International Conference on Sustainable Materials and Energy Technologies

ICSMET 2019

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International Conference on Sustainable Materials and Energy Technologies

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ICSMET 2019

International Conference on Sustainable Materials and Energy Technologies

The Coventry University, UK is honoured to host the International Conference on Sustainable Materials and Energy Technologies from the 12th to 13th September 2019, organised by International Society of Engineering Science and Technology (ISEST). The Coventry University is a public teaching focused university in Coventry, England. The origins of Coventry University can be traced back to the founding of the Coventry School of Design in 1843. The Higher Education Act 1992 afforded it university status that year and the name was changed to Coventry University. With more than 31,690 students in 2017, Coventry is the larger of the two universities in the city and the fastest growing university in the UK. Coventry also governs their other higher education institutions CU Coventry, CU Scarborough and CU London, all of which market themselves as an "alternative to mainstream higher education". Its four faculties, which are made up of schools and departments, run around 300 undergraduate and postgraduate courses. Across the university there are 11 research centres which specialise in different fields, from transport to peace studies. Nationally, Coventry is ranked 13th by The Guardian University Guide 2020, 44th by The Times/Sunday Times University Guide 2020 and 53rd by The Complete University Guide 2020. In 2017, the university gained a Gold in the Teaching Excellence Framework (THE). Coventry is a member of the University Alliance mission group.

Now, let me briefly present the main organizer of this conference, International Society of Engineering Science and Technology. The ISEST is a non-profit independent organisation founded in 2007. This is an organisation of compatible scientists, professionals, engineers, academicians, technologists, students and freelancers that promotes education and research activities in the field of Science Engineering and Technology worldwide to outfit the needs for the better future of the society.

With three keynote lectures and a total of 85 oral and poster presentations distributed in 12 sessions, the ICSMET 2019 Conference program reflects the success of this edition, in line with previous ones. There are then main topics including; energy technology and renewables, energy storage and conversion, sustainable cities and environment, nanomaterial and green chemistry, fluid flow and heat transfer, computer and applied mathematics. A closer look at the program reveals the extensive participation of both industry and academia, with the common objective of sharing the latest scientific advances to help improve knowledge about the energy, material and innovative methods and process for different applications.

Last but not least, I would like to convey our warmest welcome to all the guests attending the conference, wishing them a fruitful conference and enjoyable stay in Coventry.

Dr Farooq Sher

Conference Chairman

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Extended Abstracts

Applications and procedures of using of biomass in electricity generation, heating and cooling systems in residential areas and factories with financial evaluation

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Abstract

Nowadays, supplying of consumption energies for buildings and factories is one of the most significant discussions and concerns of the international community since the reserves of fossil fuels are limited and on the other hand use of these resources for energy production has negative effects (e.g. climate change) on the biosphere and has endangered the lives of humans and animals. Biomass in this case, is waste material from plants, farming, food processing, etc. These substances can be used in a different way, as the production of energy or as raw materials for producing chemicals. Burning biomass releases carbon emissions, however, has been classified as a renewable energy source in the EU and UN legal frameworks, because plant stocks can be replaced with new growth. It has become popular among coal power stations, which switch from coal to biomass in order to convert to renewable energy generation without wasting existing generating plant and infrastructure. Biomass most often refers to an energy source and can either be used directly by combustion to produce heat and producing electricity or indirectly after converting it to various forms of biofuels. In this study, we aimed to investigate the use of biomass as renewable energy sources and replacing these materials with conventional fossil fuels for producing energy in the form of electricity, heating and cooling systems in buildings and factories. At the end, we also aimed to evaluate the efficiency of application of these substances compared to fossil fuels in terms of energy production, economics and its environmental impacts.

Keywords

Renewable energy, Biomass, Fossil fuels, Electricity production and Climate change.

Mechanical properties and durability of sustainable concrete made with low clinker ternary blends

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Abstract

Reduction in greenhouse gas emission is being emphasized in everyday life. To meet the global infrastructure demand cement production is increasing. Cement production is the most energy-intensive process contributes 7% of total man-made carbon dioxide. To reduce the environmental impact various low carbon initiatives have been taken. Clinker replacement is one of the popular and well-known processes. Today Indian standards allow the replacement of cement with fly ash up to 35% and also the use of fine fillers like limestone in cementitious content is prominent from ancient time. In this paper, the author has tried to replace 50% of clinker with fly ash and limestone by using their synergic behaviour. Both fly ash and limestone used in this research are waste products and of low quality. The use of these materials can also be a better way of solid waste utilization. No improvement in mechanical properties like compressive strength and flexural strength have been observed but also there is no strength loss reported till 90 days. The durability properties like resistance to the chloride ion ingress, water absorption of fly ash limestone ternary blends have improved.

Keywords

Carboaluminates, Carbon dioxide, Durability, Strength, Sustainable Concrete and Ternary blends.

Effect of sawdust blending and desulphurization on flue gas emissions of Nigerian sub bituminous coal briquettes

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Abstract

The effect of blending and desulphurization of coal and biocoal briquette of Nigerian sub-bituminous coal is discussed. The flue gas of the coal and biocoal samples was analyzed to study the emission characteristics of nitrogen oxide (NO2), sulphur dioxide (SO2) and carbon monoxide (CO) due to environmental concern with the use of coal as either domestic or industrial fuel. Sub-bituminous coal samples from eight coal mines and sites in five states in Nigeria were collected. The states and sites included Kogi (Ogboyoga, Okaba), Benue (Owukpa), Nassarawa (Lafia/Obi), Ebonyi (Afikpo) and Enugu (Okpara, Onyeama and Ezinmo). The samples were pulverized and blended with sawdust at various constituent ratios of 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 sawdust : coal. Cassava starch was used as binding material while calcium hydroxide was used as a desulphurizing agent for the briquettes. Emission tests for various compositions of the briquettes were carried out and the O_2, CO_2, CO, NO_2 and SO_2 of the briquettes were compared. The sulphur dioxide of the coal deposit range between 0.02ppm and 0.028ppm, these decreased substantially with increase in sawdust concentration and addition of desulphurizing agent in all the compositions to between 0.025 ppm and 0.005 ppm for biocoal briquette samples, the Okaba 50:50 biocoal briquette has the lowest with 0.005 ppm, these are below the national ambient air quality standards which put sulphur dioxide at 1.4x101 ppm. The nitrogen oxide decreased marginally in all the coal and biocoal briquettes with an increase in sawdust concentration and addition of desulphurizer; Onyeama biocoal briquette has the lowest nitrogen oxide of 0.019ppm while sawdust briquette has 0.08ppm. These are below the national ambient air quality standards which put nitrogen oxide at 5.3 x 101 ppm. Carbon monoxide for the raw coal ranges between 0.3ppm and 0.48ppm which progressively decreased as the sawdust concentration increased from 100% coal briquettes to 50:50 biocoal briquettes and addition of desulphurizer; these are below the national ambient air quality standards at 6.67 ppm. The concentration of carbon dioxide in all the samples range between 2.4% and 3.3% which are below the harmful level. The portion of oxygen that has not been consumed by the combustion process remains as part of the flue gas. The study revealed that the addition of sawdust and desulphurizer to coal at various concentrations to form biocoal briquette resulted in the reduction of harmful emission of gases such as carbon monoxide, sulphur dioxide and nitrogen oxide.

Keywords

Renewable energy, Biomass, Fossil fuels, Electricity production and Climate change.

Effects of exhaust gas recirculation on temperature, using biodiesel blends

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Abstract

This present work focused on experimental work to compare the effects of temperature and emissions produced using WPPO biodiesel blends under the influence of EGR. The mixtures were prepared in the ratios of 10%, 20%, 30%, 40% and 100%, for WPPO10, WPPO20, WPPO30, WPPO40 and WPPO100 respectively. The EGR flow rate was 5%, 10%, 15%, 20%, 25% and 30% respectively. Testing and performance was on a Kirloskar engine, water cooled, direct injection operating at 1500 rpm and a torque of 28 Nm. The EGR system was modified with an addition of the EGR and valve in the exhaust system. The study has three objectives: (i) to investigate the effect of temperature on the emission characteristics of a diesel engine using WPPO biodiesel blends compared to conventional diesel baseline fuel. (ii) To find the effect of EGR on WPPO biodiesel ratio on the exhaust gas temperature compared to baseline conventional diesel fuel. (iii) To find out the trade-off point for the WPPO biodiesel blends temperatures in relation to the EGR % flow rate. Following testing and evaluation, the highest temperature obtained for conventional diesel was 456 ^{o}C compared to 490 ^{o}C for WPPOB100 blend both at 0 % EGR flow rate. However, the other WPPO blends show trends of decreasing temperatures with the application of EGR % flow rate. Other results show increasing blend ratio and the EGR percentage, flow rate increased smoke emissions across all the WPPO blends tested. This study confirms that the WPPO biodiesel blends can produce lower EGT temperatures with the application of the EGR technique of NOX control, but with higher emissions of UHC for WPPO100 blend.

Keywords

Biodiesel blend ratio, EGR flow rate, Exhaust gas temperature, Waste plastic and Pyrolysis oil.

Performance study of powdered waste glass reinforced recycled high density polyethylene composite for partition board

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Abstract

The research investigates the performance of waste glass powder reinforced recycled high density polyethylene composite that is fabricated by using press molding machine. Use of those waste material which is available in everywhere for the production of new composite have a great significant in minimizing landfill by waste and gives alternate accessory of partition board due to its less water absorbability relative to wood based partition board and less weight relative to sheet metals partition boards. Based on Taguchi experimental design high density polyethylene content (75%, 85%, and 95%), glass powder content (25%, 15%, and 5%), particle size of the glass (<63µm, 63-106µm, and 106-150µm), and pressing load (15 kN, 30 kN, and 45 kN) are considered as parameters of the composition in fabricating the composite. The test samples were prepared as per ASTM standards to carryout mechanical properties (like compression strength, flexural strength, impact strength, and hardness) and physical properties (like percentage water absorption and density). Since powder glass and high density polyethylene plastics have hydrophobic property their compatibility is optimum. Based on the experimental result mechanical and physical properties of the composite are optimum at the composition of 85% recycled high density polyethylene, 15% waste glass powder, 63-106 µm waste glass powder particle size, and 45 kN pressing load.

Keywords

Mechanical properties, High density polyethylene, Glass powder, Particle size, Pressing load and Composite.

Improving gaseous pollutant treatment efficiency in wet scrubbers

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Abstract

Air pollution, particularly industrial air pollution, is currently a serious global problem which has led to climate change as millions of tons per year of industrial gaseous pollutants and other substances contaminate the air basin leaving many areas unsuitable for the habitation of any form. Millions of the world's population are exposed to harmful air pollutants every year such as sulphur dioxide, nitrogen oxides and hydrocarbons from industrial activities and several cases have been fatal. This research is aimed at enhancing the efficiency of industrial air pollution control devices namely spray-type scrubbers by combining processes and improving hydrodynamic characteristics of the device. The proposed design for a cost effective, energy efficient wet scrubber for the treatment of industrial gaseous emissions consists of a contact device (drift eliminator) made up of a chain curtain with the primary purpose of intensifying absorption of pollutant gases. Experiments were conducted in air-water and sulphur dioxide-water systems using a specifically designed laboratory stand. It has been proved through conducted experiments that the use of the chain curtain as the contact surface comes in as a more rational solution for treatment devices. Furthermore, treatment efficiency as shown during the experiments increased to up to 90-95 % and droplet capture on the drift eliminator increased by 5-10%. Hydraulic resistance did not increase greatly as would have been expected, but rather, remained at the same level and in other cases, reduced by 2-5%. The proposed device also increases treatment efficiency without additional equipment, reduces metal and design complexity and the overall cost of the treatment process is reduced as a result of design simplicity. Hydraulic and mass transfer characteristics for the proposed device have been compared with known data and the designed ejector scrubber has been successfully tested under industrial conditions in Zambia and the Russian Federation.

Keywords

Ejector scrubber, Gaseous emissions, Treatment efficiency, Chain curtain and Sulphur dioxide.

The study of mixer ejector wind turbine

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Abstract

It is become necessary to full understand how to improve the efficiency of a wind turbine, as energy consumption and cost reaches record-breaking levels. Non-renewable resources are getting high in price, and the depletion of these resources will require a sustainable and environmental- friendly energy source. An improvement to wind turbine efficiency will allow meet the requirement of energy. One such method of improving turbine efficiency is a Jet engine wind turbine (MEWT) as an improvement to the conventional horizontal axis wind turbine (HAWT). MEWTs are simply a HAWT with diffuser surrounding the rotor blade. A MEWT is claimed to have a greater efficiency than conventional HAWTs, because the diffuser allows for a greater pressure drop across the rotor blade. MEWTs offer additional advantages to increased augmentation, including minimum tip speed losses, and small rotor diameter that increases RPM. Mixer ejector wind Turbine (MEWT) is high performance, next-generation wind turbine technology. MEWT is a mixer ejector nozzle. The efficiency of MEWT is higher than conventional wind turbine because of their aerodynamics, and the components used in the wind turbine. The efficiency of MEWT is consist of two shroud one called mixer while another called ejector that guides wind to increase velocity and decrease the pressure behind the blade.

Keywords

Renewable energy, Wind turbine efficient, Jet engine, Carbon dioxide and Global warming.

Going green by going digital: An applied research perspective toward creating synergy of crypto-mining and sustainable energy production in the UK

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Abstract

Despite announcing a climate emergency and the subsequent promise to go carbon neutral by 2050, UK targets for climate change are insufficient to effect the radical changes necessary to reverse the imbalance in the environment caused by human activity. This is due in large part to the high cost to profit ratio of sustainable energy production; profitability of solar, wind, thermal, wave and other green energies is only realised after significant capital investment and a long gap period to breakeven (up to 10+ years). This means that only a few players will have both the capital and time to make a profit, leaving non-sustainable energy as the cheaper (and more feasible) option. Ergo, without a short-term profit incentive, the sustainable energy industry is unlikely to grow quickly enough to counter the climate emergency that the world now faces. As the UK government has decided not to subsidise green energy until 2025, radical ideas which incentivise commercial activity toward investment in sustainable energy production must be explored. This paper suggests a specific implementation of the digital economy with a strong profit motive for green investors. Utilising a multi-disciplinary method of research, this paper argues from an applied computer science perspective that green crypto-mining can provide essential funding from the early stages of sustainable energy planning all the way to the deployment of a full crypto-mining operation scalable to the investment capabilities of the organisation. This solution works on two levels: 1. Convert excess green energy production directly to capital through crypto-mining and 2. Grow the crypto-mining industry in the UK to increase demand for renewable energy, and as a result, reduce the costs of going green. The aim, therefore, is that renewable energy outcompetes non-renewable energy on a free market basis in the UK, thereby accelerating the green revolution.

Keywords

Sustainable energy, CPU mining, crypto-currency, digital economy, free market, government subsidies, sustainability funding, profitability and sustainability.

Comparative analysis of separation techniques for Methylal-Methanol azeotropic mixture

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Abstract

The emission from engines is one of the major concerns which the country is facing nowadays. This can be overcome either by making changes in engine design or to search for alternative fuels. To make the changes in the design of engines, a major research project needs to be launched which requires high engineering rationale. The best option left with the researchers is to search for alternative fuels with minimum emissions. Methylal is found to exhibit diesel fuel characteristics with low toxicity and reduced emissions. It is formed by a catalytic reaction of methanol with formaldehyde. But, unfortunately, there is the existence of a minimum boiling azeotrope of methylal with methanol at 94.06 wt% methylal at atmospheric pressure, which needs to be separated. A method of Extractive distillation using water as an entrainer for the separation of methylal-methanol azeotropic mixture has been explored in this case study. Use of water as an entrainer for the separation of methylal-methanol azeotropic mixture has been explored first time in open literature. A comparison of this technique with the existing techniques has been deduced in this work to highlight the importance of using water as an entrainer. The simulations have been carried out using Aspen Plus and Aspen dynamics simulation software. The results show that water is an effective entrainer for the separation of methylal-methanol azeotropic mixture as it has resulted in 69.41% savings in comparison to Extractive distillation using DMF as an entrainer, 65.33% savings in comparison to Divided- wall column, and 52.72% savings in comparison to pressure swing distillation technique. Later, a robust, reliable, and an efficient control structure has been developed which has an ability to handle large disturbances in feed flow rate and feed composition.

Keywords

Cost analysis, Control studies, Extractive distillation, Methylal-methanol and Water.

Onset of vastus lateralis during sit to stand and stand to sit task

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Abstract

Electromyography has been used successfully for describing the movement physiology and estimating the human intent towards the movement. The estimation of movement onset finds many application in assistive and rehabilitation devices for intension based control, wherein the muscle onset serves as the triggering point for the actuation of such devices to initiate the movement. Sit-to-stand (standing form sitting position) and stand-to-sit (sitting from a standing position) are basic daily life movements and also an indicator of lower limb strength in individuals. These tasks have also been used as a therapeutic intervention for improving posture and stability in elderly. To encourage user participation in such therapeutic interventions of sit↔stand (sit-to-stand and vice versa), a robotic assistive cum rehabilitation device is sought. In the present study, onset time of vastus lateralis (VL) muscle group is estimated during sit-to-stand and stand-to-sit task. In the study conducted on five participants, EMG activity of VL and knee deviation was recorded. Muscle onset time was estimated using a Teager-Kaiser Energy Operator (TKEO). Before applying TKEO algorithm, the acquired raw EMG data was denoised using high pass filter and wavelet transform. It was found from the study that onset of VL is significantly different for the two tasks. This study can be used in trigger based control of a device for providing sit↔stand transfer.

Keywords

Electromyography, Teager Kaiser, energy operator, Sit to stand, Stand to sit and EMG onset.

Gender and energy for sustainable development in Egypt

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Abstract

Access to clean, modern and affordable energy as well as the achievement of gender equality can be seen as one of the cornerstones that lead to sustainable development. Access to sustainable energy and moving towards more gender equality are reciprocally strengthening objectives. Despite some worldwide transformations of gender relations and structures over the last few decades, significant gender inequalities and gaps continue to persist in both, developed and developing countries. Gender disparities are particularly evident in energy sectors around the world. Renewable energy sectors, as well as non-renewable energy industries, remain relatively male dominated which is expressed in an underrepresentation of women in the energy supply-side on the one hand, and a lack of gender mainstreamed energy interventions on the demand-side on the other hand. There exists an unfulfilled potential to investigate how gender and energy are linked to sustainable development. The main objective of this research is to develop a gender energy sustainability nexus for Egypt. This work found that Egypt has the potential to achieve certain sustainable development objectives if a gender approach is adopted on the energy supply-side and demand side. The main environmental, economic and social sustainability goals that could be targeted are the following respectively: (1) Reduced greenhouse gas (GHG) emissions from the energy sector, (2) Increased female labour force participation and (3) Achieve gender equality. Since a lot of data is publicly not available in Egypt, it was difficult to assess gender inequalities and impacts at the different levels of Egypt's energy sector. In order to formulate specific actions for Egypt's electricity and RE sector, a profound gender audit in Egypt's energy sector, including interviews with employees at the different hierarchical levels, and access to sex-disaggregated data and project documents will be necessary.

Keywords

Global warming, Renewable energy, Gender, Sustainable development and Egypt.

Effect of silica nanoparticles on mechanical property, fracture toughness and toughening mechanism of epoxy resin: Experimental and numerical analysis

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Abstract

With the increasing demands of high-performance materials, various types of inclusions are developed and added into the epoxy resin to improve its fracture toughness and mechanical properties. This paper presents the influence of adding nano-silica particles into an epoxy matrix with different weight fractions on its mechanical properties and toughness by investigating both compact tensile (CT) tests and finite element analysis (FEA). The result reveals that adding 2 wt% of nano-silica has improved the performance of the epoxy resin, leading to the fracture toughness increasing from 0.175 to 2.720 KJ/m^2 and yield strength increasing from 53.12 MPa to 57.29 MPa. While, with a relatively high fraction of 5 wt% of nano-silica, the mechanical properties of epoxy resin decrease due to the generation of nano particle clusters. The FEA results agree well with the experimental results on fracture toughness in terms of stress intensity factor (K) and J integer. The plastic zone can be determined from the stress contours, which has been compared and studied with theoretical plastic zone predictions under mode 1 fracture. The effect of the non-singular stress (T stress) and the factors affect toughing such as nano-particles dispersing in the matrix is also discussed and investigated in this paper with the supporting two-dimensional representative elementary volume (RVE) models, for studying the impact of clusters, spacing and the size of nano-particles on mechanical properties.

Keywords

Silica, Sustainable materials, fracture, numerical analysis and Nano-particles.

Healthcare in the context of artificial intelligence

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Abstract

Progress in computational sciences for cleaning, sorting, combining, digging, visualizing and managing data along with technological advancements in medical devices have urged needs for further extensive and consistent approaches to discuss the common key issues in medicine and health. Artificial Intelligence (AI) has significantly obtained grounds in everyday living in the era of information technology and it has now landed in healthcare. AI studies' in healthcare are evolving swiftly. However, it could only be the start of observing how it will influence patient care. AI tries to simulate human cognitive capacities. It is carrying a transformation pattern to healthcare, strengthened by the escalating availability of clinical data and sped up advancement in analytics systems. Nonetheless, there is a similar doubt, including some pressing warning at these elevated anticipations. This review examines the present state of AI applications in health, major developments in health AI, and the disparate consequences of health AI and offers some directions for institutions and caregivers utilizing AI techniques.

Keywords

Information technology, Artificial intelligence, Evidence-based practice, Health care and Medicine.

Investigating the engine performance characteristics of multiple nano fuel blends in a single cylinder diesel engine

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Abstract

Despite progress in the use of electric motors for transportation systems, petro-diesel remains the primary fuel for driving heavy machinery across numerous economic sectors, including the industrial and construction sub-sectors. Unfortunately, the use of petro-diesel is characterized by high environmental pollution, a situation that directly conflicts the United Nations' sustainable development goals. Nitrogen oxide specie, NOx, is a major by-product of diesel fuel combustion and has the potential to form secondary products like nitric acid, HNO_3, further threatening ecological systems. In this study, the performance, combustion and emissions characteristics of compression ignition (CI) engine running with three variants of nano-fuel blends are investigated. These characteristics include the brake specific fuel consumption (bsfc), in-cylinder pressure, heat release rate, engine thermal efficiency, and carbon monoxide and nitrogen oxide emissions. Three different nanoparticles with a concentration of 50 mg/L are considered in this study, namely graphene oxide (GO), titanium oxide (TiO_2) and GO doped with TiO_2 (GO-TiO_2). These materials are well characterized by using different spectroscopic techniques (e.g, XRD, SEM, TEM, FTIR, and UV-VIS absorption). The experiments are run with a single cylinder, air cooled, 4-stroke engine at a speed of 2000 rpm, and different engine loads (idle to 80% full load). The results reveal a 12% average reduction in fuel consumption for the diesel–TiO_2 nano-fuel over the considered load range. Furthermore, the in-cylinder pressures for all the fuel blends, especially at peak loading conditions are greater than diesel values. The GO nanoparticles also led to comparable levels of NOx emissions compared to neat diesel, while TiO_2 and TiO_2-doped-in-GO enhanced the formation of NOx. CO emissions are found to increase with the addition of different types of considered nanoparticles.

