosity in such a glued structure leads to better thermal conductivity and thus improved heat exchange. The primary objective of this work is to develop an innovative adsorption unit that incorporates a specially designed glued adsorption bed. This new configuration aims to improve the heat transfer coefficient between the adsorption material and the working fluid, thereby significantly increasing the COP of the system. As a result, the developed technology will contribute to greater energy efficiency and reduced consumption of primary energy sources in the operation of adsorption chillers.

Calorimetry of Phase Change Materials (PCM) for heat storage applications

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Keywords: PCM; thermophysical properties; calorimetry; 3-layer-calorimeter, melting enthalpy, thermal storage; TES

Abstract

Latent heat storage systems based on phase change materials (PCM) can play an important role in the transition to heating systems based on renewable but volatile energy sources. Important properties of these materials are among others the phase transition enthalpy, the phase transition temperature and the cycling stability [1]. The measurement of these properties is for example described in the PCM-RAL [2]. For salt hydrate-based PCMs, the phase transition temperature may depend not only on the sample composition, but also on the sample size. For this reason, conventional DSC using small sample sizes is not recommended for investigating them. Instead, calorimeters with a large sample volume, such as the 3-layer calorimeter, are recommended. Some of these large calorimeters also offer other advantages over standard DSCs: For example, the 3 layer calorimeter has a cost-effective design, and samples can be measured directly in the vessel necessary for cycling the PCM in a cycling machine. This makes it easy to observe how the phase change enthalpy degrades after the PCM has undergone a defined number of melting and freezing cycles. However, the 3-layer calorimeter is currently only available from one company, W&A (Wärme- und Anwendungstechnische Prüfungen, Fürstenwalde, Germany), and it is supplied pre-calibrated using water and hexadecane as reference materials, with no detailed information about measurement uncertainty [3]. Therefore, there are still some open questions in the field of 3-layer calorimetry that are addressed in this work: What level of accuracy can be achieved with the three-layer calorimeter? How can it be calibrated over the entire temperature range with less effort, and how can the measurement accuracy of both the phase change enthalpy and temperature be optimized? To answer these questions, we will investigate the temperature distribution in the 3-layer calorimeter using high-precision temperature sensors. We will also develop a calibration procedure using an electric heater in combination with water as a reference material. Finally, a simulation-based calibration and evaluation routine will be developed to improve measurement accuracy. The underlying work is ongoing, and the results of the measurements will be presented at the conference.

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NewHeatIntegrated - Development and Integration of a two stage latent heat thermal energy storage system in the built environment

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Keywords: thermal energy storage; latent heat; phase change materials; cycle stability; state of charge determination

Abstract

In the European Union, the demand of energy for heating and cooling purposes accounts for approxi mately 50% of the total energy consumption. The utilization of thermal energy storage systems plays a pivotal role in enhancing energy efficiency and reducing dependency on fossil fuels. This is achieved through the recovery of waste heat or the implementation of power-to-X applications. The EU project NewHeatIntegrated is focused on the research and development of a novel multi-stage la tent heat energy storage system (LHTES) based on phase change materials (PCM). For the purposes of evaluation and demonstration, three full-scale systems will be built, installed, and operated during a com plete heating season in Germany, Finland, and the Czech Republic.

The critical material properties that are required for a PCM to be utilized as a thermal storage material in technical applications include a suitable phase transition temperature and high storage density at a low cost. It is imperative to ascertain the cycling stability of the material itself and of its thermal properties in order to ensure reliable performance over a multitude of charge and discharge cycles. The work presented includes the modification of different salt hydrates as PCM and a machine learning based measurement approach to determine the state of charge of the LHTES.

For the material modification, the following substances were selected: calcium chloride hexahydrate (CCH), di-sodium hydrogen phosphate dodecahydrate (DSHPD), and sodium thiosulfate pentahydrate (STP). These substances have phase transition temperatures between 25°C and 50°C. A variety of thicken ers are subjected to rigorous testing to ascertain their efficacy in increasing viscosity and preventing phase separation during technical applications. The stability of the cycle is determined through the implementa tion of extensive thermal cycling, which comprises over 2,500 melting/crystallization cycles. This is fol lowed by a thorough evaluation of melt enthalpy and phase transition temperature. Following the com pletion of 1,500 cycles, a preliminary PCM composition was identified, exhibiting a stable

melting temper ature ranging from 25°C to 26°C and a minimal decline in storage capacity of 8%, from 137 kJ/kg to 128 kJ/kg.

At the system level, the primary objective of this presentation is to ascertain the state of charge (SoC) of the thermal storage. It is imperative to ascertain the precise SoC to ensure optimal thermal management and effective control of the storage system. In contrast to a sensible heat storage system, where a unique assignment can be made to a specific temperature, the SoC of a latent heat storage system cannot be uniquely assigned to a single temperature. This necessitates the collection of more detailed and precise information. Therefore, a machine learning algorithm is employed to identify a sufficient set of sensor lo cations from a dense network of sensors within a full-scale test storage system to obtain reliable state of charge information with minimal measurement effort. Preliminary results indicate that a reduced data set can be identified to accurately determine the SoC.

The findings of the research activities will be presented at the conference.

Advanced Materials for Chemical and Electrochemical Energy Conversion and Storage

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Keywords: fuel cells; supercapacitors; synthetic fuels; porous materials; 3D printing; hierarchical structure

Abstract

The transition to sustainable energy systems depends on the development of advanced materials that combine tailored chemical composition with optimized microstructure. Recent research has focused on electrochemical energy technologies, including fuel cells, supercapacitors, hydrogen storage systems, and synthetic fuel production, where porous and hierarchically structured materials play a central role. These materials enable efficient charge transport, gas diffusion, and catalytic activity, all of which are critical for high performance and long-term stability.