Keywords

Diesel, Nitrogen, Graphene oxide, Nanocomposites, Emission and Engine.

Evaluating techno-economic performance of concentrating solar power (CSP) in Spain under post subsidy conditions

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Abstract

Spain is known as one of the international pioneers in the Concentrated Solar Power industry. However, in the recent years, CSP industry in Spain has faced huge financial challenges due to a dramatic withdrawal in the Feed-in-Tariff (FIT). This paper aims to determine if CSP could be made cost-effective without any feed-in-tariff and, if not, to what extent incentives could be reintroduced. The study focuses on the area of Posadas Cordoba and considers both technical and financial parameters. The main objective is to assess the current financial performance of CSP and to optimise the different factors affecting this performance in order to reach grid parity, enabling CSP to be competitive with other renewable and fossil sources. To that end, a System Advisor Model (SAM), which is a techno-economic model seeking to support decision making in renewable energy projects, has been used. The approach involves using SAM as a simulation tool to run a discounted cash flow analysis of Internal Rate of Return, Levelized Cost of Electricity and Net Present Value to investigate the most promising case for CSP under different economic condition. The results show that the Power Purchase Agreement price, discount rate and level of incentive have a crucial impact on those values since they condition the viability of a project on its whole lifetime. Hence, optimising these parameters while ensuring the consistency of the proposed values in light of the existing literature is of major importance to develop the best model possible for CSP in Spain. Furthermore, the identification of possible funding mechanisms that can improve the profitability of CSPs is essential. In conclusion, preliminary recommendations are made based on the most viable model and we discuss policy approaches to develop the suggested model.

Keywords

Renewable energy, Solar power, Subsidy, Cash flow analysis and Feed-in-Tariff.

Numerical investigation of wind tunnel on aerodynamics of blunt wind turbine air foils

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Abstract

Blunt trailing-edge airfoils have been widely used in wind turbine blades, and determining their aerodynamic characteristics is crucial in the blade design. In this paper, the aerodynamic performance of blunt wind turbine airfoils has been experimentally and numerically investigated. The S834 airfoil, a widely used blunt wind turbine blade airfoil developed by National Renewable Energy Laboratory (NREL), is chosen as a case study. The airfoil is fabricated using 3D printer and then tested in a wind tunnel with a testing section of 1m * 0.4m * 0.3m. A Computational Fluid Dynamics (CFD) model of blunt wind turbine airfoils is also developed, employing S-A turbulent model to simulate the turbulent flow. The lift and drag coefficients of the S834 airfoil with different angles of attack under Reynolds number of 400,000 are both measured by the wind tunnel experiment and calculated using the CFD model. The CFD simulation results are compared with both wind tunnel test results and published data, achieving reasonable agreement. The original S834 airfoil is then modified through varying the relative blunt trailing-edge thickness to generate a series of new blunt airfoils. The aerodynamic performance of the original airfoil and its modifications are studied to systematically investigate the effects of the blunt trailing-edge thickness on the airfoil aerodynamic characteristics. Results indicate that the blunt trailing-edge modification can improve the aerodynamic performance of wind turbine blade airfoils.

Keywords

Renewable energy, Wind turbine, Blunt trailing-edge air foil, Wind tunnel test and CFD analysis.

For post-subsidy solar PV uptake in the UK: Techno-economic assessment of integrating solar PV and battery storage

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Abstract

With the progressive withdrawal of the Feed-in-Tariff (FiT) provided by the UK government, one promising potential to sustain rooftop solar Photovoltaic (PV) uptake is the incorporation of storage technology. However, currently it cannot be denied that the financial viability of this type of model is still in question, and further research is needed to assess its feasibility. The purpose of this paper is to evaluate the techno-economic feasibility of combining electricity storage with Solar PV in the UK's non-domestic buildings. Existing literature indicates that, in today's market conditions, the effect on the profitability of investing in storage is low. However, they neglect the advantages of combining different types of battery storage services. Consequently, this paper particularly investigates the financial impact of utilising peak shaving and balancing service for the grid on a solar PV- plus -storage system. The paper proposes a novel and viable model for combining Solar PV and storage in non-domestic buildings under the post-subsidy conditions. The approach involves, using the System Advisor Model (SAM) as a simulation tool to conduct discounted cash flow and techno-economic analyses. To investigate the most financially viable case, that of battery storage, different sizes of PVs and battery storage has been simulated under different economic conditions. The results demonstrate that the proposed model in the study fully restores the economic feasibility of solar PV projects in the UK. The model also enables the building owner to benefit from peak shaving, and generate additional revenues by providing balancing services for National Grid including non-dynamic Firm Frequency and Short Term Operating Reserve. However, the research shows that the main economic value of storage comes predominantly from peak shaving rather than balancing services. In conclusion, we discuss policy approaches to developing the suggested model.

Keywords

Solar PV, Battery Storage, Techno-economic model and Feed-in-Tariff (FiT).

Concentrated solar power in South Africa: A techno-economic assessment

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Abstract

South Africa's dependence on fossil fuels such as coal for generating power has made it the highest carbon dioxide emitter in Africa; yet the abundance of high solar irradiation and existing government policies provide the country with the potential for clean and efficient renewable energy. In a bid to reduce carbon footprint, Concentrated Solar Power (CSP) has been at the forefront; with several installations over the last years from different CSP developers. However, the high capital and generation costs incurred in developing and operating CSP plants lead to uneconomical Power Purchase Agreement prices (PPA). The purpose of this study is to analyse and optimise the techno-economic performance of a parabolic trough CSP plant using molten salt as heat transfer fluid and determine the most viable location for further installation. The research considered techno-economic modelling and financial optimisation of a parabolic trough CSP with molten salt as both heat transfer fluid and storage media using System Advisor Model (SAM). Two sites in Upington and Bloemfontein, were selected due to their potential for further CSP installations, close proximity to the transmission lines and good solar irradiation values to analyse the financial performance operating under Feed-in Tariff for CSP in South Africa. The analysis showed that the site in Upington in Northern Cape Province attained the lowest Levelised Cost of Electricity (LCOE) of 14 cents/kWh compared to 15.7 cents/KWh in Bloemfontein of Free State Province with optimum thermal energy storage of six hours. Despite this, the financial models developed showed a substantial reduction in PPA price by 20% from the existing bidding cap in literature. In conclusion, this research recommends a policy incentive system with tax holidays for CSP investments and grants to reduce interest on loans for new CSP Plants.

Keywords

Levelised cost of electricity (LCOE), Thermal energy storage and Power purchase agreement.

Wind tunnel numerical study on the aerodynamics of thick wind turbine aerofoils

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Abstract

South Africa's dependence on fossil fuels such as coal for generating power has made it the highest carbon dioxide emitter in Africa; yet the abundance of high solar irradiation and existing government policies provide the country with the potential for clean and efficient renewable energy. In a bid to reduce carbon footprint, Concentrated Solar Power (CSP) has been at the forefront; with several installations over the last years from different CSP developers. However, the high capital and generation costs incurred in developing and operating CSP plants lead to uneconomical Power Purchase Agreement prices (PPA). The purpose of this study is to analyse and optimise the techno-economic performance of a parabolic trough CSP plant using molten salt as heat transfer fluid and determine the most viable location for further installation. The research considered techno-economic modelling and financial optimisation of a parabolic trough CSP with molten salt as both heat transfer fluid and storage media using System Advisor Model (SAM). Two sites in Upington and Bloemfontein, were selected due to their potential for further CSP installations, close proximity to the transmission lines and good solar irradiation values to analyse the financial performance operating under Feed-in Tariff for CSP in South Africa. The analysis showed that the site in Upington in Northern Cape Province attained the lowest Levelised Cost of Electricity (LCOE) of 14 cents/kWh compared to 15.7 cents/KWh in Bloemfontein of Free State Province with optimum thermal energy storage of six hours. Despite this, the financial models developed showed a substantial reduction in PPA price by 20% from the existing bidding cap in literature. In conclusion, this research recommends a policy incentive system with tax holidays for CSP investments and grants to reduce interest on loans for new CSP Plants.

Keywords

Levelised cost of electricity (LCOE), Thermal energy storage and Power purchase agreement.

Wind tunnel and numerical study on the aerodynamics of thick wind turbine aerofoils

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Abstract

Thick aerofoils have been extensively used in wind turbine blades, especially at the blade root region and for large-scale offshore wind turbines. Determining their aerodynamic characteristics is an important part of the blade design process. In this paper, the aerodynamic performance of thick wind turbine aerofoils has been numerically and experimentally studied. A Computational Fluid Dynamics (CFD) model of thick wind turbine aerofoils are developed. The Selig S1223 aerofoil, a widely used thick wind turbine blade aerofoil, is taken as a case study. The 3D printer is used to fabricate the aerofoil specimen, which is tested in an open-section closed-return wind tunnel. The aerodynamic characteristics (such as lift and drag coefficients) of the aerofoil at Reynolds number 250,000 are both calculated using the CFD model and measured by the wind tunnel test. The CFD simulation results are compared with both wind tunnel test results obtained in this work and the published data available in the literature. The original S1223 aerofoil is then modified through changing the relative thickness to generate a series of new thick aerofoils. The aerodynamic performance of the original aerofoil and newly generated thick aerofoils are studied to systematically investigate the effects of the relative thickness on the aerofoil aerodynamic characteristics.

Keywords

Renewable energy, Wind energy, Thick aerofoil, Wind tunnel test and CFD simulation.

Improving energy efficiency in buildings through the use of solar shading products: A review

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Abstract

When analysing the key factors in reducing energy consumption, the built environment sector must be looked into as it accounts for over 60% of global energy consumption. Also, about 50% of building operational energy consumption in the EU is for heating and cooling. With these figures in mind, various methods need to be implemented to reduce the energy consumption especially tackling the negative effects of overheating and thermal retention in buildings which are becoming more common due to factors such as varying weather conditions and more glazing buildings. In addition to building design improvements one of the tools that can be utilised for optimal energy management in buildings is Solar Shading Products (SSP) as, many of the heating and cooling requirements can be reduced by 94% for a house through some changes and utilisation of SSP and also General energy savings of 40% could be achieved by utilising passive design principles such as shading elements. The energy-saving capabilities of SSP are one of its main strengths as it can assist in both reducing heat loss in the winter and preventing heat gain in summer and as a result, reduces the need for use of heating and cooling systems throughout the year. Besides, the use of SSP facilitates natural lighting and reduces the need to use artificial lighting in buildings. The combination of these factors can result in a sizeable financial saving. However, in Part L compliance tools, Simplified Building Energy Model (SBEM), Standard Assessment Procedure (SAP) and The National Building Specification (NBS) SSP can be seen as misrepresenting and not well recognised as an energy-saving application in the UK. So by doing this paper, a comprehensive review is done to represent the results of previous projects and studies on the benefits of SSP on energy-saving.

Keywords

Solar Shading Products (SSP), Energy Saving, Built Environment, Thermal Retention, Overheating and Renewable energy.

Healing efficacies of nano curcuma longa and ZnO in third degree burn wounds

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Abstract

Wounds had a vital role in diseases and deaths. There is a natural spice Curcuma longa (C. longa) which is used for the healing of injuries for years. Although its activity power is not so much efficient due to the less absorption rate. In this research, ZnO NP and C longa were prepared and both were combined with the wet mixing to make a new material. In animal farm, there were 30 rabbits and they were categorized into 6 different groups i.e. A to F and each group had 5 rabbits. These rabbits were branded with red hot iron rod for 15 seconds, the diameter of rod is 10 mm, and it's done after the application of anaesthesia. A 1% up to date skin lotion is prepared. Four groups A, B, C, and D were given ZnO-NPs, Curcuma longa, raw Curcuma longa nanoparticles (CUR-NPs) and combined material of ZnO and C. longa nanoparticles. While rest of the two groups E and F were considered as standard positive and negative groups. After the pain of burn injury, different examinations were conducted at 7th, 14th, 21th, and 28th day and these examinations were consisting of injury contraction rate and healing time while histopathological examination was conducted at 28th day. By the help of statistical analysis, it was concluded that ZnO-CUR-NPs give better results as compared to other treatment group and these groups have a healing time period of 24.25D±0.5. While the healing time of other groups A, B, C, and E is 26.25D±0.5, 26. 25±0.5, 28D±0.82 and 36.25D±0.5 days. Group A, B, C, and E shows significant relations with value of p= 0.017, 0.00, 0.00, and 0.00 respectively. The effectiveness of ZnO-NPs and CUR-NPs was not found on day 0, 7, 14, 21, and 28 with value of p=0.7626. Histopathological examination showed good burn healing in group A, C, and D. Over all it includes application of ZnO-CUR-NPs has a quick recovery as compared to C. longa, CUR-NPs and ZnO-NPs.

Keywords

Wound, Burn, Curcumin, Curcuma longa, ZnO, Nanoparticles, Wound Healing and Rabbits.

Ferric doped nano ZnO based solar photocatalytic reactor for remediation of textile effluent for irrigation

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Abstract

A textile industry generates a large quantity of effluent being the greatest consumer of water. The advanced oxidation process offers great potential for effluent treatment. Solar photocatalysis is a promising and cost effective technique to degrade the dye residues present in textile effluent. A series of Fe3+ doped ZnO photocatalysts have been synthesized through microwave assisted sol-gel method. The crystallinity and elemental composition of fabricated material was determined by X-ray diffraction (XRD). Two-dimensional disc-shaped morphology of Fe3+doped ZnO photocatalyst and elemental composition was examined by SEM, TEM, HRTEM, STEM and EDX. Diffused reflectance spectroscopy (DRS) revealed its high photocatalytic activity in solar range on the reduction of band gap from 3.2 to 2.8 eV after doping. The optical and surface properties determined were photoluminescence (PL), contact angle and zeta potential. The contact angle measurements further supported the hydrophilic nature of the synthesized material. The characterized Fe3+ doped ZnO powdered samples have been used to degrade RB5 dye on irradiating with artificial sunlight (D65). The reaction parameters i.e. initial dye and oxidant concentration, pH and irradiation time have been optimized by Response surface methodology (RSM). The extent of dye degradation has been evaluated by UV/vis and FTIR spectroscopy in addition to HPLC. The maximum degradation up to 98.32 % was achieved on using ZnO doped with 5 mM of Fe3+ under optimized conditions. The kinetic studies were also performed under optimized reaction conditions. The values of water quality parameters i.e. BOD, COD and TOC also indicated the removal of dye residues present in textile effluent. The decrease in phytotoxicity was also observed by using untreated and treated effluent on length of root and shoot of Spinacia oleracea. The remarkable increase in vegetative growth of plants was examined using treated textile effluent.

Keywords

Solar photocatalysis, Hydrophilicity, Response surface methodology and Vegetative growth.

Intelligent building investigation

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Abstract

The aim of this paper is to demonstrate the investigation of the concept of the Eco-Building based on series of experiments with the measuring such parameters as the occupancy of the building, the lighting use, the temperature and humidity. The project includes results of tests and investigations about Heating, Ventilation and Air Condition systems (HVAC), lightening systems and the occupancy of the building in different hours in order to understand the ECO-efficiency of the building, i.e. the level of the energy consumption in the relation to the building occupancy. This investigation could help to further improve the efficiency of the building and to make the building more comfortable for users.

Keywords

Eco-building, Intelligent building, Heating, Ventilation, Air condition systems, Energy consumption and Energy efficiency.

Fuel cell vehicles in Ukrainian perspective

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Abstract

Catastrophic climate change in Europe and the world is pushing scientists to conduct research with fuel that does not produce greenhouse gases. One of these fuels is hydrogen. We need to refuse the mineral energy resources "increasing the share of renewable hydrogen sources in the global energy system" according to energy association "Ukrainian Hydrogen Council". Hydrogen Fuel Cell Car was designed in Zhytomyr Polytechnic State University. The car was tested in the SIMPLORER-ADVISOR link developed by Ansoft. About 60% of chemical energy of fuel in Hydrogen Fuel Cell Vehicle lost in the conversion into electrical energy by the fuel cell. Cars with hydrogen fuel cells emit only water and warm air. Unfortunately, hydrogen fuel stations have not yet been built in Ukraine. But Ukraine ranks first in Europe and third in the world in zirconium reserves. So, Solid Oxide Fuel Cell (Ceramic Fuel Cell) that can use a common fuel is a good perspective in Ukraine. Zirconia based ceramics (1Ce10ScSZ) are considered as the most promising electrolyte for Ceramic Fuel Cell. The novel zirconia powders were designed for cathode and anode in Frantcevych Institute for Problems of Material Science. The main problem with fuel cell is a degradation problem of film electrolyte where electrolyte material is influenced by high temperature and exposes to reducing and oxidizing gases through contacting gas permeable porous electrode materials during a long time. The conception of the "positive degradation" was proposed to transform the degradation phenomena into an instrument for the directional influence of degradation processes via structural optimization of fuel cell material. Electrolytes made of Ukrainian powder has three times higher ionic conductivity (0.035 Scm^{-1} at 700.

Keywords

Fuel cell vehicles, Hydrogen, Fuel consumption, Ceramic fuel cell and Structural optimization.

Control strategy for energy management of AC microgrid

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Abstract

Climate change and increase in energy demand is leading a shift of focus to the use of renewable and sustainable energy sources. Microgrid is gaining more significance as they can successfully integrate different renewable energy sources. Control of the microgrid proves to be a challenging research area. In recent years, many control strategies have been developed such as centralized control, master-slave control, distributed control, droop control, etc. This study presents a coordinated control strategy for an AC microgrid using multiple distributed energy resources with the capability of operating in both stand-alone and grid-connected mode. This control system allows a seamless transition between stand-alone and grid-connected modes without reconfiguring the whole control system. This would ultimately make the power network reliable and stable. In grid-connected mode, the control system performs as an active-reactive power controller but in stand-alone mode, the system is controlled according to the bus voltage and frequency. In this paper, we discuss a droop control with voltage feedback compensation method and its implementation in the energy storage system to efficiently minimize bus frequency and voltage fluctuations, especially during load variations. Furthermore, the proposed control strategy operates independent of synchronization of the DC/AC inverter with the utility grid. This is an efficient solution for situations where no communication system is designed or the point of common coupling (PCC) between the DC/AC inverter and utility grid are far apart. MATLAB simulation results would be shown and the measured results would be analysed to guarantee the stable operation and voltage stability of the microgrid.

Keywords

Renewable energy, Microgrid, Solar PV, Control system, DC/AC inverter and Power flow.

The inclusion of roadcem additive in cementitious materials for soil stabilisation

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Abstract

The use of sustainable binders has dominated much of the discussion in engineering in a bit to conserve resources and preserve the environment. Hence, in keeping with the objective of reducing carbon foot-printing, a zeolite/alkali earth metal-based additive called "RoadCem" (RC) is used with granulated blast furnace slag (GGBS) and pulverised fuel ash (PFA) in a partially substituted OPC-stabilised soil in this research. RoadCem is an additive that is manufactured based on nanotechnology and contains zeolite, alkali earth metal with an activator as some of its constituents. Geotechnical investigation (mainly strength, swell and consolidation) involving a series of novel combinations of the binders with up to 50% of the OPC replaced in the stabilised soil were performed. Results of an extensive laboratory study indicated an improvement in the consistency limits shown by a clear reduction in the plasticity index property of the soil-binder mixes. An obvious effect of the RC was observed in the quick unconfined compressive strength gain in the 7-day cured samples with 50% of the OPC replaced. A promising trend of reduction in the swelling potential and settlement of the stabilised samples containing the GGBS, PFA and RC was also noticed as compared to the samples stabilised by the OPC used alone. A pore size model was formulated from the soil-water retention behaviour to explain the swell mechanism of the stabilised samples. The OPC-stabilised exhibited the greater inter-aggregate porosity with a corresponding reduced intra-aggregate porosity and reduced water retention. Overall, the results obtained in this study were adjudged to have met relevant standards for pavement construction.

Keywords

Sustainability, Metal based additives, pore size and cementitious materials.

Evaluating the effect of adding two kerosene-like fuels on the combustion, performance and emissions characteristics of diesel-biodiesel blends in a direct-injection diesel engine

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Abstract

Biofuels represent an effective solution to the global warming crisis due to its short carbon cycle. Biodiesel is a biofuel that has many unfavourable physical and chemical properties that stand against its applicability as a single fuel in diesel engines. These properties include high viscosity, density and pour point and low calorific value, in addition to high NOx emissions. Seeking to compensate these disadvantageous properties, biodiesel was introduced in different binary and ternary blends to diesel engines. This work investigates the effect of adding two kerosene-like fuels including jet fuel and paraffinic solvent to diesel-biodiesel blends on performance, combustion characteristics and emissions of high compression ratio diesel engine. The two additives have the same distillation temperature 150-250 °C and the number of carbon atoms C10-C16. However, after investigating their composition and structure using FT-IR and GC-FID systems, it was found that the jet fuel has higher aromatic and less paraffinic contents than the solvent. Engine experiments were conducted at a constant speed of 2000 rpm over the entire load span. Three blending ratios including 5%- 10%- 15% of kerosene were well-blended with 30% waste cooking oil biodiesel and the remaining was diesel. Experimental results revealed that relative to diesel, the paraffinic solvent blends showed no effect on fuel consumption. It was found also that a significant reduction was achieved in NOx and CO emissions relative to diesel. For B30-K15 (55% diesel- 30% biodiesel- 15% solvent) the reduction in NOx and CO reached an average value of 6.36% and 50.2%, respectively. For jet fuel blends, a reduction in fuel consumption about 6.3% was achieved for B30-J15 (55% diesel- 30% biodiesel- 15% jet fuel) relative to diesel at low load but no change in medium and high loads were noted. Also, for B30-J15 reduction in NOx and CO emissions reached 14.3% and 53%, respectively.

Keywords

Renewable energy, Biodiesel, Jet fuel, Paraffinic solvent and Diesel engines.

Numerical analysis of flat corners cooling of 3D-printed high-pressure tools for Aluminium casting

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Abstract

Mould cooling is regarded as the biggest influence in the production cost of injection moulding due to the fact it contributes to the largest percentage of cycle time. Conventional manufacturing methods have always been the biggest constraint in mould cooling design where the solution is only limited to circular straight-drilled channels. Conformal cooling is an alternative to conventional cooling where 3D printed moulds have cooling channels shaped in the same outline as the cavity. Despite the considerable number of literatures in conformal cooling for injection moulding, limited work has been carried out in cooling for corner regions where the volume of cast to surface area of interface vary significantly. Moreover, the coolant may experience flow separation and subcooled boiling condition. In this study, the effects of the main independent parameters for cooling corners of 3D printed H13 steel mould for aluminium casting are investigated. The heat flux and the interface temperature have been identified using a conjugate heat transfer 3-D CFD model. The model is developed based on steady conditions which are validated using experimental data. The spatial temperature distribution at the cast-mould interface has been evaluated and presented. A generic equation has then been developed using multiple linear regression method to calculate the interface temperature and its standard deviation as a function of the main parameters which include depth, pitch, diameter and coolant flow velocity. The equation can be used as a guide for cooling channel design without a need for running multiple CFD simulations. The results are compared against a flat plate geometry to identify the differences between cooling channels with 90-degree corner bend and straight channel flow for mould cooling. The results showed also that the shape factor equation available in literature cannot be used to fully describe the orientation and positioning of the channel relative to the cast interface without applying a correction factor.

Keywords

Aluminium cast cooling, Conformal cooling, 3D printed mould cooling and Corners cooling.

Cooling analysis of a U-shaped 3D-printed high-pressure tools for Aluminium casting

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Abstract

A die casting process requires efficiency and consistency to be profitable for manufacturers. The cooling phase is the most important of all the processes involved, taking up about 70% of the cycle time. Final cast quality is also determined by the cooling process, more specifically the cooling rate and temperature uniformity. Studies have shown improved cooling in these aspects using conformal cooling channels (CCC) as compared to conventional straight channels. However, investigations into the design of CCC are limited for high-pressure 3D printed tools for aluminium casting. The purpose of this study is to investigate the cooling effect of parameters including flow velocity, diameter, depth and pitch on a U-shaped cooling channel. The channel is studied as an external and internal cooling channel for an aluminium cast of variable sizes. The entire cast geometry is divided into individual elements for detailed analysis. CFD simulations are carried out considering the aluminium cast, H13 steel mould and water as three separate regions to identify the cast-mould interface temperature for various design parameters. Linear regression method is then used to formulate the parameters and to obtain solutions for temperature and temperature uniformity. Results highlight the effects of the corners in a U-shaped cooling channel. When a cast is internally cooled, cooling at the corners are reduced, whereas externally cooled casts have excessive cooling at the corners. Relationship between cavity temperature and depth shows linear trends on all surfaces. The study concludes with the formulation of all parameters for individual sectioned elements that makes up the entire geometry.

Keywords

Aluminium cast cooling, Conformal cooling, 3D printed mould cooling and U-shaped cooling.

Mainstreaming renewable energy in the Ghanaian real estate: can renewable energy be a deciding factor in energy consumption?

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Abstract

The study assesses the prospects of introducing renewable energy into the real estate industry of Ghana in an attempt to reduce their dependency on non-renewable energy (national grid). The research adopted qualitative techniques in data collection and analysis. In-depth interviews were conducted with 20 architects and engineers of both PV and Biogas companies, whereas a simple survey among 50 respondents in the Accra Metropolis (Kaneshie) was also undertaken. The findings from the study show that the source of energy used by individuals within the area of study is dependent on the reliability and the cost of the source of renewable energy; renewable energy sources (PV and biogas) were indicated as the best option for Ghana because of key contextual factors. The capital needed to invest in these energy sources were revealed as high for the average Ghanaian to afford but the benefits of investing in the renewable energy outweighs the cost. Aside from the energy generation the use of non-renewable energy provides added advantages through specific by-products. It is therefore recommended that the Ministry of energy invest in PV and biogas production.

Keywords

Renewable energy, Sustainability, Real estate, Photovoltaic, Biogas and National grid.

Fabrication of Barium-strontium Hexaferrites and their Sn-Ti doped derivatives

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Abstract

Fabrication of Barium-strontium hexaferrites and their Sn-Ti doped derivatives Ba0.5Sr0.5Fe12-2xSnxTixO19(x=0.0-1.0), was carried out by chemical co-precipitation route. The synthesized hexaferrites were characterized by thermogravimetric (TG), X-ray diffraction (XRD) and scanning electron microscopic (SEM) techniques. The results of XRD analysis confirmed a single magneto plumbite phase of these materials with an average crystallite size in the range 28-32nm.SEM analysis revealed enhanced porosity with dopants and platelet like surface of the synthesized hexaferrites. Magnetic and dielectric properties of the parent and substituted samples (x=0.0-1.0) were also explored. The saturation magnetization (Ms) and remanence (Mr) decreased with dopant contents in the range of applied magnetic field which may be explained in terms of magnetic dilution due to non-magnetic (Sn2+) and less magnetic (Ti4+) character of the substituents. The squareness ratio of all the doped samples investigated was found to be less than <0.5, advocating their existence in multi magnetic domains. The coericivity (Hc) decreased by the substitution of Sn2+ and Ti4+ in Ba-Sr hexaferrites in nominated range of doping contents (x=0.0-1.0). This trends may be related to the reduced magnetic exchange coupling and the site occupation of the dopants in different crystallographic sites of the hexaferrite unit cell. The dielectric parameters (dielectric constant, dielectric loss and dielectric tan loss) were measured at ambient temperature and in 1.0 MHz to 3.0 GHz frequency range. In the synthesized Sn-Ti substituted Ba-Sr hexaferrites, dielectric parameters initially decreased with frequency then became almost constant followed by resonance type behaviour. The magnitude of dielectric parameters, however, increased with dopant contents owing to site preferences of all the doped captions. Magnetic characteristics of the studied materials make them a suitable candidate for perpendicular recording media and their dielectric properties indicates their suitability for miniaturization of microwave devices.

Keywords

Hexaferrites, Thermogravimetric (TG), Chemical co-precipitation route and coercivity.

Life cycle costing analysis: tools and applications for determining hydrogen cost for fuel cell vehicle technology

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Abstract

Hydrogen can be produced from conventional fossil fuels and renewable resources. The total annual world production of hydrogen for 2008 was around 368 trillion cubic meters. The 80% of the produced amount was mainly consumed by the chemical industry and in petrochemical refineries. The remaining amount was used in various processes including situations that hydrogen used as an energy carrier. The hydrogen as the alternative fuel is used as a potential energy carrier at the transportation sector by using fuel cell electric vehicles. Hydrogen produced via steam methane reforming and water electrolysis can be either generated in centralised or decentralised facilities. In centralised production, hydrogen is distributed to the area of the application via tank trailer in liquefied or gaseous forms. In decentralised production, hydrogen is produced and stored in the location of usage at hydrogen fuelling station. This work investigates the life cycle cost analysis as a tool to estimate the cost of hydrogen to be used as fuel for Hydrogen Fuel Cell vehicles (HFCVs). The method of life cycle costing and economic data was considered to estimate the cost of hydrogen for centralised and decentralised production processes. In the current study, the two major hydrogen production methods were considered, methane reforming and water electrolysis. The costing frameworks were defined for hydrogen generation, transportation and the final application. The results showed that hydrogen generation via centralised methane reforming is financially viable for future transport applications. The ownership cost of HFCv showed the highest cost among other costs of life cycle analysis.

Keywords

Hydrogen economy, Cost analysis, Life cycle costing, Methane reforming, Water Electrolysis and Centralised production.

A transient multi-dimensional quasi-discrete model for multicomponent and blended fuel droplet heating and evaporation

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Abstract

A new transient multi-dimensional quasi-discrete model is suggested and tested for the analysis of heating and evaporation of 119 blended E85-diesel fuel droplets. As in the original multi-dimensional quasi-discrete model, the components of 119 E85-diesel fuel with close thermodynamic and transport properties are grouped together to form quasi-components. In contrast to the original multi-dimensional quasi-discrete model, the new model takes into account the transient contribution of all groups of hydrocarbons; quasi-components are formed within individual groups.

Keywords

Energy, Fossil fuels, Diesel engine, Fuel economy, modelling, heating and evaporation.

Spontaneous Fruit Fly Optimisation for truss weight minimisation: Performance evaluation based on the "no free lunch" theorem

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Abstract

Over the past decade, several researchers have presented various optimisation algorithms for use in truss design. The "no free lunch" theorem implies that no optimisation algorithm fits all problems; therefore, the interest is not only in the accuracy and convergence rate of the algorithm but also the tuning effort and population size required for achieving the optimal result. The latter is particularly crucial for computationally intensive or high-dimensional problems. Contrast-based Fruit-fly Optimisation Algorithm (c-FOA) proposed by Kanarachos et al. in 2017 is based on the efficiency of fruit flies in food foraging by olfaction and visual contrast. The proposed Spontaneous Fruit Fly Optimisation (s-FOA) enhances c-FOA and addresses the difficulty in solving nonlinear optimisation algorithms by presenting standard parameters and lean population size for use on all optimisation problems. Six benchmark problems were studied to assess the performance of s-FOA. A comparison of the results obtained from documented literature and other investigated techniques demonstrates the competence and robustness of the algorithm in truss optimisation.

Keywords

Fruit Fly optimisation, Truss weight minimisation, Tuning and population size.

Spontaneous Fruit Fly Optimisation for truss weight minimisation: Performance evaluation based on the "no free lunch" theorem

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Abstract

Single use plastics has become a modern symbol of consumerism due to their quick, convenient and cheap production. However, this has translated into the overabundance of plastic waste in landfills. SALTS healthcare Ltd is working with Swansea University to mitigate excess waste and work towards a positive environmental policy. Together we are upcycling its polymer-based ostomy bags into carbon nanotubes (CNTs). CNTs are cylindrical carbon nanostructure with great strength, thermal and electrical conductivity properties. This makes them a viable option to use as electrical conduction cables. Thus, this project has the potential to be upscaled in which other items such as sanitary waste products can be used to make commercially relevant electric cables. To date, there are two main methods of converting plastics to CNTs, pyrolysis and dissolution. Pyrolysis is a resource and energy-intensive process so we are using the dissolution method. The main components of the ostomy bag include MF films, hydrocolloids and polyester. We have determined suitable solvents and conditions which guarantee the complete dissolution of each individual polymer. This is followed by the dissolution of the whole ostomy bag using a single dissolution step. Chemical vapour deposition is then used to produce carbon nanotubes from, initially the individual polymer solutions and finally the whole ostomy bag. The effect of multiple parameters on the quality of carbon nanotubes produced will be demonstrated through characterisation techniques such as thermogravimetric analysis, scanning electron microscopy, energy-dispersive X-ray spectroscopy and Raman spectroscopy.

Keywords

Nanomaterials, Circular Economy, Nanotechnology, Carbon Nanotubes, Chemical Vapour Deposition and Plastic recycling.

Characterization of viscosity of bio-oil produced by fast pyrolysis of wheat straw

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Abstract

The intention of this exertion is to assess the role of the viscosity of the organic condensate extracted from fast pyrolysis of wheat straw. A model has been developed on the basis of experimentation that is able to adequately define the viscosity as a function of relevant process parameters. The developed model is quite useful to investigate the drop of heat transfer in heat exchangers of organic condensate cycle when glycol is replaced by an organic condensate. Temperature, solid contents and water contents play a substantial role and affect the viscosity of bio-oil. As temperature upsurges, the viscosity of oil reduces rapidly. Viscosity-temperature profile trails Arrhenius-type relationship, where viscosity of bio-oil decreases exponentially with cumulative temperature. As solid content increases, exponential increase of viscosity takes place. However, the increase in water contents yields decrease in viscosity on logarithmic scale. The range of water addition in the organic condensate is conceivable up to a certain limit, after certain limit it starts to separate out in two phases. Investigation of drop of heat transfer in heat exchanger exhibits that Nusselt number decreases with the increase of viscosity. Therefore, the overall heat transfer coefficient decreases in case of organic condensate as compared to glycol.

Keywords

Fast pyrolysis, Wheat straw, Viscosity, Bio-oil, Heat transfer and Bioliq.

Thermo-gravimetric analysis of bagasse fractions (fibre and pith) for solid fuel beneficiation in boilers, stoves and open fires

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Abstract

Effective separation of bagasse fractions of fibre and pith to be beneficiated as solid fuels, opens up new opportunities, opens up energy potential for use in boilers, stoves and open fire applications. Their potential use as briquettes would require the characterization of their thermal behaviour and degradation which is vital for the determination of the best fraction with better thermal behaviour. Thermo-gravimetric analysis of bagasse, fibre and pith fractions were carried out under inert atmospheres. Thermal degradation of fibre and pith briquettes took place in two stages of volatilization and carbonization. Kinetics factors: reaction rate, activation energy, entropy change, enthalpy change and Gibbs free energy were calculated. Results indicate that fibre briquettes have high activation energy and reaction rate for volatilization which indicated least of activation energy and reaction rate for carbonization while pith fraction indicates a contrary behaviour. The implication is that potential fraction of bagasse can be deployed as the solid fuels in the form of bagasse for boilers, stoves and open fires.

Keywords

Fibre, pith, Activation energy, Reaction rate, Volatilization and Carbonization.

PET production via modified Lurgi Zimmer process using biomass derived raw material

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Abstract

Polyethylene Terephthalate, commonly abbreviated PET, is a thermoplastic polymer resin of the polyester family which finds wide application in bottles, fibre and industrial use. Its application includes synthetic fibres, beverages, food and other liquid containers; thermoforming applications; plastic, film and engineering resins often in combination with glass fibre. PET fabrics and PET bottles are two widely used applications. The wide scale industrial production of PET employs purified terephthalic acid and ethylene glycol as the raw materials and is carried out using Lurgi Zimmer process. This paper extensively reframes the process of production by modifying the Lurgi Zimmer process in terms of unit operations and thus optimizing and making the production easier and yield to be larger. The paper also covers the manufacturing of raw material ethylene glycol from biomass particularly corn stover which is present in abundance and thus reducing the use of chemicals for the same production and also ensuring greener and cleaner production. From complete process design and calculation for the amount of product and raw material, it is found that for 1 kt/day production of PET, around 0.58 kt/day and 0.86 kt/day of ethylene glycol and purified terephthalic acid are required. For the production of 0.58 kt/day of ethylene glycol, 2479.92 kt/day of ethanol is required. 23 kg of ethanol can be produced from 100 kg of biomass, which estimates the biomass requirement of 10,800 kt/day which is enough as compared to the total biomass generated. PET had already entered into use for bottle grade manufacturing whose major players include Coca-Cola and others. The global PET packaging market is forecast to have a 5% CAGR rise in the coming years owing to the growing demand for packaged food items across the globe.

Keywords

PET, Thermoplastic polymer, Purified Terephthalic Acid, Ethylene Glycol, Lurgi Zimmer and Biomass.

Feasibility analysis of different energy optimisation techniques for a steel plant to improve its energy efficiency in a steam distribution system

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Abstract

An efficient steam distribution system is essential if steam of the right quality and pressure is to be supplied, in the right quantity, to the steam using equipment in any industry. This paper describes a feasibility study of the implementation of different energy optimisation opportunities in a steam distribution system of a steel plant to evaluate their energy saving potentials and economic benefits. The main producers of superheated steam (11 barg and 300-320 °C) in the investigated steam distribution system are service boilers (medium pressure water tube boilers), superheater at Basic Oxygen Steel (BOS) plant, backpressure steam turbine, pressure reducing stations and high lift pumps at blast furnaces where steam is transported to the whole plant through a large, complex system of pipes, several take-off lines that operate at different temperature and pressures and is approximately 20 km in length. Mass and energy balance of whole steam distribution network is carried out and feasibility of recommended energy-saving opportunities i.e. isolation of redundant steam lines, re-routing steam flows, improved insulation of steam lines and installation of non-return valves are carried out on the basis of Annualised Life Cycle Cost (ALCC) analysis and payback. The results of energetic analysis of different energy-saving recommendations will results in 112TJ (tera joule) of annual energy savings which equals to 56kt (kiloton) of steam and will also results in the efficient operation by isolating cold steam lines, reduce pressure and temperature loss in the steam main through improved insulation and reduced maintenance cost within end-users by using better quality steam. Based on the economic analysis, it is also concluded that proposed energy-saving recommendations will create annual savings worth of £0.5 million with a payback of less than 1.5 years.

Keywords

Energy efficiency, Steam distribution system, Life cycle Cost analysis, Steel plant and Boilers.

The use of kalman filter in diesel engine test cells back pressure measurement for control

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Abstract

Diesel engine combustion releases many harmful components such as Carbon Monoxide (CO), Nitrogen Oxide (NOx), and exhaust particulate (Carbon). Yet for many applications such as heavy duty and high horsepower, there is no suitable alternative to diesel engines. There are continuous research efforts into improving the efficiency of these engines and reducing the harmful exhaust gasses and particulates to set targets regulated by the various emissions authorities. To develop and audit this technology requires running in performance test cells. A critical measurement for benchmark testing is exhaust back pressure which must be set to defined limits for each engine to give a true comparison. Setting this parameter costs time and fuel, thus a control solution to regulate this exhaust back pressure is desirable. In current practice, there is a challenge of applying feedback control due to the lag caused by the time delay caused by the use of running an average filter in the pressure measurement. A more suitable alternative of the filter would be to use Kalman Filter with tuneable measurement uncertainty (R) and process noise (Q) gains. This filter provides a more realistic transient response. This filter has been applied at the High Horse Power test cells running the SGS CyFlex and AVL Puma Data Acquisition and control systems. The results have been initially simulated by a script created from a live sample of data for the purposes of tuning and once optimized applied live at the test cell and results logged to compare to the running average filter performance. Both systems effectively reduce the noise of the system, with the Kalman filter showing a closer tracking to the system response. This shows the potential of applying Kalman Filter to provide a feedback signal to construct a closed loop controller.

Keywords

Exhaust back pressure, Kalman filter, Closed-loop control, Diesel engine and Combustion.

A time-series neural network architecture configuration for vehicular navigation using inertial navigation sensors

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Abstract

Road localisation of autonomous vehicles are reliant on consistent accurate GPS positioning information. More so, GPS which relies on a number of satellites to perform triangulation may experience signal loss around tall buildings, bridges, tunnels and trees. An approach to overcoming this problem involves integrating a GPS with a vehicle mounted Inertial Navigation Sensor (INS) to provide a more reliable positioning solution. INS are however plagued by unbounded exponential error drifts during the double integration of the acceleration to displacement. Several deep learning algorithms have been employed to learn the error drift in the sensors for a better positioning prediction. Their approach has generally involved the use of complex mathematical analysis on the INS data for location determination before estimating the positioning error based on the ground truth provided by the GPS receiver before signal loss. Deep learning algorithms nevertheless have the ability to learn better relationships directly from the raw INS data providing better vehicular navigation. The proposed neural network configuration enhances the prediction performance of the deep learning model on noisy INS-GPS data. To demonstrate the superior performance of the configuration, a comparison is made to others published in existing literature and analysed on relevant performance metrics.

Keywords

Inertial navigation sensors (INS), GPS, Deep learning, Neural network, Autonomous vehicle navigation, Architecture and LSTM.

Design and optimization of horizontal axis wind turbine for low wind velocities

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Abstract

The global demand for cleaner energy has been steadily increasing. With wind energy being one of the top sources of renewable energy, more efficiency would result in reduced emissions and better access to cleaner energy. This project aims to develop a wind turbine design that is optimised for low wind velocities. Thus, increasing the feasibility of a wind farm in many further locations and helping to promote wind turbine adoption. The turbine could be used in cases where connection to the main grid would be costly, therefore being both economically and environmentally beneficial. The design process included calculating the optimum rotor height, optimum blade aerofoil shape and determining a valid target wind velocity. Existing literature will be reviewed to gain a fundamental understanding of wind turbine design and possible avenues to optimise a wind turbine for low wind velocities. The blade shape is a critical component in turbine design and is analysed using QBlade; the simulation presented lift forces allowing for the selection of the optimum aerofoil. The simulations have also predicted the performance of the turbine at various wind velocities. To ensure to the blade will be able to sustain the operating conditions, modal analysis and finite element analysis was also be carried out. The design problems were researched and simulated using QBlade. The power generation of the proposed wind turbine design was compared to an existing design and should show a 3kW increase in power generation at 6 m/s. A design was produced that will be competitive in terms of power generation however due to the limited scope of the project there may be overlooked issues with the design such as transient responses to turbulent airflow. The design successfully exceeded the target of 4.2kW power generation at 6 m/s wind velocity, however further optimisations may still be possible to improve efficiency.

Keywords

Renewable energy, Low wind velocity, Wind turbine, Aerofoil and Computational fluid dynamics (CFD).

Novel strategies to reduce engine emissions and improve energy efficiency in hybrid vehicles

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Abstract

To reduce the impact of cars on the atmospheric environment, different auto companies have proposed different solutions. The use of hybrid vehicles to replace traditional power vehicles is widely adopted. Hybrid electric vehicles can provide the same power as the gasoline-powered vehicles and diesel-powered vehicles, while also reducing fuel consumption by 40 to 50 per cent. However, the main power output of the hybrid electric vehicle derives from the internal combustion engine and the motor assists in acceleration. Therefore, hybrid electric vehicles will still produce exhaust emissions. Therefore, the use of power control strategies can help cars improve their work efficiency, improve fuel economy and reduce emissions. This paper mainly studies the influence of the fuzzy logic algorithm on the hybrid electric vehicle powertrain. Determine whether the hybrid electric vehicle powertrain can improve the fuel economy of the car and reduce the exhaust emissions of the car through fuzzy logic algorithms. By using a fuzzy logic algorithm for random operations, the operating range of the internal combustion engine is controlled as much as possible in the most efficient range. Through the control of 121 different algorithms, the operating efficiency of the powertrain optimise to the optimum value. Through the operation of the fuzzy logic algorithm, the hybrid electric vehicle is significantly reduced to reduce exhaust emissions and improve fuel efficiency. Improve the fuel economy of hybrid electric vehicles. At the same time, the use of a fuzzy logic algorithm does not affect the driving performance of the hybrid electric vehicle itself. By comparing the acceleration time variation and the climbing efficiency comparison, it can see that the vehicle performance is not significantly affected in the process of using the confused logic algorithm. Through the description of this paper, the specific application and optimisation effects of the fuzzy logic algorithm in hybrid vehicles can embody. Under the optimisation of fuzzy logic algorithm, it can achieve a certain degree of optimisation. It allows the internal combustion engine to be in a dynamic working range for most of the time.

Keywords

Air pollution, Hybrid electric vehicles, Emissions, Fuzzy logic algorithms and Hill climbing efficiency.