In high-temperature fuel cells, novel electrode and support materials are being designed to enhance electrochemical activity, durability, and fuel flexibility. Strategies include the use of metal-ceramic composites for the electrodes. The integration of hierarchical porosity improves mass transport and facilitates the distribution of reactive species. For supercapacitors, the focus is on materials with high surface area and pseudocapacitive behavior. Transition metal oxides, heteroatom-doped carbons, and hybrid nanostructures are being engineered to increase energy density while maintaining rapid charge-discharge characteristics.

In the domain of synthetic fuels, 3D-printed catalytic structures are emerging as game changers. These catalysts, often based on structured metal or ceramic frameworks, offer enhanced heat and mass transfer properties and can be functionalized post-printing to tune activity and selectivity. Such innovations are particularly relevant for CO_2 conversion and hydrocarbon synthesis.

Hydrogen storage remains a critical bottleneck for hydrogen-based energy systems. New materials, such as complex metal hydrides, porous aerogels, are being developed to meet the challenges of gravimetric capacity, reversibility, and operating temperature. Structural design at the nano- and mesoscale is essential to optimize kinetics and thermodynamics. This abstract highlights the synergistic role of material innovation and 3D architecture in advancing electrochemical energy systems. By combining experimental techniques with computational modeling, researchers are uncovering the structure-property relationships that drive performance, paving the way for scalable, efficient, and sustainable energy technologies.

Investigating pretreated sewage sludge by hydrothermal carbonisation in energy or soil applications

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Keywords: hydrochar; process water; toxicity; fuel properties; biomethane potential

Abstract

Hydrothermal carbonization has been suggested as a potential and successful solution to improve the dewaterability of sewage sludge. The solid and liquid products might be successfully used for energy production or applied in other sectors. For this study, the hydrothermal carbonization of sewage sludge was investigated at 210°C for a period of 2 hours. Hydrochar was tested in terms of fuel properties using ultimate and proximate analyses supported by thermal analysis. The biomethane potential of process water was determined. The process water exhibited favourable biogas potential, while the combustible properties of hydrochar were weak due to the high ash content that exceeded 50%. Therefore, another option for hydrochar disposal was investigated, such as its application as a fertiliser or soil improver. For that reason, it was necessary to determine the toxicity of hydrochar and its aqueous extracts before their use in agriculture. Hydrochar toxicity tests were evaluated for hydrochar aqueous extracts on the inhibition of crustaceans, bacteria, and macrophytes. Regarding hydrochar, the inhibition of monocotyledon and dicotyledonous plants was also determined. In summary, hydrochar aqueous extracts were toxic to shellfish and bacteria, excluding macrophytes. In addition, they indicated a stimulating effect in the above-ground parts of Horodeum vulgare and Sinapis alba even though the hydrochar inhibited the growth of the tested plants.

Microwave Plasma Reforming of CH_4/CO_2 Mixtures

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Keywords: hydrogen; syngas; warm plasma; sustainability

Abstract

The increasing generation of paper production waste presents both an environmental challenge and an opportunity for sustainable energy recovery. Anaerobic digestion offers an effective solution by converting organic waste into biogas, primarily composed of methane (CH_4) and carbon dioxide (CO_2). While biogas is commonly used for combustion in combined heat and power (CHP) units, its potential extends further. One promising pathway is dry reforming of methane (DRM), a process that converts both CH_4 and CO_2 into syngas, a mixture of carbon monoxide (CO) and hydrogen (H_2). Following membrane separation, this syngas can serve as a renewable hydrogen source.

In this work, we investigate an alternative, catalyst-free approach to DRM using microwave plasma. This non-thermal plasma generates high temperatures and reactive species, enabling efficient reforming reactions without the need for catalysts. Experiments were conducted with simulated CH_4/CO_2 mixtures, varying gas composition, input power, and volumetric flow rate. Methane conversion ranged from 40% (at 40 SLM, 1800 W) to 90% (at 20 SLM, 3000 W). Results indicate that maintaining a CO_2/CH_4 ratio above 2 prevents soot formation but reduces H_2 yield due to its reaction with CO_2 to form H_2O. Under soot-free conditions, the maximum H_2:CO ratio achieved was approximately 0.4.

Determination of pressure loss caused by the catalyst body itself in relation to increasing volumetric flow of the medium.

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Keywords: flue gas purification; small scale combustion appliances

Abstract

The increasing use of small biomass combustion appliances for household heating highlights the importance of effective flue gas treatment to comply with tightening emission limits. Catalysts, often integrated into flue gas paths, represent a promising secondary measure for reducing pollutants such as CO and organic gaseous compounds. However, their honeycomb structures are prone to clogging and may contribute to higher pressure losses in flue gas systems. This study investigates the course of pressure loss caused by catalyst structures depending on the increasing volumetric flow rate of the flowing medium. Seven honeycomb catalysts differing in material composition, cell density, and height were experimentally tested using a laboratory measuring stand with controlled air flow. Pressure losses were continuously monitored before and after each catalyst, while volumetric flow was determined via the Venturi effect. The results show that the structural parameters of the catalysts, particularly height and cell density, significantly influence the magnitude of pressure loss. For instance, doubling the height of a FeCralloy-based catalyst led to a fourfold increase in pressure loss at comparable flow rates. Catalysts with higher cell density exhibited markedly higher resistance compared to those with coarser structures. These findings underline the necessity of considering both emission reduction efficiency and hydraulic resistance in the design and application of catalytic converters in small-scale biomass combustion units.

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