CFD analysis of PV/T air systems

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Abstract

Photovoltaic/Thermal (PV/T) systems are a mechanism to keep the PV cell temperature at the operating range leading improves the efficiency at an acceptable level, as well as producing heat and electricity simultaneously. In this study, PV/T air systems are considered. There are three main challenges to overcome with PV/T air systems; 1) the fan power requirement, 2) extreme weather temperature, 3), and the poor heat capacity of air, which leads to poor thermal performance, compared to other coolants such as water. A comparison between different PV/T systems is conducted in this research. The CFD software of COMSOL Multiphysics is used. The designs of PV/Thermal (PV/T) can be categorised into four main types: Model 1 is a single duct single pass, where the air is directed under the PV module while the top/front its surface is exposed directly to ambient conditions. Model 2 is similar to model 1, but an air gap is made between the top/front surface of the PV module and the bottom/rear surface of the upper glass cover. In model 4, the air is fed under and over the PV module in which the flow in the same direction (co-current flow). In the four design model, air flows between the glass cover and the PV module and reverses in the second pass between the PV panel and lower absorber plate, making a U-shape flow (double-pass single duct). When the five design models are compared, preliminary results show that model 3 has the best thermal performance, but model 1 has the highest performance for electrical efficiency. In total, model 3 has the highest combined efficiency. Also, the results reveal that model 4 has the highest pressure drop magnitude.

Keywords

PV/T, PV cooling, Combined efficiency, Thermal efficiency, PV temperature and Pressure drop.

CFD modelling of the effect of side wind on ground transportation system (GTS)

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Abstract

Heavy good vehicles are extensively used in the UK transport sector, and this has led to an increase in fuel consumption. Improving the HGV design contributes in decreasing the fuel consumption. For that, different strategies have been used such as shape optimisation or use the add-on devices on various positions in the Vehicle to reduce fuel consumption, however, this may lead to increase the instability of HGVs. Far too little attention has been paid to enhance stability, handling and safety operation of the HGVs especially, under worst conditions such as gusty and side wind. This work focuses on the study the effects of side wind on the drag and side forces as well as yawing and rolling moment of the HGVs. A simplified model (Ground Transportation System) (GTS) is investigated in this study using numerical analysis. Computational Fluid Dynamics (CFD) uses the finite volume method (FVM) (Ansys Fluent) to model the GTS design to show the structure of the flow around a typical HGV and calculates the aerodynamic forces. The validating with experimental data shows a good agreement. The preliminary results revealed that the side wind has strong effect on aerodynamic forces, hence, the side wind parameter should be taken into account in designing the HGVs.

Keywords

Drag, side wind, GTS, Stability and Shape optimisation.

Experimental study of biomass energy potential using bubbling fluidized bed gasifier

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Abstract

The current study investigates the short rotation coppice (SRC) gasification in a bubbling fluidized bed gasifier (BFBG) with air as gasifying medium. The thermochemical processes during combustion were studied to get better control over the air gasification and to improve its effectiveness. The combustion process of SRC was studied by different thermo-analytical techniques. The thermogravimetric analysis (TGA), derivative thermogravimetry (DTG), and differential scanning calorimetry (DSC) were performed to examine the thermal degradation and heat flow rates. The product gas composition (CO, CO_2, CH_4 and H_2) produced during gasification was analyzed systematically by using an online gas analyzer and an offline GC analyzer. The influence of different equivalence ratios on product gas composition and temperature profile was investigated during SRC gasification. TG/DTG results showed degradation occur in four stages; drying, devolatilization, char combustion and ash formation. Maximum mass loss ~70% was observed in devolatilization stage and two sharp peaks at 315–500 °C in TG/DSC curves indicate the exothermic reactions. The temperature of gasifier was increased in the range of 650–850 °C along with the height of the reactor with increasing equivalent ratio (ER) from 0.25 to 0.32. The experimental results showed that with an increment in ER from 0.25 to 0.32, the average gas composition of H_2, CO, CH_4 decreased in the range of 9–6%, 16–12%, 4–3% and CO_2 concentration increased from 17 to 19% respectively. The gasifier performance parameters showed a maximum high heating value (HHV) of 4.70 MJ/m^3, Low heating value (LHV) of 4.37 MJ/m^3 and cold gas efficiency (CGE) of 49.63% at 0.25 ER. The ER displayed direct effect on carbon conversion efficiency (CCE) of 95.76% at 0.32 ER and tar yield reduced from 16.78 to 7.24 g/m^3 with increasing ER from 0.25 to 0.32. All parametric results confirmed the reliability of the gasification process and showed a positive impact of ER on CCE and tar yield.

Keywords

Renewable energy, Biomass gasification, Thermo-analytical techniques and Product gas composition.

Flow analysis and CFD simulation of a wind turbine with inverse chord blades

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Abstract

One feasible source for renewable energy is small wind turbines. Small turbines can be placed in urban environments such as a bridge or a building rooftop. In this study, we simulate the performance of a new wind turbine design and compare it with the conventional commercial design. The new design uses an "inverse" blade, which is narrower at its base and widest at its tip. The inverted NACA 6412 was compared against four other aerofoils using XFOIL and BEM Method calculations in QBlade to identify optimum coefficients of lift, drag, power and torque at different angles of attack and wind speeds. This aerofoil was chosen as it proved to be the most consistent and reliable in these simulations, performing well at low wind speeds, allowing progress to move forward to CFD. We then perform 3-D CFD simulations using StarCCM+ (by Siemens), with an overset mesh in a fixed fluid domain, to capture the blade rotation. The overset mesh consists of a coarse mesh region for the background and a second refined mesh region around the turbine blades. We exploit the symmetry of the turbine to reduce the computational runtime, by simulating a single blade (instead of six in the actual design). Reynolds-Average Navier Stokes (RANS) with a k-omega turbulence solver has been used. Results show the spatial distribution of flow velocity, turbulence intensity and the vorticity for various tip speed ratio (TSR). The wind turbine performance in terms of torque and power is evaluated and show that the inverted blade provides higher torque at lower wind speed relative to the conventional blade. Our results provide an optimal rotational speed, where the wind turbine provides the most power. This optimal speed provides good performance that suggests potential for commercialisation.

Keywords

Renewable energy, Wind turbine, turbulence, Computational Fluid Dynamics and Mesh rotation.

Extended Abstracts

Improving building energy efficiency through use of solar shading products

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Abstract

When analysing the key factors in reducing energy consumption, the built environment sector must be looked into as it accounts for over 60% of global energy consumption. Also, about 50% of building operational energy consumption in the EU is for heating and cooling. With these figures in mind, various methods need to be implemented to reduce the energy consumption especially tackling the negative effects of overheating and thermal retention in buildings which are becoming more common due to factors such as varying weather conditions and more glazing buildings. In addition to building design improvements one of the tools that can be utilised for optimal energy management in buildings is Solar Shading Products (SSP) as, many of the heating and cooling requirements can be reduced by 94% for a house through some changes and utilisation of SSP and also General energy savings of 40% could be achieved by utilising passive design principles such as shading elements. The energy-saving capabilities of SSP are one of its main strengths as it can assist in both reducing heat loss in the winter and preventing heat gain in summer and as a result, reduces the need for use of heating and cooling systems throughout the year. Besides, the use of SSP facilitates natural lighting and reduces the need to use artificial lighting in buildings. The combination of these factors can result in a sizeable financial saving. However, in Part L compliance tools, Simplified Building Energy Model (SBEM), Standard Assessment Procedure (SAP) and The National Building Specification (NBS) SSP can be seen as misrepresenting and not well recognised as an energy-saving application in the UK. So by doing this paper, a comprehensive review is done to represent the results of previous projects and studies on the benefits of SSP on energy-saving.

Keywords

Renewable energy, Wind energy, Thick aerofoil, Wind tunnel test, CFD simulation.

Introduction

When analysing the key factors in reducing energy consumption, the built environment sector must be looked into as it accounts for over 60% of global energy consumption (85% is operational). Also, a large portion of the consumed energy in built environment sectors relates to operational energy such as the energy used for cooling and heating which account for about 50% of operational energy consumption in the EU. With these figures in mind, various methods need to be implemented to reduce the energy consumption especially tackling the

negative effects of overheating and thermal retention in buildings which are becoming more common due to factors such as varying weather conditions and more glazing buildings. In addition to building design improvements, one of the tools that can be utilised for optimal and efficient temperature and energy management in buildings are Solar Shading Products (SSP). For this study, a systematic review had been undertaken on the previous studies regarding the effects of Shading Products on energy saving in buildings.

Energy saving via solar shading products

To illustrate the impact of solar shading products and especially its direct correlation with the environment, reviewing a previous study that analysed the climate conditions of four European countries Brussels, Stockholm, Budapest and Rome, identified some key statistics. This case showed that blinds and shutters have the ability in single glazing scenarios to provide heating energy savings of up to 35% and by 25% with double glazed windows and have the potential to reduce energy CO2 emissions by 31 million tonnes per year which was the ultimate conclusion of this study [13]. The utilisation of solar shading products such as blinds and shutters in both commercial and domestic buildings have seen to have a positive impact on tackling overheating and energy consumption in buildings. To illustrate this better, it can be stated that blinds and shutters can reduce window surface temperatures quite extensively due to its passive cooling methods and will assist in maintaining operational temperatures within the maximum boundaries. One key finding from recent research projects has been the impact of dynamic external shading products compared to fixed shading products. An example of this can be found in a research carried out by Dubois who investigated the differences in energy savings when a fixed awning was positioned year-round on a south facing window in Stockholm and when a seasonal awning was only used in summer. The seasonal awning reduced annual cooling energy by 80% where the fixed awning decreased heat loss by 31%. These results showcase how seasonal use of shading can greatly benefit in reducing energy consumption and highlights the importance of product selection and utilisation specific to the application and environment they're used in [12].

Despite the clear advantages of using external shading in preventing solar radiation from entering the building in summer buildings, this is not always possible and utilising internal shading can be considered as an option as well. A study carried out by Seguro and Palmer (2016) identified that internal venetians could reduce total energy end use by 5% (-£1.40 per m^2) and internal rollers by 12% (-£3.20 per m^2). It should be noted that these energy savings could be potentially higher if the side of an internal blind that faces the glazing was coated with a reflective layer that returns more of the solar radiation before it is absorbed by the internal environment [10]. Other examples showcasing the benefits of various shading products can be seen in a study performed in Greece where PV shading devices were both simulated and physically installed to ascertain their impacts within the buildings. So despite today's buildings being predominantly based around artificial lighting and cooling / heating systems, it proved that PV shading devices can help limit the overall energy consumption by reducing direct solar gains during the overheated period [9].

Additional studies have been completed intending to analyse the impact of climate change such as the building energy simulation study conducted in Hong Kong to analyse the impacts of climate change on summer conditions for the high-density urban environments within Hong Kong. The application of shading panels in different orientations was simulated on the building façades and it was concluded that the potential energy saving of implementing the most suitable shading panels can be up to 8% [8]. Another simulation-based study which utilised various algorithmic modelling environments intending to minimise energy consumption whilst maximise daylight lighting has been conducted. The study found that taking in to account the energy efficient design solutions, the optimal shading device reached up to 14% reduction in overall energy consumption whilst maintaining the above 50% daylight which is mandatory for office spaces [6]. The importance of shading devices in reducing energy consumption is further illustrated in a project run in Saudi Arabia where a multi-story hotel building situated in a very hot and humid climate was analysed. Similar to previous studies the impact of external shading was simulated and modelled and it concluded that the annual energy consumption of the building can be reduced by 20.5% by utilising the passive external shading methods whilst the additional cost for these shading devices would be recovered within 2 years. This is another example of how the shading devices can both meet the technical energy consumption requirements and also be a commercially viable option for building investors [1].

The significance of both energy and economic savings can be seen in a simulation study carried out in South Korea for high-rise residential buildings to minimise heat gain and reduce cooling energy costs in the summer. This study concluded that utilising exterior shading devices would reduce the annual cooling loading (19.7% for horizontal and 17.3% for vertical shading panels). Taking in to account the relatively short payback period, this study shows how these design improvements can be implemented early on in the design and planning phase of the building construction [2].

Performance gap

With the rapid increase of energy consumption in buildings in recent years especially with the rise in population and growing economies, the importance of energy savings in buildings becomes more critical. One of the key factors in ensuring energy consumption is controlled and kept at a minimum is to utilise building energy modelling (BEM) at the very early stages of the design [4]. The growth in the use of building modelling software packages opens the door for improvements in the design and also in the modelling itself by introducing novel methods such as building information modelling-based software packages which promote conventional building energy modelling into the digital building design process [5].

To better identify the real-world results and understand the most effective implementation tools, research projects undertaken should include elements of real-world experiments and not just rely on theoretical and simulated approaches. Upon review of the related studies undertaken, it’s evident that there are mostly based

on modelling and simulation which can be due to various reasons such as the more expensive and time consuming nature of real-time data based studies. Taking in to account the recent rise of building energy software modelling packages and the increasing number of studies utilising these methods in their projects and research, the accuracy and reliability of these modelling software packages has become even more crucial and critical. This energy performance gap refers to the discrepancy between the predicted energy savings and the realised actual savings especially after buildings implement energy-efficient technologies [7].

To illustrate the criticality of the energy performance gap, an example can be mentioned where a research study performed in 2016 on a refurbished building in London was investigated. The software used in this project was IES and the aim was to analyse its predictive weather projections and how it implemented the use of blinds and shutters and extreme weather scenarios especially with regards to thermal gain. Upon comparison the real world data with Simulation results a performance gap was seen due to the lack of extreme weather data in software [11] and [3]. Another example which shows that the performance gap needs addressing is in the United States where there is a rise in buildings being certified to energy saving and environmental standards but when analysing their actual savings it was found that a third of certified buildings were saving less energy than standard buildings and even in the cases that there were some energy savings, the predicted and simulated results were showing 1.5 to 3 times more savings that their actual energy results [7].

Barriers in the UK

In order to be in a position to initiate the correct and efficient implementation of shading products based on the overwhelmingly positive findings in various research studies and projects, there also needs be a good and broad understanding throughout the various government and industry institutions in the UK. Unfortunately in comparison with other developed countries, the UK is still lagging with regards to utilisation of shading products and there seems to be a vast misrepresentation and devaluing of these products in Part l compliance tools, the simplified building energy model (SBEM) and the standard assessment procedure (SAP) which is quite worrying. To tackle this issue, engagement of all parties including the public perception is key.

Professionals must be aware of the benefits of shading products in buildings. Most of them are familiar with the visual effects of the shading products and not necessarily about the energy efficiency advantages of them. So, it is important to make the key individuals in the industry and academia aware of the advantages of shading products. This is not only limited to industry professionals, but the general public and consumers / occupants themselves also need to be educated as well so the demand matches the supply especially regarding the advantages related to thermal and visual comforts it can bring not to mention the positive effect on people's health and wellbeing. Retailers of the products will need various training as well to ensure they have a full understanding of the benefits of the products and how they can be tailored and targeted to specific consumer needs [10] and the accuracy of virtual models in changing climate must be improved.

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Go green go digital (GGGD): An applied research perspective toward creating synergy of crypto-mining and sustainable energy production in the UK

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Abstract

Despite announcing a climate emergency and the subsequent promise to go carbon neutral by 2050, UK targets for climate change are insufficient to effect the radical changes necessary to reverse the imbalance in the environment caused by human activity. This is due in large part to the high cost to profit ratio of sustainable energy production; profitability of solar, wind, geothermal, wave and other green energies is only realised after significant capital investment and a long gap period to breakeven (up to 10+ years). This means that only a few players will have both the capital and time to make a profit, leaving unsustainable energy as the cheaper (and more feasible) option. Ergo, without a short-term profit incentive, the sustainable energy industry is unlikely to grow quickly enough to counter the climate emergency that the world now faces. As the UK government has decided not to subsidise green energy until 2025, radical ideas which incentivise commercial activity toward investment in sustainable energy production must be explored. This paper suggests a specific implementation of the digital economy with a strong profit motive for green investors. Utilising a multi-disciplinary method of research, this paper argues from an applied computer science perspective that green crypto-mining can provide essential funding from the early stages of sustainable energy planning all the way to the deployment of a full crypto-mining operation scalable to the investment capabilities of the organisation. This solution works on two levels: 1. Convert sustainable energy production directly to capital through crypto-mining and 2. Grow the digital industry, in particular crypto-mining, in the UK to increase demand for sustainable energy, and as a result reduce the costs of going green for all energy consumers. The aim, therefore, is that renewable energy outcompetes unsustainable energy on a free market basis in the UK, thereby accelerating the green revolution. "For however many things have a plurality of parts and are not merely a complete aggregate but instead some kind of a whole beyond its parts, there is some cause of it since even in bodies, for some the fact that the there is contact is the cause of a unity/oneness while for others there is viscosity or some other characteristic of this sort." Aristotle, Metaphysics 8.6 [1045a].

Introduction

GGGD is an augmentation of the renewable energy power plant powering passively-cooled, CPUs capable of converting electrical energy into virtual currency using a free, open source mining algorithm, i.e. crypto-mining. Moreover, once all of the hardware is installed, there are only marginal costs for the life of the system. In

addition, GGGD has wide portability insofar as harvested free energy can be redistributed back to the grid and the CPUs at any ratio depending on market conditions. In fact, CPUs need not only mine crypto-currency; CPUs can be sub-contracted to customers such as the NHS, NASA, ESA, SETI, or any other data-centred organisation located around the world with complex algorithms to solve.

Simplified GGGD model of wind, solar, crypto-mining, and Monero (XMR) virtual currency production.

Fig. 1. Simplified GGGD Model (Source: author's creation).

Government money to renewable energy is insufficient to create the incentives needed for a radical change in the markets toward self-sustaining / self-sufficient systems. Instead, public funds are redistributed to unsustainables such as hydraulic fracturing, i.e. fracking, which have documented histories of damaging the environment and poisoning the water supply in the United States (Holloway 2018; Malin and DeMaster 2015; Zhang and Yang 2015; Kuwayama 2015), or nuclear, which suffers not only a public relations problem after such disasters as Chernobyl and Fukushima (Wheatley, Sovacool and Sornette 2016), but also a "decline of the average selling price on the margin of safety" (Deutsch, Fiáith, Virág et al. 2018), meaning simply that nuclear power is both unpopular and expensive.

GGGD offers a solution which incentivises the markets to invest concurrently into two technologies – renewable energy and computing power – which together this paper argues can spark a dot-com style hyperbolic inflation of investment in its fast and broad adoption (See Appendix D). The positive side effect is a significant increase in dynamically controlled energy capacity which can be used to stabilise the UK's power grid as it transitions to 100% renewables (Kroposki, Johnson, Zhang et al. 2017; Short and Infield 2007). The hypothesis of this paper is that renewable energy combined with crypto-mining will, as a combined force, breakeven earlier in its lifecycle than either technology deployed alone (with market conditions a mediating factor). The evidence for this statement is well-documented in each independent technology's tested and benchmarked capabilities (See Appendix C). The design in this paper is a particular iteration of their combination for the purposes of moving to the next stage after this paper: building the prototype.

Methods

The methods of this paper are investigatory, broadly surveying existing data on renewable energy and crypto-mining. The academic foundation is multidisciplinary with concepts in physics, computer science and economics

all playing a role in thought-testing and real-world application. The primary research is independently-funded, with IT facilities support from Coventry University, who authorised research to be conducted on-site. All primary and secondary research complies with university ethics.

First, the primary research conducts an open-ended interview with a CEO of a virtual currency mining firm to evaluate the feasibility of GGGD against the experience of an existing global operation. Second, the researcher selects and benchmarks various crypto-currencies to determine whether it is more cost effective to mine with CPUs, GPUs or ASICs. Third, the particular CPU and cooling options are selected based on the ratio of power (hash rate) to efficiency (equipment and electricity costs). And finally, the combination of wind and solar are selected to power the crypto-mining rig based on scalability and equipment costs.

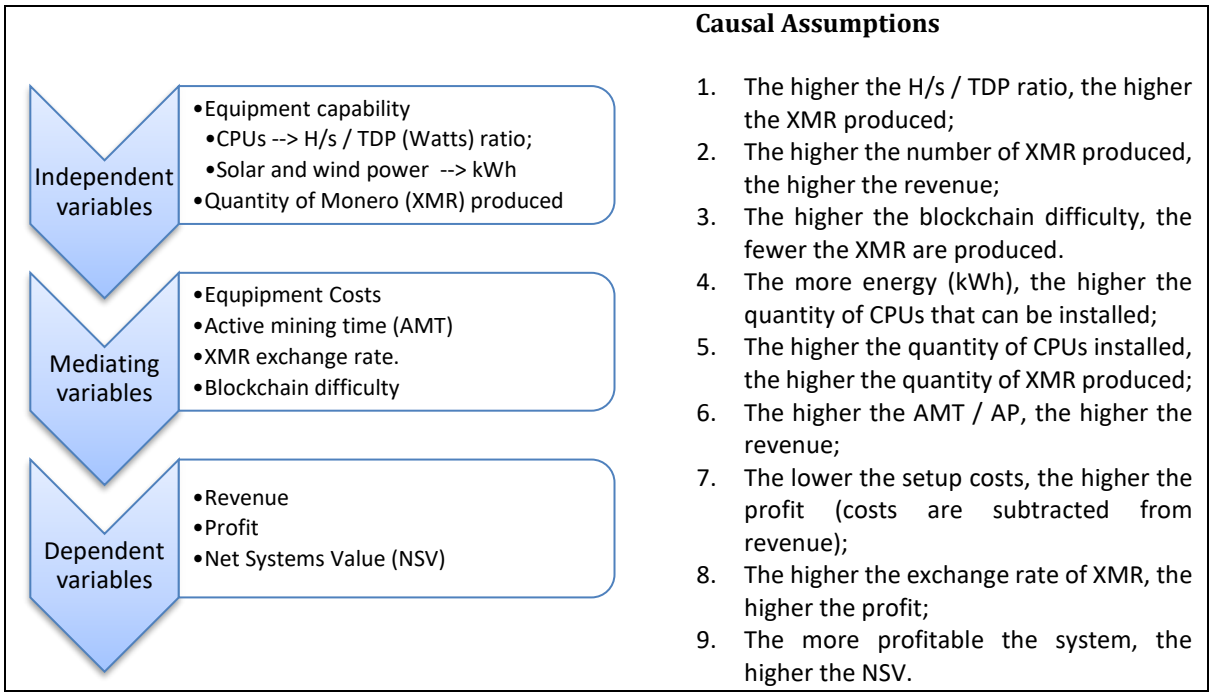

Fig. 2. Operationalisation of GGGD. Source: author's creation.

Table 1. Preliminary forecasted profits from mining with AMD Ryzen 9 3900x. Source: Adapted from Coinwarz.com (2019).

CPU: AMD Ryzen 9 3900x		**Time Frame**	**XMR Coins**	**Profit (in USD)**
Hashrate	11765 hashes/second	Hourly	0.00282	$0.22
	24.74 XMR	Daily	0.06778	$5.39
Average yearly reward	1,967.30USD	Weekly	0.47447	$37.73
		Monthly	2.03343	$161.70
Energy requirements	105 Watts	Annually	24.74	$1,967.30

Scientific theory

The following scientific theories together come together to support the GGGD design:

(1) Second law of thermodynamics:

Entropy is reduced by cutting out stages in energy transfer (to the grid) and storage (in batteries); electricity goes straight to the appliance. Mechanical and chemical engineering have an inherent prerogative to waste less as a matter of design (Li 2018; Kjelstrup, Bedeaux and Johannessen 2010).

(2) Fluid dynamics:

Passive Cooling Units (PCUs) are affordable, are low maintenance and have long lifecycles with future compatibility with upgraded CPUs. Their one off marginal cost is further mitigated by indefinite reusability as sustainable CPU coolers (Septiadi, Ula, Wulandan et al. 2019; Heydari et al. 2012).

(3) Moore's Law:

Modern processors have reached the ceiling of Moore's Law classically-understood; however, Moore's Law is still relevant in new CPU designs which incorporate multi-cores and processor supplementary capability (Flamm 2018; Shalf and Leland 2015).

(4) Dennard (MOSFET) Scaling:

Dennard (MOSFET) scaling is the theory that as the size of CPUs over their frequency decreases, frequency over watts increases (Dennard, Gaensslen and Rideout 1974).

General systems theory (GST)

The following typology links the scientific theory above with capital production:

(1) "General System Theory . . . is a general science of 'wholeness'":

Integrating two separate technologies – renewable energy and crypto-mining – makes whole a system designed to reduce per capita CO2 output by increasing green GDP.

(2) "There is a general tendency towards integration in the various sciences, natural and social":

GGGD earns profit directly by processing computer algorithms which have an inherent social value, i.e. money. Scientific innovation drives the renewable and digital economies.

(3) "Such integration seems to be centred in a general theory of systems":

GGGD is based on science fundamentals. In particular, the scientific notion of rate of entropy: efficiencies slow the rate of entropy and, in these gains, a profit can be attained.

(4) "Developing unifying principles running 'vertically' through the universe of the individual sciences, this theory brings us nearer to the goal of the unity of science":

GGGD generates profit from free energy making money for the proprietor without doing harm to the environment and furthermore builds green infrastructure which becomes cheaper to build as it grows.

(5) "This can lead to a much-needed integration in scientific education":

Understanding the connection of power to the growing digital industry, as well as the energy gap the UK inevitably faces, is important for students of all academic disciplines.

Source: Adapted from Bertalanffy (1968).

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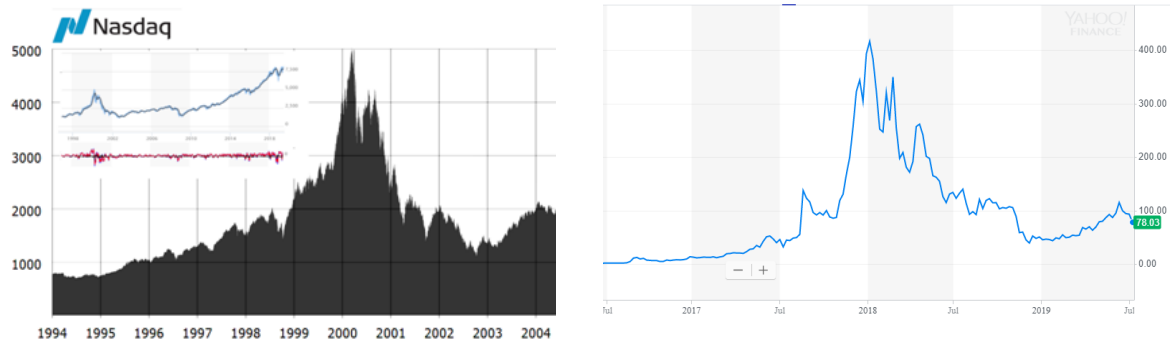
Appendix D. Economic hyperbolic inflations

The dot-com and virtual currency bubble compared.



A. Nasdaq dot-com bubble (1994-2004)

B. Monero (XMR) bubble (2017-2019)

Source: Adapted from Nasdaq.com (2019) and Coinmarketcap.com (2019).

Looking at the above diagrams, it is clear from the dot-com bubble that despite the bubble bursting that the market recovered and doubled from the peak of the bubble. Future technologies that will become dominant will attract early attention, and this is apparent in the crypto-currency boom. The lesson is that despite losing significantly from the peak in 2017, crypto-currencies are starting to recover and slowly gain back previous losses. Both the dot-com bubble and crypto-currency bubble took place over roughly the same time frame. The question is whether the crypto-currency, like the NASDAQ, will double from its previous peak.

Comparative analysis of separation techniques for Methylal-Methanol azeotropic mixture

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Abstract

The emission from engines is one of the major concerns which the country is facing nowadays. This can be overcome either by making changes in engine design or to search alternative fuels. To make the changes in the design of engines, a major research project needs to be launched which requires high engineering rationale. The best option left with the researchers is to search for alternative fuels with minimum emissions. Methylal is found to exhibit diesel fuel characteristics with low toxicity and reduced emissions. It is formed by a catalytic reaction of methanol with formaldehyde. But, unfortunately, there is the existence of a minimum boiling azeotrope of methylal with methanol at 94.06 wt % methylal at atmospheric pressure, which needs to be separated. A method of Extractive distillation using water as an entrainer for the separation of methylal-methanol azeotropic mixture has been explored in this case study. Use of water as an entrainer for the separation of methylal-methanol azeotropic mixture has been explored first time in open literature. A comparison of this technique with the existing techniques has been deduced in this work to highlight the importance of using water as an entrainer. The simulations have been carried out using Aspen Plus and Aspen dynamics simulation software. The results show that water is an effective entrainer for the separation of methylal-methanol azeotropic mixture as it has resulted in 69.41% savings in comparison to Extractive distillation using DMF as an entrainer, 65.33% savings in comparison to Divided- wall column, and 52.72% savings in comparison to pressure swing distillation technique.

Keywords

Cost analysis, control studies, extractive distillation, methylal-methanol and water.

Introduction

The importance of methylal in chemical industries has grabbed the attention of researchers to find an efficient, reliable and robust technique for the separation of an azeotropic mixture of methylal-methanol in a safe and profitable manner. Methylal is primarily used as a molecular weight modifier for polyacetal resin [1,2]. Methylal exhibits quite attractive properties of having good dissolution property, low viscosity, and high evaporation rate. It is used as an intermediate for the synthesis of paints, varnishes, insecticides etc. An important feature of methylal is its use in pharmaceutical industries where a highly pure form of methylal is used [1, 3-4]. But due to the existence of a minimum boiling azeotrope between methylal and methanol, the separation of this azeotropic

mixture has become a sought goal process. Since, the separation of this complex azeotrope between methylal and methanol is impossible by conventional means of distillation; therefore, some enhanced separation techniques need to be explored. Having a look on previously published literature on this azeotropic mixture, we have found few papers which have done a good work on the separation of methylal-methanol azeotropic mixture. The separation of methylal-methanol using membrane separation techniques like pervaporation, membrane distillation etc. has been investigated [1] but due to the technical disadvantage of membranes like poor permeating flows, membrane wear and tear issues etc., some other separation techniques have been investigated. A technique of reactive separation has been explored by a group of researchers for the separation of this azeotropic mixture but the results show that the purity of methylal is less than 99% [5].

Pressure swing distillation has been also reported for methylal-methanol azeotropic mixture but the technique involves complexities in maintaining the high pressure in the column and also leads to high capital cost [6]. Another method of divided wall column (DWC) has been reported in literature which utilises only single column for the separation purposes. A technical disadvantage associated with the DWC is the internal interactions involved within it. Moreover, the control of DWC is highly complex and requires high maintenance online composition controllers to maintain the product purity [7]. Extractive distillation is known to be a simple and widely used separation process used for the separation of azeotropic mixtures [8]. Because of the numerous advantages of Extractive distillation process like, less complexity involved, low maintenance cost, no internal interactions etc., the mixture of methylal-methanol can be separated using Extractive distillation process. This process uses an external agent, known as solvent for the separation of complex azeotropic mixtures. The solvent alters the relative volatility of the mixture to be separated which helps in breaking the azeotrope formed between the different components of the mixture. This process has huge economic benefits in comparison to other separation techniques (Azeotropic distillation, Pressure swing distillation, Divided wall column, membrane separation etc.) provided an appropriate entrainer is selected. The selection of entrainer plays a crucial role in determining the feasibility and economy of the entire process.

For the separation of methylal-methanol azeotropic mixtures, various entrainers have been recommended. Many researchers have evaluated Dimethyl sulfoxide (DMSO), Dimethyl formamide (DMF), Ethylene glycol (EG) and ionic entrainers [9]. But all of these entrainers have negative impact on environment. To overcome the environmental impact of entrainers, a new entrainer with zero environmental impact has been explored in this study. Water is used as an entrainer for separating methylal-methanol which to our best knowledge has not been reported in open literature. The work has focussed on the steady state design f extractive distillation process for separating methylal-methanol using water as an entrainer. All simulations have been carried out using simulation software of Aspen Plus. The steady state design is followed by the economic analysis of this technique with the existing techniques already published in literature. The comparison is based on the different operating and design parameters to evaluate total annual cost (TAC) of all schemes of separation for methylal-methanol.

Steady state process design

The thermodynamic property package used in this case study is NRTL [10]. The binary interaction parameters for the model are obtained from Aspen Plus. The model selection is done on the basis of comparing the available experimental data [11] with the simulated data generated from Aspen Plus. NRTL model is used for liquid phase calculations and SRK calculates vapor phase fugacity coefficients that predict the vapor liquid equilibrium (VLE) correctly. The minimum boiling azeotrope of methylal and methanol at 94.06 wt % methylal at atmospheric pressure has been separated using Extractive distillation scheme with water as an entrainer. A two column distillation scheme operating at atmospheric pressures have been used for the separation of methylal-methanol. The feed mixture consists of an equimolar solution of methylal and methanol at a flow rate of 100kmol/h at atmospheric pressure. The number of stages in both distillation columns has been taken to be equal to 20.

The number of stages in two columns is set by performing the DSTWU analysis in Aspen Plus which provides the minimum number of trays. The number of trays calculated from DSTWU analysis is multiplied by a factor of 2 or 3 as per the rule of thumb to get the exact number of trays to be taken in a Radfrac column [12]. The stages are numbered from top to bottom of the column using the Aspen notation of considering condenser being stage 1 and reboiler being stage 20 [13]. Both columns are operated at 1atm pressure with a column pressure drop of 0.2 atm. After fixing the number of trays in both columns, the feed stage location and entrainer stage location are evaluated by using the sensitivity analysis tool of Aspen Plus which estimates the feed stage tray at stage 19 and entrainer stage location at stage 12. The operating parameters in both columns are distillate rate and Reflux ratio (RR). The design spec/vary tool of Aspen Plus is used to fix the product purities of both products. The steady state design flow sheet schematic is shown in Fig. 1. From Fig. 1, we observe that pure methylal is obtained from the top of column 1 while the bottom of column 1 which is an azeotropic mixture of methylal and methanol is sent to column 2 at stage no 12. From the top of column 2, pure methanol is recovered and the bottom of column 2 is recycled back to column 1 at stage no. 12.

Cost comparison

We have made a thorough comparison of Extractive distillation method with the alternative separation methods reported in open literature. Table 1 provides the details about the comparison drawn between Extractive distillation technique using water as an entrainer (present work) and Extractive distillation using DMF, EG, ionic entrainers, divided wall column (DWC) and pressure swing distillation (PSD) [6,7,10,14,15]. The cost correlations used in this study are same as that used in reported literature [16] to maintain consistency. From the table of comparison, we have observed that the entrainers reported in literature have resulted in very high total annual costs (TAC) besides causing environmental concerns. The number of stages used in column 1 and column 2 are also higher than those used in the present work. The purity of methylal in our study is slightly less than the reported one but the recovery is 100% for both products. The results reported in published work has less methanol purity in comparison to the purity attained by using water as an entrainer.

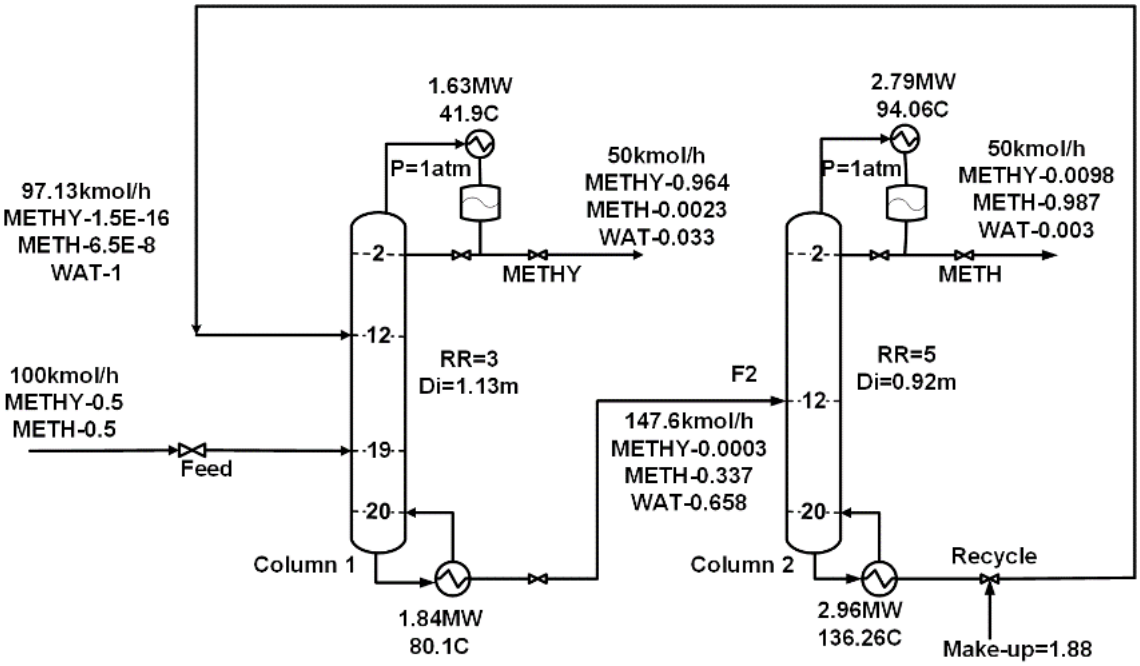

Fig. 1. Steady state design flow sheet schematic.

Table 1. Cost comparison of different alternative schemes for methylal-methanol separation.

Parameters		Published work					Present
		DMF	***EG*** [14]	***Ionic Entrainer***	***DWC***	***PSD*** [6]	***Water***
No of stages	***Col 1***	52	11	18	52	16	20
	Col 2	22	4	10	-	28	20
RR	***Col 1***	1.321	0.6	1.1	-	0.226	3
	Col 2	0.54	3.8	1.6		1.34	5
IDI	***Col 1***	0.79	-	-	-	0.83	1.13
(m)	***Col 2***	0.46	-	-	-	0.78	0.92
Product purities	***Methylal***	99.9	99.9	99.9	99.9	99.9	96.4
(%)	***Methanol***	97.7	96.4	97.2	97.7	97.7	98.7
QR_{total} (MW)		1.072	0.03542	0.03069	0.982	1.5096	4.81
TAC, $(10^5)		8.5	-	-	7.5	5.5	2.6

Conclusion

A comparison between proposed technique of Extractive distillation using water as an entrainer and the existing alternative techniques of separation reported in literature (Extractive distillation using DMF, EG, ionic entrainers and PSD scheme) has been addressed in this case study. The proposed technique has economic benefits over all

other reported schemes in literature. It has been assessed that the current scheme results in 69.41% savings in TAC in comparison to extractive distillation using DMF as an entrainer, 65.33% savings in TAC in comparison to DWC, 52.72% using PSD scheme. The proposed scheme is thought to be environmental friendly also as water is used as an entrainer.

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For post-subsidy solar PV uptake in the UK: Techno-economic assessment of integrating solar PV and battery storage

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Abstract

With the progressive withdrawal of the Feed-in-Tariff (FiT) provided by the UK government, one promising potential to sustain rooftop solar Photovoltaic (PV) uptake is the incorporation of storage technology. However, currently it cannot be denied that the financial viability of this type of model is still in question, and further research is needed to assess its feasibility. The purpose of this paper is to evaluate the techno-economic feasibility of combining electricity storage with Solar PV in the UK's non-domestic buildings. Existing literature indicates that, in today's market conditions, the effect on the profitability of investing in storage is low. However, they neglect the advantages of combining different types of battery storage services. Consequently, this paper particularly investigates the financial impact of utilising peak shaving and balancing service for the grid on a solar PV- plus -storage system. The paper proposes a novel and viable model for combining Solar PV and storage in non-domestic buildings under the post-subsidy conditions. The approach involves, using the System Advisor Model (SAM) as a simulation tool to conduct discounted cash flow and techno-economic analyses. To investigate the most financially viable case, that of battery storage, different sizes of PVs and battery storage has been simulated under different economic conditions. The results demonstrate that the proposed model in the study fully restores the economic feasibility of solar PV projects in the UK. The model also enables the building owner to benefit from peak shaving, and generate additional revenues by providing balancing services for National Grid including non-dynamic Firm Frequency and Short Term Operating Reserve. However, the research shows that the main economic value of storage comes predominantly from peak shaving rather than balancing services. In conclusion, we discuss policy approaches to developing the suggested model.

Keywords

Solar PV, Battery Storage, Techno-economic model and Feed-in-Tariff (FiT).

Introduction

With the progressive withdrawal of the Feed-in-Tariff (FiT) provided by the UK government, one promising potential to sustain rooftop solar Photovoltaic (PV) uptake is the incorporation of storage technology. However, currently it cannot be denied that the financial viability of this type of model is still in question, and further research is needed to assess its feasibility. The purpose of this paper is to evaluate the techno-economic feasibility of combining electricity storage with Solar PV in the UK's non-domestic buildings. Various scholars

have begun to explore the potential opportunities of integrating battery storage and renewable energy, such as Jones et al (2017), who investigate the financial viability and Life Cycle Assessment (LCA) of solar PV systems, including battery storage within non-domestic buildings. The financial feasibility of integrating electricity storage and wind farms has also been evaluated by Dufo-López et al. (2009). Other scholars have focused on the use of electricity storage at distribution level, evaluating its role in reducing demand during the peak times of a distribution network (Walawalkar & Apt, 2008).

The economic feasibility of using storage systems to implement peak shaving (reducing electricity demand during peak price period) has also been explored by Telaretti et al. (2016). The majority of these studies indicate the low profitability of investing in storage in today's market conditions. This could be due to the fact that all studies have only considered one service of electricity storage, whereas He et al. (2011) highlight the importance of combining different types of battery storage services in order to increase financial viability. Consequently, this paper particularly investigates the financial impact of utilising peak shaving and balancing service for the grid on a solar PV- plus -storage system. The paper proposes a novel and viable model for combining Solar PV and storage in non-domestic buildings under the UK's post-subsidy conditions.

Methodology

This paper employs System Advisor Model (SAM) as a simulation tool to conduct discounted cash flow and techno-economic analyses. To investigate the most financially viable case, that of battery storage, different sizes of PVs and battery storage has been simulated under different economic conditions. Fig. 1 presents the overview of employing SAM as a simulation tool to run a techno-economic analysis of integrating of solar PV and electricity storage and to investigate how these can be structured to be a viable model for Solar PV-plus-storage in non-domestic buildings.

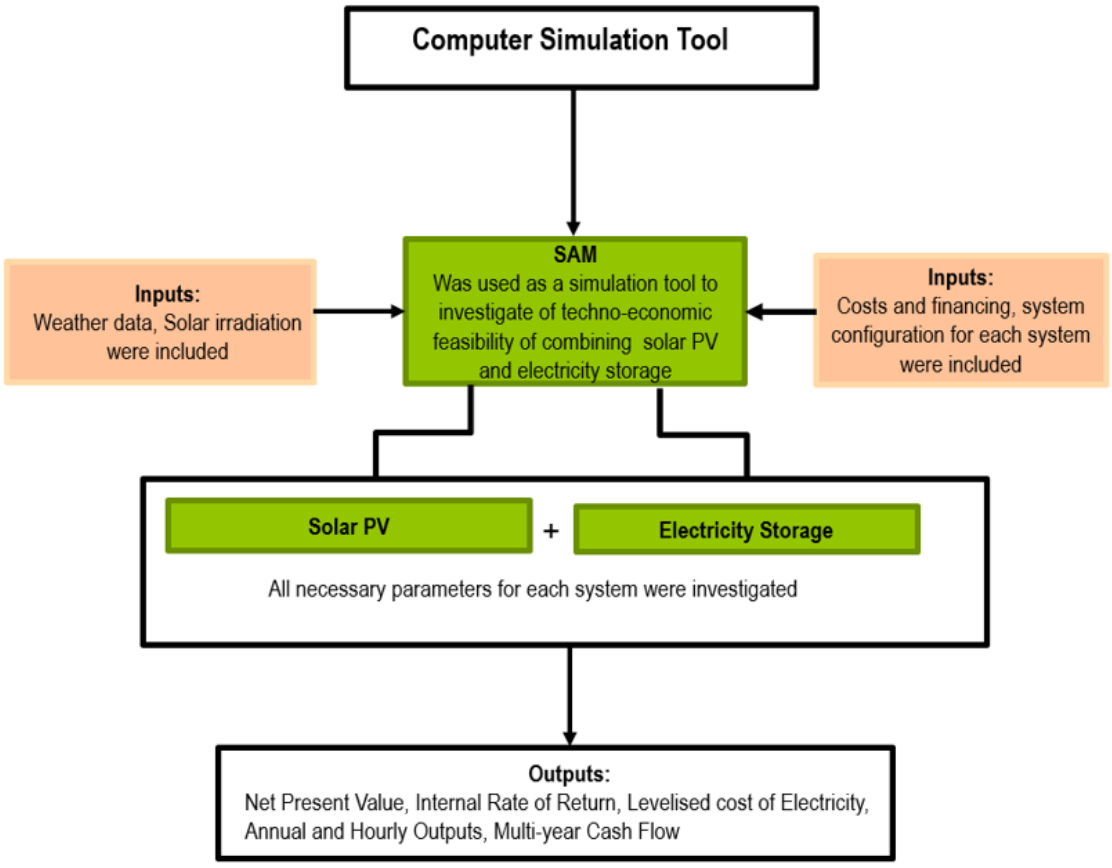

Fig. 1. Techno-Economic Simulation of Integrating Solar PV and Storage in SAM.

Results and discussion

This paper proposes an approach and illustrates how individual non-domestic buildings with small storage capacity can provide both balancing and peak shaving services. Balancing services can be delivered either in a large capacity or can be aggregated. Therefore, due to the relatively small size of battery storage in non-domestic buildings, this study proposes that a non-domestic building owner wishing to generate revenue by providing balancing service should work in partnership with an Aggregator. An Aggregator works in collaboration with System Operator (SO) including the National Grid to deliver balancing services. The majority of Aggregators work based on cloud services that aggregate the energy stored in the systems that the business or households already own such as stationary and mobile storage (e.g. electric cars and battery storage). Which, create a virtual energy pool that can be grid to help grid stability and reduce its need for power stations (Fig. 2). Under the designed model the building owner would benefit from peak shaving; as well as generate additional revenues by providing Firm Frequency Response (FFR) and Short Term Operating Reserve services (STOR) for National Grid.

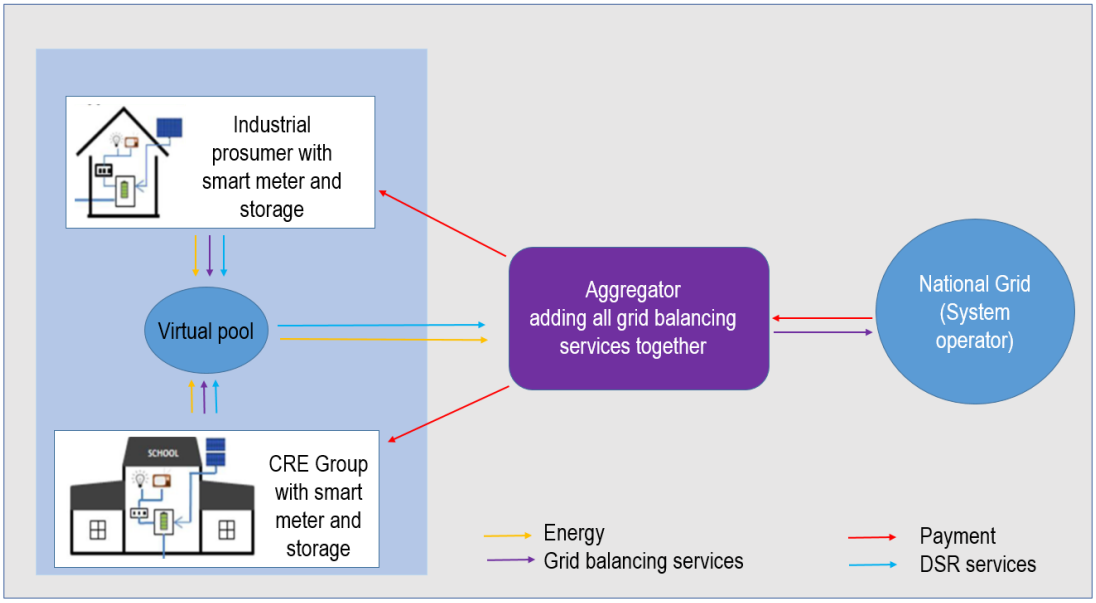

Fig. 2. Providing peak shaving and grid balancing services by individual non domestic buildings.

Table 1. Gross revenue from providing balancing services and peak shaving.

Services	**Revenue (£) for 70 kW PV +50 kWh storage (Year 1)**
Peak Shaving	£10,691
Short Term Operating Reserve	£1,462
Firm Frequency Response	£20
Total Gross Revenue (Year 1)	£12,173

Conclusions

The designed model in the study enables a non-domestic building to utilise more than one balancing services during the day. The research has shown that investment in electricity storage for non-domestic buildings will pay off and it will have a shorter payback period by peak shaving and providing STOR and FFR. However, the results indicate that peak shaving through network charge avoidance generates the highest revenue out of three revenue services (Table). Therefore, if a storage provider cannot utilise all three services together priority should be given peak shaving followed by STOR and finally FFR.

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Concentrated solar power in South Africa: A techno-economic assessment

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Abstract

South Africa's dependence on fossil fuels such as coal for generating power has made it the highest carbon dioxide emitter in Africa; yet the abundance of high solar irradiation and existing government policies provide the country with the potential for clean and efficient renewable energy. In a bid to reduce carbon footprint, Concentrated Solar Power (CSP) has been at the forefront; with several installations over the last years from different CSP developers. However, the high capital and generation costs incurred in developing and operating CSP plants lead to uneconomical Power Purchase Agreement prices (PPA). The purpose of this study is to analyse and optimise the techno-economic performance of a parabolic trough CSP plant using molten salt as heat transfer fluid and determine the most viable location for further installation. The research considered techno-economic modelling and financial optimisation of a parabolic trough CSP with molten salt as both heat transfer fluid and storage media using System Advisor Model (SAM). Two sites in Upington and Bloemfontein, were selected due to their potential for further CSP installations, close proximity to the transmission lines and good solar irradiation values to analyse the financial performance operating under Feed-in Tariff for CSP in South Africa. The analysis showed that the site in Upington in Northern Cape Province attained the lowest Levelised Cost of Electricity (LCOE) of 14 cents/kWh compared to 15.7 cents/KWh in Bloemfontein of Free State Province with optimum thermal energy storage of six hours. Despite this, the financial models developed showed a substantial reduction in PPA price by 20% from the existing bidding cap in literature. In conclusion, this research recommends a policy incentive system with tax holidays for CSP investments and grants to reduce interest on loans for new CSP Plants.

Keywords

Levelised cost of electricity (LCOE), Thermal energy storage and Power purchase agreement.

Introduction

Nations worldwide have drawn targets to increase renewable energy generations and reduce fossil fuels in order to meet the increasing electricity demand while supporting growth of a green economy [1]. As a consequence, there have been dramatic reductions in renewable energy technologies costs in line with factors related to technologies, finance, increased competition, research and development and accelerated deployment [2]. South Africa, a coal based economy with the highest Africa carbon emissions, has embarked on Concentrated Solar Power as an option to meet its energy and emissions target. [3].

South Africa's Department of Energy (DoE) rolled out bids given by the renewable energy independent power producer programme (REIPPP) to meet its goal of 43 percent energy supply from renewables by 2030 and enable increased supply of renewable energy to combat climate change. The total installed CSP capacity from seven projects by 2018 was 600MW and five of the plants are parabolic trough type. The rate of installation of CSP plants is majorly affected by the high levelised cost of electricity (LCOE). Past research on parabolic trough CSP by Archimedes plant in Italy employed molten salt [4] as a heat transfer fluid and increased the capacity factor and efficiency. However, the existing literature has not covered the financial impact of using molten salt as a head transfer fluid. The aim of this research is to analyse and optimise the techno-economic performance of a parabolic trough CSP plant using molten salt as the heat transfer fluid and determine the most viable location for further installation.

In this research, a method of reducing the levelised cost of electricity (LCOE) of parabolic trough in South Africa is presented with molten salt as HTF while eliminating a heat exchanger employed in thermal oil plants. Other components of the parabolic trough CSP plant are to be optimised and their performance is analysed to improve the thermal conversion efficiency of the solar collector field, improve capacity factor and increase net present value by selecting an economically viable site between Upington and Bloemfontein.

Material and methods

The research used system advisor model (SAM) to model 100MW parabolic trough CSP plant at two locations in South Africa. The modelled plant used molten salt as a heat transfer fluid and thermal energy storage and analysed the technical and financial performance. Sensitivity analysis for solar multiple and thermal energy storage were run to optimise the CSP plant and improve the technical and economic performance as shown in **Error! Reference source not found.**. The thermal storage was optimised to determine the levelised cost of e nergy, internal rate of return, net present value and power purchase agreement prices for the two locations.

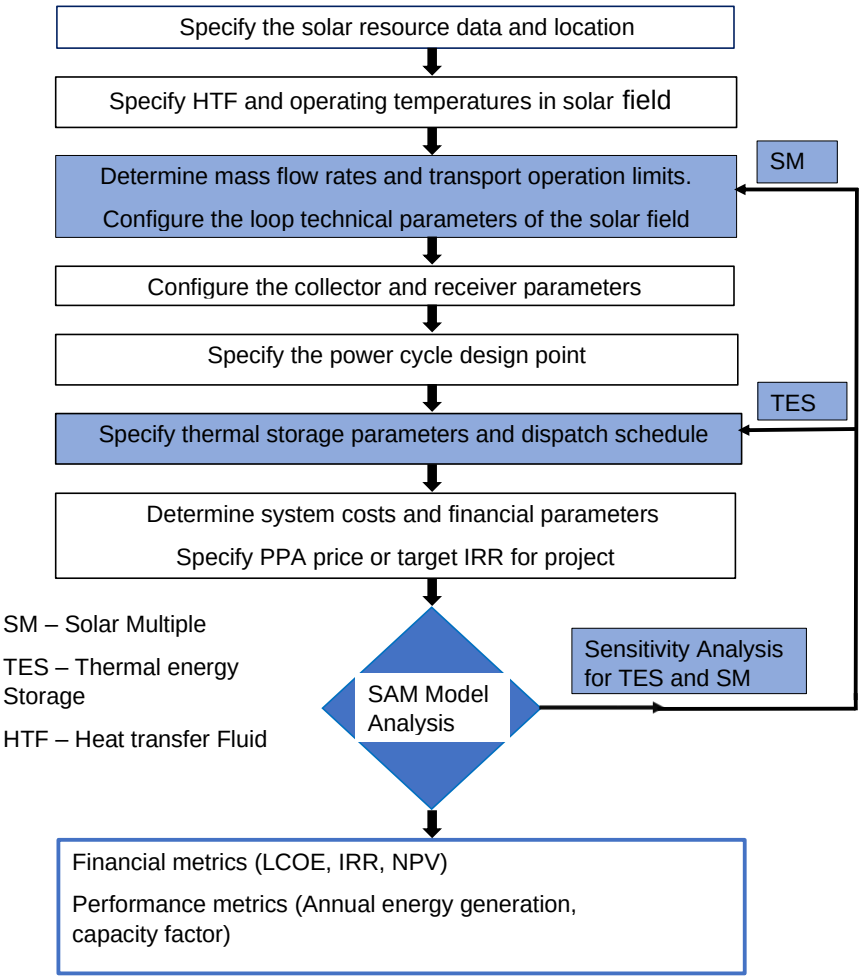

Fig. 1. Methodology flow approach for System advisor model (SAM) for techno-economic analysis.

Results and discussion

Simulations were carried out using SAM for Upington, Northern Cape province and Bloemfontein, Free State province to determine the more economically viable location of 100MW parabolic trough CSP using both performance and economic parameters. Two performance parameters, solar multiple, thermal energy storage were optimised to determine the least LCOE for the two locations in South Africa. The sensitivity analysis/optimisation showed that the lowest LCOE was observed at a thermal energy storage of 6 hours and solar multiple of 2.2 in Upington. These are shown in **Error! Reference source not found.** and **Error! Reference source not found.** respectively. Bloemfontein also had an optimised thermal energy storage of 6 hours but its optimised solar multiple of 2.4 increased the capital expenditure of the plant in comparison to Upington.

Evaluation of techno-economic performance

The technical performance is determined by the capacity factor and the annual energy generated at the CSP plants in Upington and Bloemfontein. CSP parabolic trough plant of 100MW located at Upington had a

significantly higher capacity factor of 39.7% compared to 34.6% at the plant in Bloemfontein. The annual energy generated at the CSP plant in Upington shows a 13% increase compared to that at the Bloemfontein site as shown in **Error! Reference source not found.**.

Table 1. Technical and economic parameters comparison for CSP plant at Upington and Bloemfontein.

Metric	Upington	Bloemfontein
Annual energy (year 1)	3.48E+08 kWh	3.03E+08 kWh
Capacity factor (year 1)	39.70 %	34.60%
Levelized PPA price	$0.138 /kWh	$0.158/kWh
Levelized LCOE	$0.136/kWh	$0.156/kWh
Net present value	$8.29E+06	$8.35E+06
Internal rate of return (IRR)	11.00%	11.00%
Net capital cost	$5.92E+08	$5.91E+08

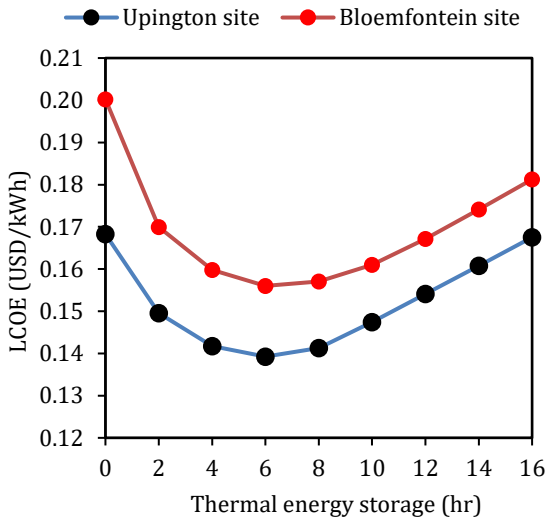

Fig. 2. Optimisation of thermal energy storage.

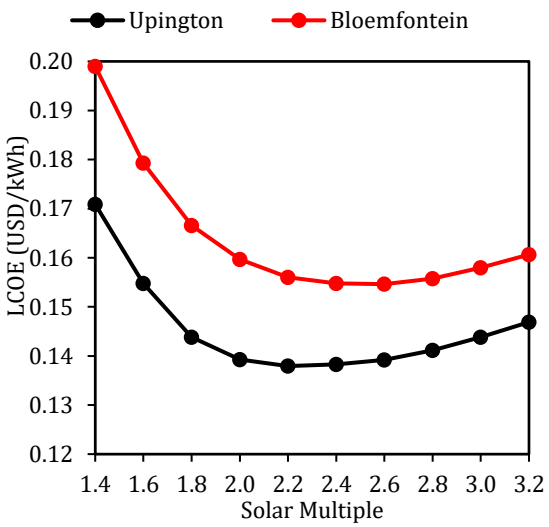

Fig. 3. Optimisation of solar multiple.

The results showed that developing CSP in Upington is financially more viable as it led to a lower LCOE, higher capacity factor and higher NPV. The presence of higher direct normal irradiance value in Upington compared to Bloemfontein influenced optimal results for the development of CSP plants in Upington. Different economic parameters were analysed to evaluate their impacts on the NPV and capital costs of the CSP Plant. Increasing the IRR target for the project increases both the NPV and the PPA price for both Upington and Bloemfontein . An IRR target of 11% was selected for this particular project to have a lower PPA price of $0.138/kWh for Upington yet giving a positive NPV which can favourably compete when bidding for projects under the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP). PPA price was used to

establish an economically viable but competitive price for REIPPPP. PPA price of $0.14/kWh for Upington gives NPV of $28.19 million compared to a loss of $45.11 million for the Bloemfontein site as shown in Table 2 .

Table 2. Comparison of NPV for Upington and Bloemfontein CSP sites with different PPA prices.

PPA Price	NPV (million) Upington	NPV (million) Bloemfontein
$0.12/kWh	$-56.57	$-119.08
$0.13/kWh	$-14.19	$-82.10
$0.14/kWh	$28.19	$-45.11
$0.15/kWh	$70.56	$-8.12
$0.16/kWh	$112.94	$28.86
$0.17/kWh	$155.32	$65.85
$0.18/kWh	$197.69	$102.84

Upington was chosen as the most economically viable location for CSP plant using molten salt as both the heat transfer and thermal energy storage media because it provides investors with both better technical and economic performance values. PPA price of $0.14/ kWh was chosen as the base price for input into the bidding process which is about 20% decrease from Bookport CSP plant price [5].

Conclusion

The research showed that optimising the parabolic CSP plant reduces the LCOE and PPA agreement prices. However, for these projects to become more economically attractive, a financing approach of providing grants to Investors to reduce the interest rates on loans and lower the risks associated with CSP projects is needed. This study recommends a policy incentive system with tax exemptions for CSP investments to attract investors.

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Onset of Vastus Lateralis during Sit-to-Stand and Stand-to-Sit task

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Abstract

Electromyography has been used successfully for describing the movement physiology and estimating the human intent towards the movement. The estimation of movement onset finds many application in assistive and rehabilitation devices for intension based control, wherein the muscle onset serves as the triggering point for the actuation of such devices to initiate the movement. Sit-to-stand (standing form sitting position) and stand-to-sit (sitting from a standing position) are basic daily life movements and also an indicator of lower limb strength in individuals. These tasks have also been used as a therapeutic intervention for improving posture and stability in elderly. To encourage user participation in such therapeutic interventions of sit↔stand (sit-to-stand and vice versa), a robotic assistive cum rehabilitation device is sought. In the present study, onset time of vastus lateralis (VL) muscle group is estimated during sit-to-stand and stand-to-sit task. In the study conducted on five participants, EMG activity of VL and knee deviation was recorded. Muscle onset time was estimated using a Teager-Kaiser Energy Operator (TKEO). Before applying TKEO algorithm, the acquired raw EMG data was denoised using high pass filter and wavelet transform. It was found from the study that onset of VL is significantly different for the two tasks. This study can be used in trigger based control of a device for providing sit↔stand transfer.

Keywords

Electromyography, Teager Kaiser, energy operator, Sit to stand, Stand to sit and EMG onset.

Introduction

Electromyography has been used successfully for describing the movement physiology and estimating the human intent towards movement [1]. The estimation of movement onset finds many applications in assistive and rehabilitation devices for intension based control, wherein the muscle onset serves as the triggering point for the actuation of such devices to initiate the movement [2]. Sit-to-stand (standing form sitting position) and stand-to-sit (sitting from standing position) are basic daily life movements and also an indicator of lower limb strength in individuals. These tasks have also been used as a therapeutic interventions for improving posture and stability in elderly [3, 4]. To encourage user participation in such therapeutic interventions of sit-stand tasks (sit-to-stand and then stand-to-sit), a robotic assistive cum rehabilitation device is sought. In the present study, onset time of vastus lateralis (VL) muscle group is estimated during sit-to-stand and stand-to-sit task.

Material and methods

Design of experiment

Five healthy male university graduate students (age: 23.3 ± 2.7 years) participated in the study. Repeated experimental trials for sit-stand task were conducted. A sit-stand trail consisted of the participant performing first a sit-to-stand followed by stand-to-sit task after waiting 5 s while in standing posture. For each participant the sitting height was fixed to their respective knee height. Each participant performed three trials of sit-stand task at their natural speed of movement. Sitting height for each participant was fixed to the participant's knee height. EMG activity of VL (right leg) and right knee flexion/extension (K_{FE}) were recorded during the trials.

Instrumentation and data acquisition

LabVIEW program was used to log the time synchronized EMG and K_{FE} data in the PC at 1000 Hz sampling frequency. The EMG activity was measured using SX230 EMG electrode (Biometrics, UK) tethered with DataLINK DLK900 data acquisition (DAQ) unit (Biometrics, UK) and NI USB-6211 DAQ card (National Instrument, USA). While, K_{FE} was measured using a 22 kΩ rotary potentiometer tethered to MyDAQ data acquisition unit (National Instrument, USA) for interfacing with PC.

Approach for analysis

Raw EMG signal was filtered using 2nd order IIR filter with a 20 Hz cut off frequency and subsequently denoised using discrete wavelet transform [5]. To further improve the onset detection, Teager-Kaiser Energy Operator (TKEO) was applied to the denoised signal and mean absolute value (MAV) was evaluated using 125 ms sliding window. Onset was marked when the slope of EMG MAV and K_{FE} increase or decrease for continuous 100 samples. Onset difference (δ_{onset}) was calculated as given by eq. (1).

$$\delta_{onset} = \tau_{onset}^{VL} - \tau_{onset}^{K_{FE}} \quad (1)$$

Where, τ_{onset}^{VL} is the onset time of VL EMG activity and $\tau_{onset}^{K_{FE}}$ is the onset time of K_{FE}.

Results and discussion

Fig. 1 shows the normalized data for the processed EMG and K_{FE}. Wavelet denoising combined with TKEO (EMG TKEO-MAV) was found to improve the signal quality and facilitated onset detection. The average onset difference between EMG and K_{FE} during sit-to-stand and stand-to-sit was 456.26 ms and -539.86 ms respectively (as shown in Fig. 2). In sit-to-stand task δ_{onset} was found positive indicating the onset of muscle take place prior to the movement onset of knee, while in stand-to-sit task δ_{onset} was negative indicating knee movement

preceding the onset of EMG activity. VL being an extensor muscle group is responsible for earlier onset in sit-to-stand task as compared to stand-to-sit task.

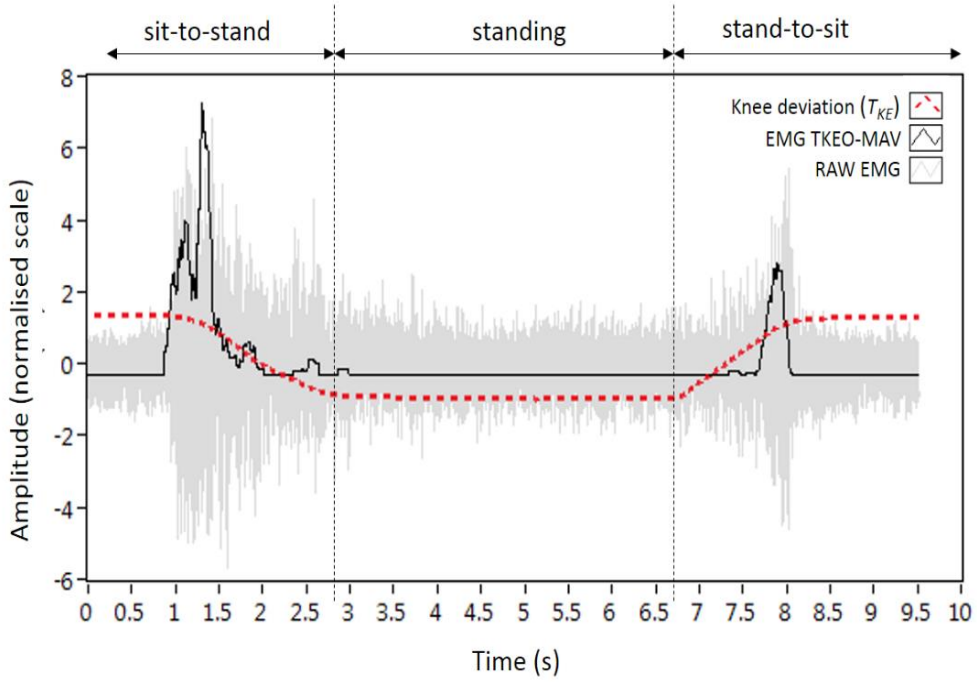

Fig. 1. Sample result for onset of VL and onset of knee movement in the STS task.

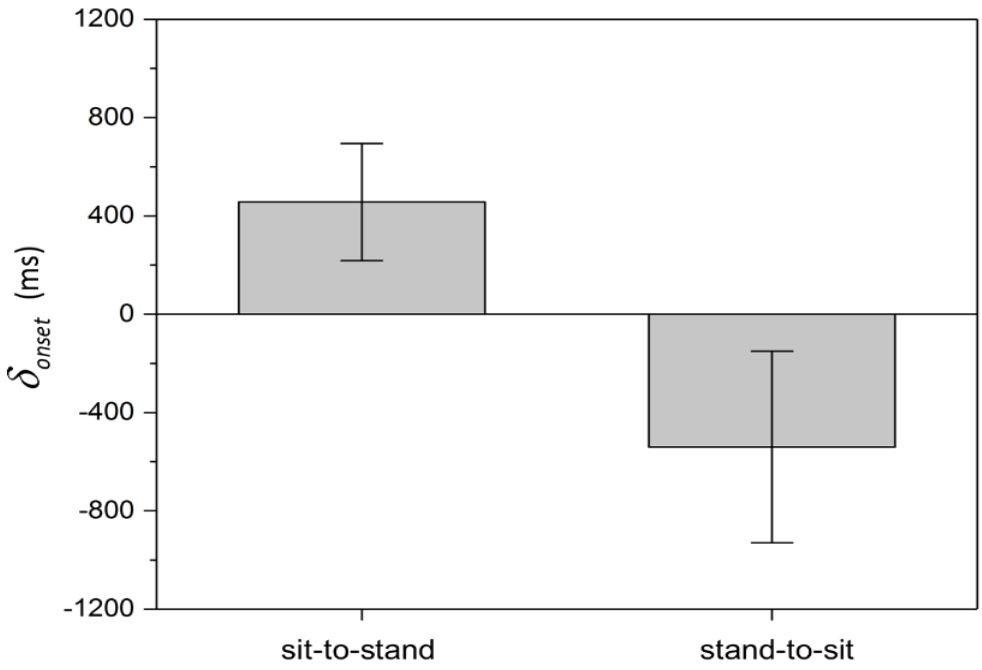

Fig. 2. Difference in onset of EMG activity of VL and knee extension/flexion in sit-to-stand and stand-to-sit task. Note: Negative δ_{onset} indicates onset of knee extension before the onset of knee in stand-to-sit task.

Conclusions

In this study, the EMG onset is measured with reference to the onset of knee flexion/extension, which is an important factor in the sit-stand task's phase classification for proactive control of assistive and rehabilitative devices. Onset in EMG activity of VL in sit-to-stand task was found to precede the knee extension; however, in stand-to-sit task knee flexion occurs earlier than the onset of VL.

Acknowledgement

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Fuel cell vehicles: Ukrainian perspective

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Abstract

Catastrophic climate change in Europe and the world is pushing scientists to conduct research with fuel that does not produce greenhouse gases. One of these fuels is hydrogen. We need to refuse the mineral energy resources "increasing the share of renewable hydrogen sources in the global energy system" according to energy association "Ukrainian Hydrogen Council". Hydrogen Fuel Cell Car was designed in Zhytomyr Polytechnic State University. The car was tested in the SIMPLORER-ADVISOR link developed by Ansoft. About 60% of chemical energy of fuel in Hydrogen Fuel Cell Vehicle lost in the conversion into electrical energy by the fuel cell. Cars with hydrogen fuel cells emit only water and warm air. Unfortunately, hydrogen fuel stations have not yet been built in Ukraine. But Ukraine ranks first in Europe and third in the world in zirconium reserves. So, Solid Oxide Fuel Cell (Ceramic Fuel Cell) that can use a common fuel is a good perspective in Ukraine. Zirconia based ceramics (1Ce10ScSZ) are considered as the most promising electrolyte for Ceramic Fuel Cell. The novel zirconia powders were designed for cathode and anode in Frantcevych Institute for Problems of Material Science. The main problem with fuel cell is a degradation problem of film electrolyte where electrolyte material is influenced by high temperature and exposes to reducing and oxidizing gases through contacting gas permeable porous electrode materials during a long time. The conception of the "positive degradation" was proposed to transform the degradation phenomena into an instrument for the directional influence of degradation processes via structural optimization of fuel cell material. Electrolytes made of Ukrainian powder has three times higher ionic conductivity (0.035 Scm^{-1} at 700.

Keywords

Fuel cell vehicles, Hydrogen, Fuel consumption, Ceramic fuel cell and Structural optimization.

Introduction

Catastrophic climate change in Europe and the world is pushing scientists to conduct a research with fuel that does not produce greenhouse gases. One of these fuels is hydrogen. We need to refuse the mineral energy resources "increasing the share of renewable hydrogen sources in the global energy system" according to energy association "Ukrainian Hydrogen Council". Transport is one of the largest polluting sectors of Ukrainian economics where greenhouse gas emission is still rising. So, Hydrogen Fuel Cell vehicles is good decision for Ukraine that can avoid dangerous exhaust gases from Internal combustion engine and reduce CO_2 rising. Cars

with hydrogen fuel cells emit only water and warm air [1]. Unfortunately, hydrogen fuel stations have not yet been built in Ukraine. But Ukraine ranks first in Europe and third in the world in zirconium reserves. So, Solid Oxide Fuel Cell (Ceramic Fuel Cell) that can use a common fuel is a good perspective in Ukraine.

Material and methods

Hydrogen Fuel Cell Car [1] was designed in Zhytomyr Polytechnic State University. The car was tested in the SIMPLORER-ADVISOR link developed by Ansoft. The materials used for ceramic fuel cells were made of zirconium sand at the Frantcevych Institute for Problems of Material Science. Zirconia (ZrO_2) doped with 10-mol. % Sc_2O_3 and 1-mol. % CeO_2 (1Ce10ScSZ) was used for ceramic electrolyte.

Results and ddiscussion

Hydrogen fuel cell car

Fig. 1 shows the block diagram of the Hydrogen Fuel Cell Car. Proton Exchange Membrane Fuel Cell (PEMFC) was selected that is most suitable for use in the automotive industry.

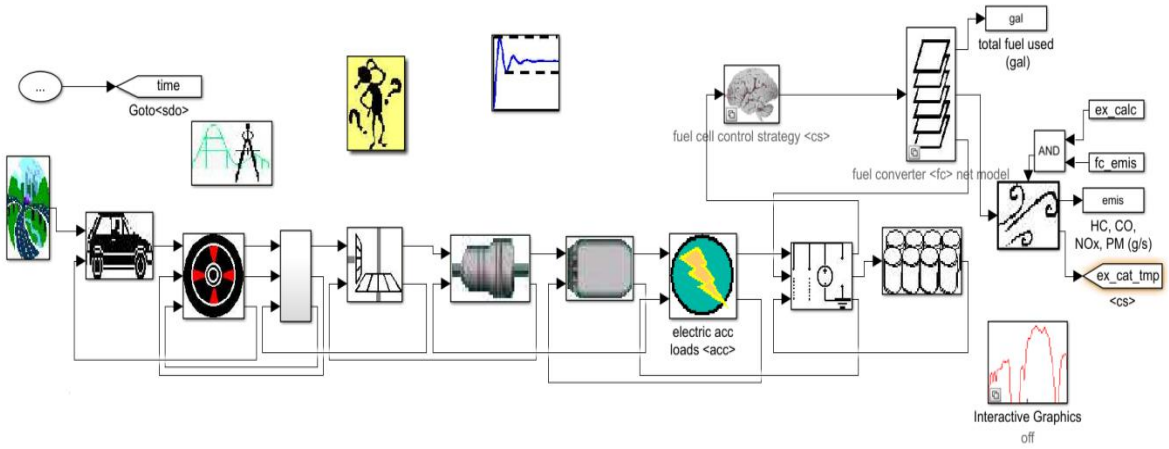


Fig. 1. Block diagram of the vehicle in ADVISOR.

About 60% of chemical energy of fuel in Hydrogen Fuel Cell Vehicle lost in the conversion into electrical energy by the fuel cell [2]. The results of simulations define how the vehicle can decrease fuel consumption. Using the ADVISOR program the dependence of specific fuel consumption from the power of the fuel cell stack was calculated that is shown in Fig. 2. The range between 10 and 40 Kw is good for the vehicle.

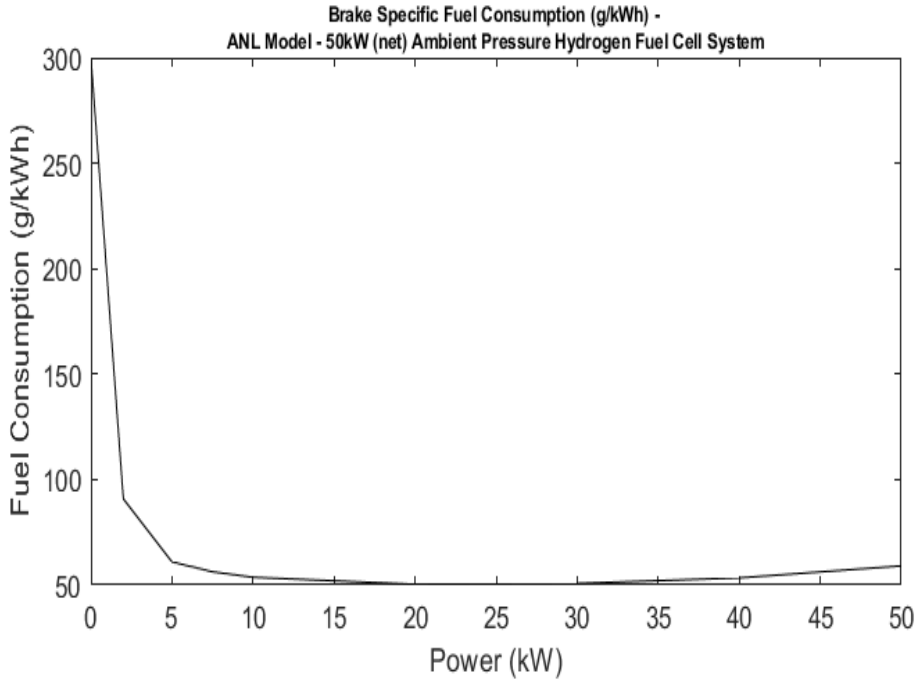


Fig. 2. Dependence of specific fuel consumption from power of PEMFC.

Seven riding cycles have been tested using ADVISOR. The test showed a maximum vehicle speed of 129.23 km/h with maximum load on the car. The graph of the test is shown in Fig. 3.

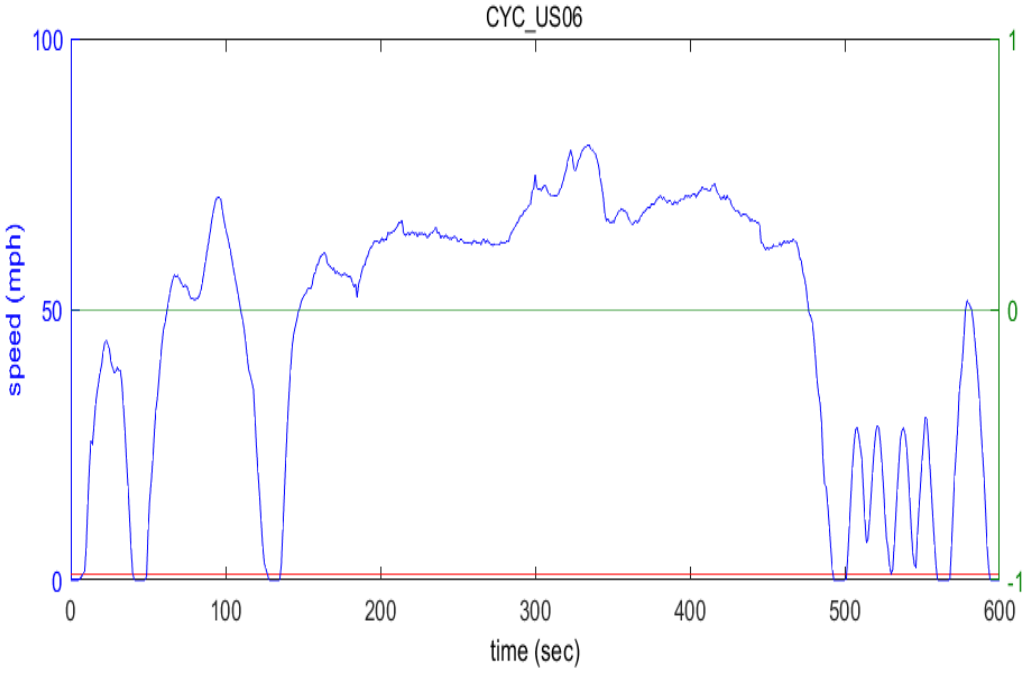
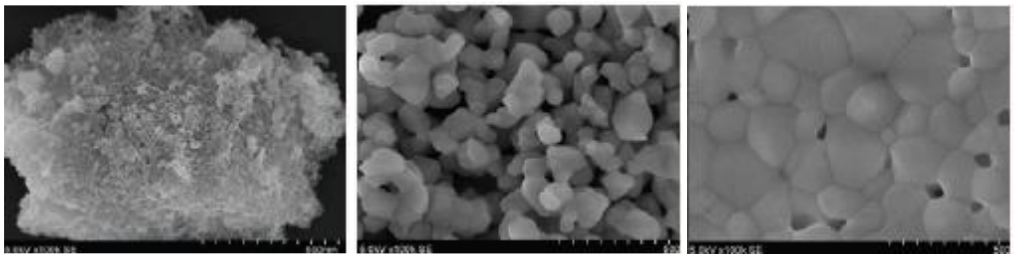


Fig. 3. Graph of speed for drive cycle (CYC_US06) vs time.

Solid oxide fuel cell (Ceramic fuel cell)

Zirconia based ceramics (1Ce10ScSZ) are considered as the most promising electrolyte for Ceramic Fuel Cell (CFC). The novel zirconia powders were designed for cathode and anode in Frantcevych Institute for Problems of Material Science [3]. The electron microscopy pictures of three types of the powders are shown in Fig. 1.



I II III

Fig. 4. Electron microscopy images of three 10Sc1CeSZ powder Types.

The porosity *P* of 1Ce10ScSZ ceramics was approximated by the Arrhenius's exponents as:

$$P = P_0 \exp(U_c / kT_s). \quad (1)$$

The imaginary energies of activation for strengthening/weakening, U_s, of three Types of 1Ce10ScSZ ceramics at temperatures below and higher their inflection points is given in Table 1.

Table 1. The imaginary activation energies of strengthening/weakening, U_s of electrolyte ceramics

Powder type	U_s **(T < To)**	U_s $(T > T_0)$
I	1.5	0.87
II	1.17	–0.43
III	1.46	0

The main problem with fuel cell is a degradation problem of film electrolyte where electrolyte material is influenced by high temperature and exposes to reducing and oxidizing gases through contacting gas permeable porous electrode materials during a long time [3]. The conception of the "positive degradation" was proposed to transform the degradation phenomena into an instrument for directional influence of degradation processes via structural optimization of fuel cell material. Electrolyte made of Ukrainian powder has three times higher ionic conductivity (0.035 Scm-1 at 700 °C), the highest strength (450 MPa) and fracture toughness (1.2-1.7 MPa·m ½) than international analogies. Using pure hydrogen, new Ukrainian CFC based on 8YSZ electrolyte could ensure 4.2 kW/m^2 at temperature 800° C.

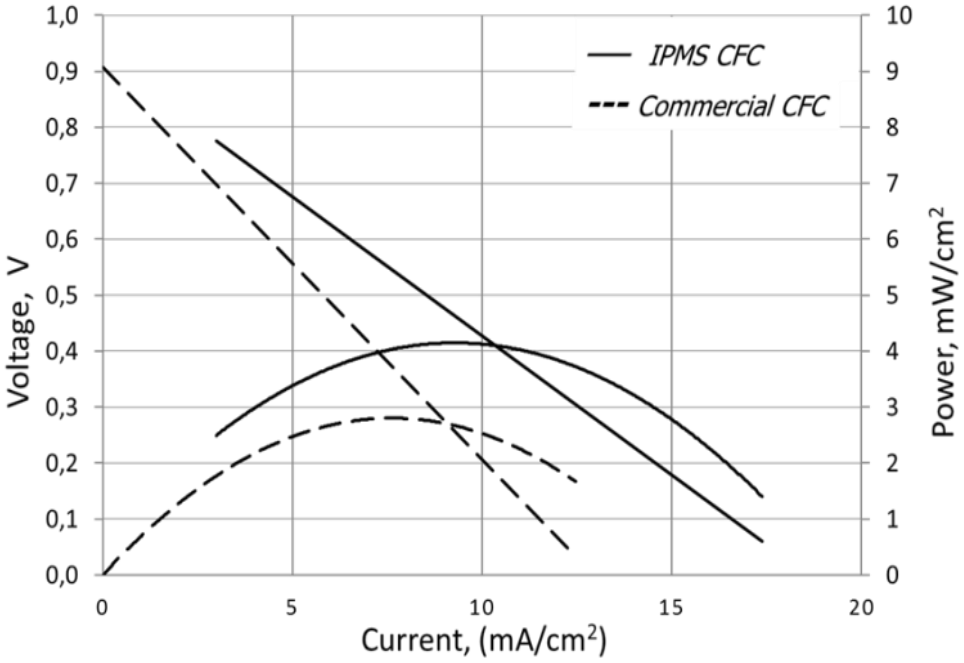


Fig. 5. Electrochemical properties of Ukrainian 8YSZ CFC and its commercial analog.

Nomenclature

k	Boltzmann's constant
P	porosity
T_0	inflection points (K)
T_s	sintering temperature (K)
U_c	activation energy of densification (eV)
U_s	activation energy of strengthening (eV)

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The inclusion of RoadCem additive in cementitious materials for soil stabilisation

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Abstract

The use of sustainable binders has dominated much of the discussion in engineering in a bit to conserve resources and preserve the environment. Hence, in keeping with the objective of reducing carbon foot-printing, a zeolite/alkali earth metal-based additive called "RoadCem" (RC) is used with granulated blast furnace slag (GGBS) and pulverised fuel ash (PFA) in a partially substituted OPC-stabilised soil in this research. RoadCem is an additive that is manufactured based on nanotechnology and contains zeolite, alkali earth metal with an activator as some of its constituents. Geotechnical investigation (mainly strength, swell and consolidation) involving a series of novel combinations of the binders with up to 50% of the OPC replaced in the stabilised soil were performed. Results of an extensive laboratory study indicated an improvement in the consistency limits shown by a clear reduction in the plasticity index property of the soil-binder mixes. An obvious effect of the RC was observed in the quick unconfined compressive strength gain in the 7-day cured samples with 50% of the OPC replaced. A promising trend of reduction in the swelling potential and settlement of the stabilised samples containing the GGBS, PFA and RC was also noticed as compared to the samples stabilised by the OPC used alone. A pore size model was formulated from the soil-water retention behaviour to explain the swell mechanism of the stabilised samples. The OPC-stabilised exhibited the greater inter-aggregate porosity with a corresponding reduced intra-aggregate porosity and reduced water retention. Overall, the results obtained in this study were adjudged to have met relevant standards for pavement construction.

Keywords

Sustainability, Metal based additives, pore size and cementitious materials and RoadCem

Introduction

This study proposes the addition of a nanotechnology-based additive called RoadCem in a soil-binder mix that includes OPC that is partially substituted by industrial by-products (GGBS and PFA) in the soil stabilization process. Therefore, an investigation into the strength, consolidation and swelling behaviour of a single and multiple combinations of OPC and the by-products additives in the stabilization shall be carried out in this research. A comparison of the effect of using GGBS and PFA in the soil-binder mix will also be investigated.

Material and methods

The soil material considered in this research is a commercially processed china clay (kaolinite). The binders and by-products are OPC (C), GGBS. PFA and RoadCem. 8% of the OPC binder obtained by dry weight of the soil was used shall be substituted by 49%, 59%, 69% GGBS or PFA and then 1% of RoadCem in each of the ternary combinations of the binders in the soil as shown in the mix design of **Table** 1. The atterberg limit tests , unconfined compressive strength and one-dimensional oedometer tests shall be performed to determine the geotechnical properties of the stabilized soil mix.

Table 1. Soil-binder mix design.

Binder proportion/notation in soil	Binder proportion by dry wt. of OPC (%)
C100	100
C30/GGBS70	100
C40/GGBS60	100
C50/GGBS50	100
C30/GGBS69/RC1	100
C40/GGBS59/RC1	100
C50/GGBS49/RC1	100
C30/PFA69/RC1	100
C40/PFA59/RC1	100
C50/PFA49/RC1	100

Results and discussion

Results of an extensive laboratory study indicated an improvement in the consistency limits shown by a clear reduction in the plasticity index property of the soil-binder mixes as seen in Figure 1. An obvious effect of the RC was observed in the quick unconfined compressive strength gain in the 7-day cured samples with 50% of the OPC replaced (Fig. 2).

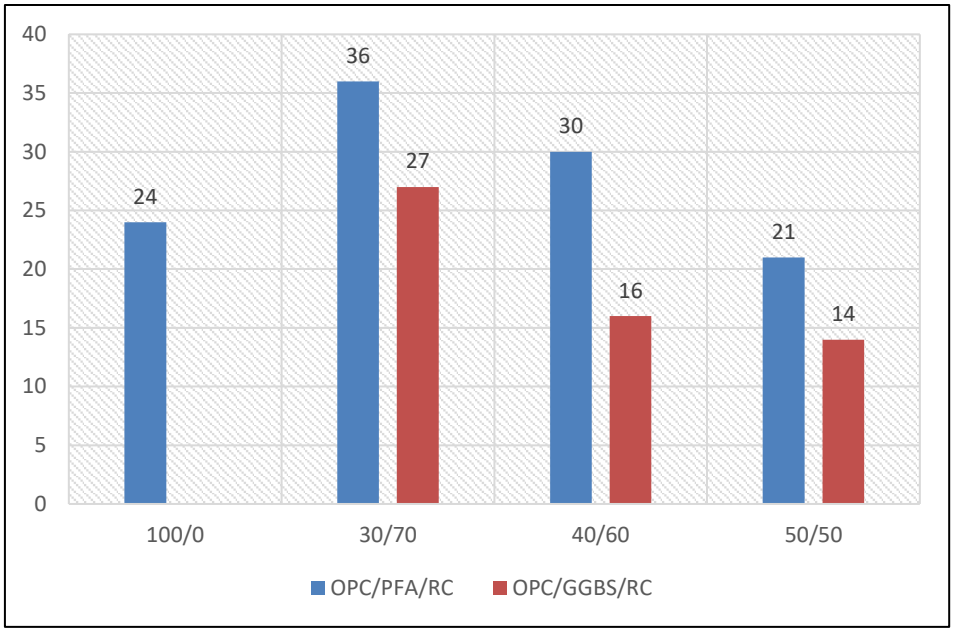

Fig. 1. Plasticity indices of the stabilized soil.

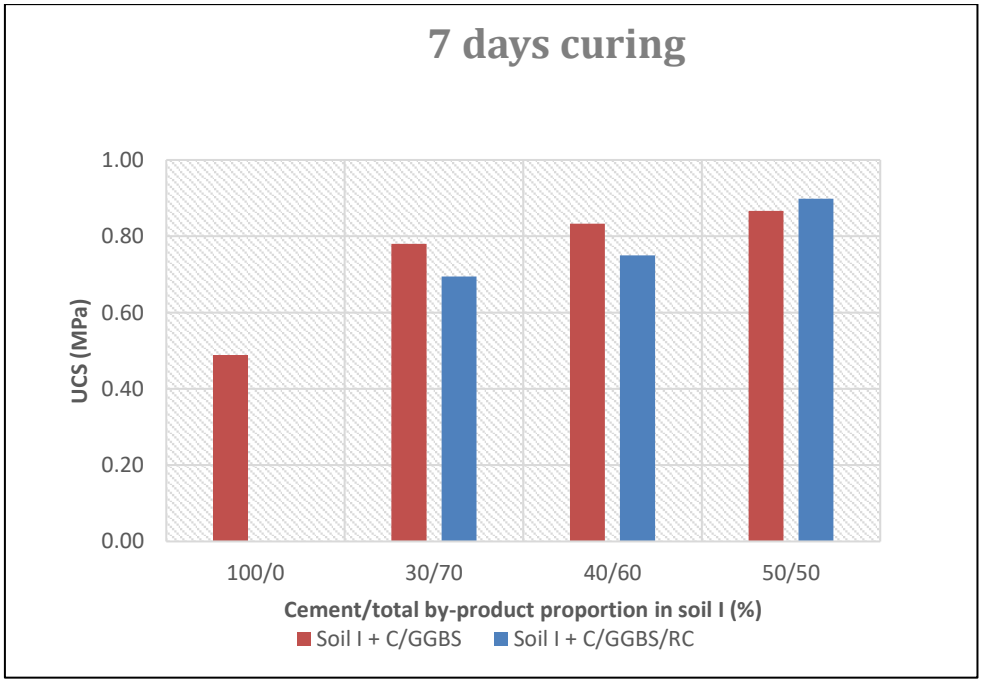

Fig. 2. UCS of the OPC/by-product stabilized soil.

The UCS is an important index in construction and aids the determination of the usability and effectiveness of compacted natural and stabilized soil samples. The (ASTM D 4609) does recommend an UCS of about 0.35 MPa for stabilised soil to be regarded as being effective. Hence, in more generic terms, the UCS for the soil-binder mixes in Fig. 1 could be said to be effective according to the ASTM standard. However, for application in pavement subbase and subgrade, the American Concrete Institute, Ingles and Metcalf and the U.S Corps of Engineers, [1–3]do suggests a range of UCS values between 0.7-1.4 MPa for OPC-stabilized soils at 7 days of

curing. By following these suggested protocols, the OPC used alone may not meet the requirements for pavement applications. However, the mix at 50% replacement of the OPC which gives the highest UCS at 7-days of curing will be perfectly valuable in the stabilization of road subgrade and probably subbases.

Nomenclature

UCS Unconfined Compressive Strength

OPC Ordinary Portland Cement (C)

GGBS Ground granulated blast furnace slag

PFA Pulverized fuel ash

RC RoadCem

Acknowledgement

The authors hereby expressed their gratitude to Coventry University for the research studentship granted to the first author to enable his research.

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Effects of exhaust gas recirculation on temperature using biodiesel blends

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Abstract

This present work focused on experimental work to compare the effects of temperature and emissions produced using WPPO biodiesel blends under the influence of EGR. The mixtures were prepared in the ratios of 10%, 20%, 30%, 40% and 100%, for WPPO10, WPPO20, WPPO30, WPPO40 and WPPO100 respectively. The EGR flow rate was 5%, 10%, 15%, 20%, 25% and 30% respectively. Testing and performance was on a Kirloskar engine, water cooled, direct injection operating at 1500 rpm and a torque of 28 Nm. The EGR system was modified with an addition of the EGR and valve in the exhaust system. The study has three objectives: (i) to investigate the effect of temperature on the emission characteristics of a diesel engine using WPPO biodiesel blends compared to conventional diesel baseline fuel. (ii) To find the effect of EGR on WPPO biodiesel ratio on the exhaust gas temperature compared to baseline conventional diesel fuel. (iii) To find out the trade-off point for the WPPO biodiesel blends temperatures in relation to the EGR % flow rate. Following testing and evaluation, the highest temperature obtained for conventional diesel was 456 ^{o}C compared to 490 ^{o}C for WPPOB100 blend both at 0 % EGR flow rate. However, the other WPPO blends show trends of decreasing temperatures with the application of EGR % flow rate. Other results show increasing blend ratio and the EGR percentage, flow rate increased smoke emissions across all the WPPO blends tested. This study confirms that the WPPO biodiesel blends can produce lower EGT temperatures with the application of the EGR technique of NOX control, but with higher emissions of UHC for WPPO100 blend.

Keywords

Biodiesel blend ratio, EGR flow rate, Exhaust gas temperature, Waste plastic and Pyrolysis oil.

Introduction

Plastics have formed part of our day today life with wide area of application in domestic and industrial areas. Plastics are durable, light weight, energy efficient in their production cost, and design elasticity [1]**.** Plastics are petroleum derivatives composed of hydrocarbons containing oxidants, colorants and other stabilizers as additives in their morphology [2-4]. The most commonly used plastics are the High-Density Polyethylene (HDPE), followed by the Polyvinyl Chloride (PVC) and the polypropylene (PP) [5, 6]. The conversion of the waste plastic

is done through the pyrolysis process which transforms the polymers into basic monomers or hydrocarbons as a chemical way of recycling of plastic waste [7].
However, studies show that WPPO blends have lower BTE coupled with high exhaust emissions of CO, UHC and NO_X. The maximum heat release rate of WPPO blends is to be higher as compared to conventional diesel fuel, due to the effect of longer ignition delay associated with WPPO blends. On emissions, low smoke emissions, which reduced significantly by 40 % to 50 %, with soot emissions were reportedly low. Soloiu et al (2000) reported that the higher viscosity of the waste plastic pyrolysis oil blends increased the injection duration as compared to diesel fuel [8, 9], with a gradual in-cylinder pressure increase and low peak pressure rise.

There has been additional research in other areas of engine performance notably the effects of advanced injection timing (AIT) on diesel engines. Especially on biodiesels that are derived from plastic waste by the process of pyrolysis. Researchers such as [10, 11] reported increased CO_2 compared to the emissions of CO, UHC and NO_X which reduced significantly with application of the AIT technique and WPPO diesel blends, with reported increase in BTE. However in another research using the AIT technique with 20 % tire pyrolysis oil and 80 % Jatropa ester oil [12] it was reported that there was increased NO_X observed but with lower BSFC, CO, UHC and PM reported respectively. [13] using a ratio of 90 % diesel and 10 % waste tire pyrolysis oil as a follow up experiment reported a high BTE and increased NO_X emissions. However, on BSFC and emissions of CO and UHC they observed decreased values when using AIT with waste tire pyrolysis oil.

Material and methods

Apparatus and equipment

The engine experimental set up by its position names are as: 1. Cylinder pressure sensor, 2. EGR control valve, 3. EGR cooler, 4. Injection Control Unit, 5. Exhaust gas exit, 6. Air box, 7. Signal amplifier, 8. Gas analyser, 9. Air flow meter, 10. Data acquisition system, 11. Crank position sensor, 12. Dynamometer, 13. Engine, 14. Airflow rate meter, 15. Cooling water exit to the cooling tower, 16. Dynamometer drive coupling.

Waste plastic preparation and conversion process

The plastic waste is from a municipal solid waste management site. The waste was sorted, Dust and other unwanted particles removed. The sorted and cleaned plastics were shredded into appropriate sizes of 25 mm to 50 mm ready for the reactor and loaded. Using an electrical control panel, the system is activated, with the preceding processes running automatically. After the completion of the pyrolysis process, the reactor system requires a cooling time of 4 hours to 5 hours. This can take two forms: the natural cooling and the gas cooling which also shortens the cooling time by almost half. The gases recommended are nitrogen and carbon dioxide as cooling agents in this case natural cooling was preferred. Table 1 showing physical properties of WPPO and testing standards.

Physical properties of waste plastic pyrolysis oil (WPPO) sample

Table 1. The test fuel properties, their units of measurement, standard methods of testing and the values for conventional diesel in comparison to the values of waste plastic pyrolysis oil.

Property	Unit	CD	WPPO	Standard
Appearance	-	Clear/brown	Clear/amber	Visual
Density @20	kg/M^3	838.8	788.9	ASTM D1298
Kinematic viscosity @40^{o}C	cSt	2.32	2.17	ASTM D445
Flash point	^{o}C	56.0	20.0	ASTM D93
Cetane index	-	46	65	ASTM D4737
Hydrogen	%	12.38	11.77	ASTM D7171
Cu corrosion	3hrs@100^{o}C	-	1B	ASTM D130
Carbon	%	74.99	79.60	ASTM D 7662
Oxygen	%	12.45	7.83	ASTM D5622
Sulphur content	%	<0.0124	0.15	ASTM D4294
IBP temperature	^{o}C	160	119	ASTM D86
FBP temperature	^{o}C	353.5	353.5	ASTM D86
Recovery	%		98	-
Residue and loss	%		2.0	-
Gross calorific value	kJ/kg	44.84	40.15	ASTM D4868

Experimental procedure

a. The engine that was employed for this work is a Kirloskar experimental variable compression engine, four stroke single cylinder; water-cooled developing 3.75 kW of power at 1500 rpm

b. The EGR system was modified to suit the experimental engine and enable data and study to be conducted. The exhaust gases were tapped from the exhaust pipe and joined to the intake manifold air intake system via the air flow meter box. Through a manually controlled gate valve, two things were done, the mixing of EGR gases and the fresh air intake.

c. The EGR quantity is determined as per Equation 1. The EGR % rate flow is divided into the following rates 0 %, 5 %. 10 %, 15 %, 20 %, 25 %, and 30 % spaced at intervals of 5% [1].

$$EGR\ \% = \frac{Mass\ of\ EGR}{Mass\ of\ total\ inlet\ intake} \times 100 \quad (1)$$

d. The waste plastic pyrolysis oil fuel blends were prepared in the following percentages order and mixed with diesel fuel in 10 %, 20 %, 30 %, 40 % and 100 %. Where WPPO10 blend is 90 % conventional, diesel fuel and 10 % waste plastic pyrolysis oil (WPPO) fuel in that order respectively for the remaining blends. Therefore, throughout this experiment blends are referred to as WPPOB10 with 10 denoting the percentage blend of plastic oil by volume supplied.

e. To avoid experimental fuel from contamination each test was conducted after a thorough evacuation procedure was conducted on the previous preceding experiment on the fuel lines and the fuel injection system mechanism of the test engine. This made it possible to conduct an

experiment and collect good data and measurements with inputs from the test mode only, without fear of contamination and error.

Results and discussions

Brake specific fuel consumption (BSFC)

The WPPO biodiesel blends with EGR % flow rate application showed a better fuel economy especially the lower blend ratios of WPPOB10 and WPPOB20 as compared to conventional diesel test fuels. However, as the EGR % flow rate is increased there is a noticeable increase in the BSFC across all the test fuels used. At 0 % EGR conventional diesel is 0.4 g/kW.hr as compared to 30 % EGR flow rate which is 0.495 g/kW.hr. While for the WPPO biodiesel blends WPPOB10 is 0.3225 g/kW.hr as compared to 0.5780 g/kW.hr at 30 % EGR flow rate. From Fig. 1 the test fuel that showed the highest BSFC among the blends of diesel and conventional diesel test fuel is WPPOB100, which at 0 % EGR flow rate had a value of 0.4751 g/kW.hr as compared to 0.7235 g/kW.hr at 30 % EGR % flow rate.

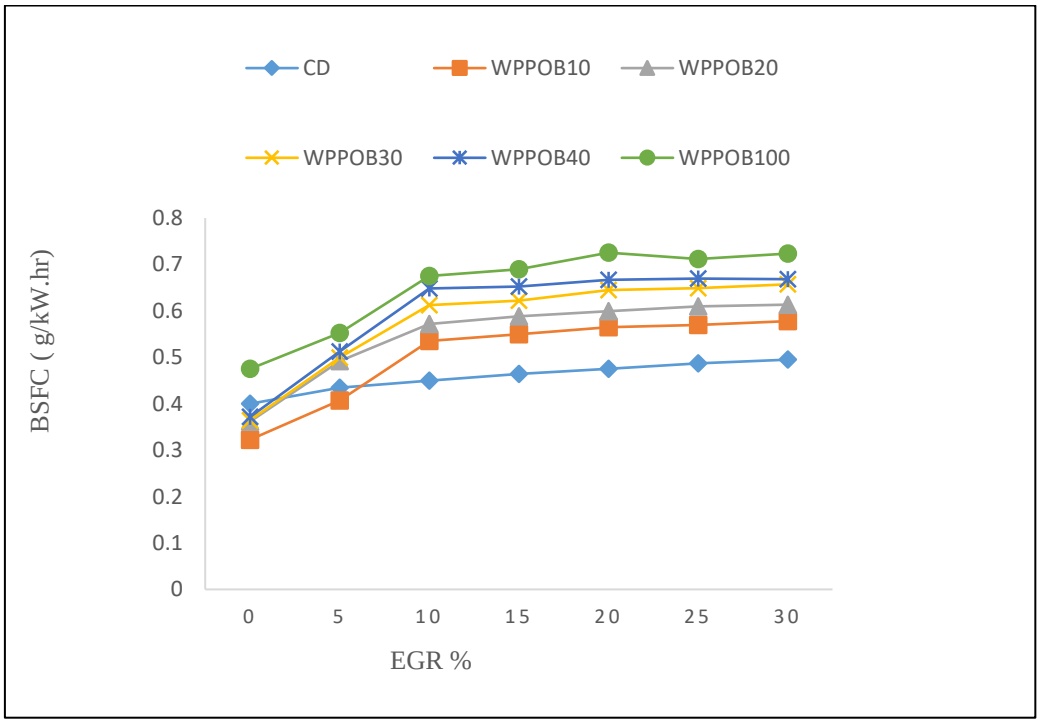

Fig. 1. BSFC versus EGR % at engine full load conditions.

Exhaust gas temperature (EGT)

The application of EGR % flow rate in increasing modes, brings further reduction in exhaust gas temperature with the highest value for conventional diesel test fuel obtained being 440 ^{o} C with an EGR % flow rate of 5 % while the lowest value of 340 ^{o} C is obtained at 30 % EGR flow rate. The WPPO blends show similar trends with decreasing temperatures and application of EGR % flow rate. Blend WPPOB10 showing its highest values to be

467 ° C and lowest to be 362 ° C at 5 % and 30 % EGR rate flow respectively. Blend WPPOB40 shows its highest value at 472 ° C and the lowest at 330 ° C with 5 % and 30 % EGR flow rate respectively. Fig. 2 showing the influence of EGT compared to the flow rate of EGR gases.

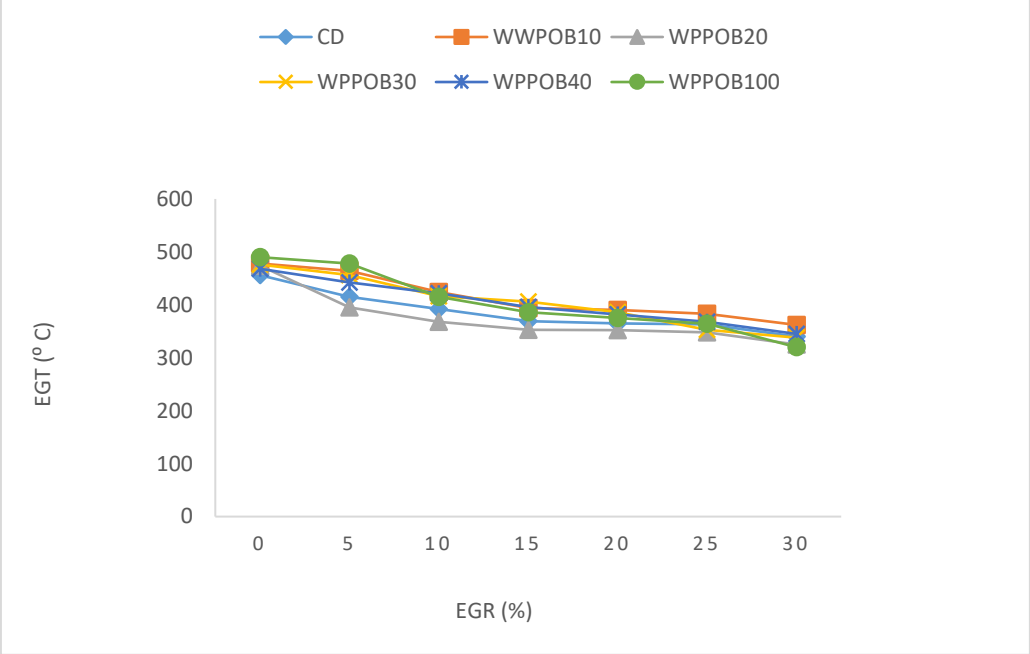

Fig. 2. Exhaust gas temperature (EGT ° C) versus EGR % flow rate.

The main cause of the reduction in the exhaust gas temperature can be attributed to several factors. The reduction in exhaust gas temperature among the different blends of WPPO is due to low calorific value of the blends and the low exhaust loss. This concurs with the findings of [14, 15]. The WPPO has a calorific value of 40.15 kJ/kg compared to the calorific value of conventional diesel at 44.84 kJ/kg as shown in Table 1.The third cause is directly linked to the effects of exhaust gas recirculation rate flow, the dilution effect, chemical effects and thermal effects [16, 17].

Conclusions

- EGT decreases with different blends of WPPO as compared conventional diesel test fuel.
- WPPO blends have higher temperature increases in all the test conditions compared to conventional diesel fuel
- Reduction in exhaust gas temperature among the different blends of WPPO is observed to be as a result of low calorific value of these blends and causes directly linked to the effects of exhaust gas recirculation rate flow application, the dilution effect, chemical effects and thermal effects
- Data presented in this work provides more reasons to support the widespread use of WPPO as an alternative fuel for all types of compression ignition engines. This is with or without modifications to the engines, especially when blends of WPPOB10 and WPPOB20 are used because their peak brake

power and brake specific fuel consumption (BSFC) values have identical values to conventional diesel fuel.

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Investigating the engine performance characteristics of multiple nano fuel blends in a single cylinder diesel engine

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Abstract

Despite progress in the use of electric motors for transportation systems, petro-diesel remains the primary fuel for driving heavy machinery across numerous economic sectors, including the industrial and construction sub-sectors. Unfortunately, the use of petro-diesel is characterized by high environmental pollution, a situation that directly conflicts the United Nations' sustainable development goals. Nitrogen oxide specie, NOx, is a major by-product of diesel fuel combustion, and has the potential to form secondary products like nitric acid, HNO3, further threatening ecological systems. In this study, the performance, combustion and emissions characteristics of compression ignition (CI) engine running with three variants of nano-fuel blends are investigated. These characteristics include the brake specific fuel consumption (bsfc), in-cylinder pressure, heat release rate, engine thermal efficiency, and carbon monoxide and nitrogen oxide emissions. Three different nanoparticles with concentration of 50 mg/L are considered. These are graphene oxide (GO), titanium oxide (TiO2) and GO doped with TiO2 (GO-TiO2). The experiments are run with a single cylinder, air cooled, 4-stroke engine at a speed of 2000 rpm, and different engine loads (idle to 80% full load). The results reveal a 12% average reduction in fuel consumption for the diesel – TiO2 nano-fuel over the considered load range. Furthermore, the in-cylinder pressures for all the fuel blends, especially at peak loading conditions are greater than diesel values. The GO nanoparticles also led to comparable levels of NOx emissions compared to neat diesel, while TiO2 and GO doped with TiO2 enhanced the formation of NOx. CO emissions are found to increase with the addition of different types of considered nanoparticles.

Keyword

Diesel, Nitrogen, Nano-particle, Emission and Engine

Introduction

Energy is the main driver of industrialization, and in order for countries around the globe to meet the United Nation's 2030 developmental target, there is a profound need to accelerate progress in the manufacturing sector

of world economies. Without doubt, conventional fuels provide the main energy source for the movement of goods and heavy equipment in the world today, while petro-diesel consumption, currently at 45% of global fuel use, is expected to increase into the future [1]. Utilization of diesel fuel for present and future applications is a major concern to environmentalists, particularly when we consider the enormous CO_2 and NOx emissions that lead to environmental degradation, and health concerns due to particulate matter emission. [2]. With limited fuel options for heavy machinery, certain diesel-based hybrid fuels have emerged as alternatives to improve the combustion properties of petro-diesel, and hence, its suitability as a sustainable fuel. This hybridization of petro-diesel could be achieved using biodiesel, blending with alcohols, and enhancement with fuel additives like nano particles, among other options.

In terms of diesel fuel research, several literatures have tried to capture the influence of nanoparticles on fuel properties and engine performance characteristics. As an example, Graphene oxide and graphene nano platelets have been used in the combustion of n-butanol – Jatropha methyl ester, at constant engine speed of 2000rpm and varying loads, with 6% and 22% improvement in peak pressure and brake specific fuel consumption respectively [3]. These fuel enhancing properties of Graphene based nano particles were further collaborated by [4], who reported nearly 10% improvement in brake thermal efficiency of graphene nano fuel. A wide variety of nano particles have been used as diesel-fuel additives including but not limited to Al_2O_3, CeO_2, TiO_2, $FeCl_3$, GO, CNT, MnO, ZnO, and CuO [5]. Engine tests involving Fe_2CeO_3 nanoparticles for a constant speed of 2000 rpm, at various loads reveal a 4% improvement in peak cylinder pressure for a B30 waste cooking oil blend, with encouraging reduction in emission levels [6]. There is frequent use of metal additives in nanofuels, with Fe, Al and Ti widely quoted in literature [5], [6],[7],[8]. Recent study showed that the presence of certain metals and their oxides could significantly improve the magnetic, optical and thermal properties of nano particles themselves [3].

This is certainly the case for Al_2O_3 and CeO_2 nanoparticles, where significant improvement in brake thermal efficiency, and 30% – 60% reduction in environmental pollutants is observed, due to the high surface area to volume ratio characteristics of nano particles [8]. Further, while investigating the engine performance and combustion characteristics of common rail direct injection assisted diesel engine, the presence of Aluminium based nano particles led to encouraging results in brake thermal efficiency and heat release rate [9]. [10] also used CeO_2 nano particles to improve the brake thermal efficiency and emission values of a biogas – diesel internal combustion engine. While nanoparticles usually enhance engine fuel performance, some selective literature have reported decreased combustion quality, and increased CO emissions, at least in the case of carbon nano tubes [11],[12],[13]. For waste cooking oil biodiesel blends, the presence of Fe_2CeO_3 nano particles could lead to remarkable improvements in brake specific fuel consumption, better engine performance with B30 blends, and lower NOx and CO emission levels especially at low to medium loads [6]. It should be noted that higher engine speeds beyond 2500 rpm could lead to extended ignition time and longer crank angle intervals, and consequently, reduced efficiency of the engine cycle [14]. Therefore, the main objective of this work is to compare the effect of fuel additives GO, TiO2 and GO-TiO2 nano particles on engine combustion parameters,

and the subsequent NOx emissions. Test results are obtained for a constant speed of 2000 rpm, for 0 to 80% full engine load.

Material and methods

Experimental setup

The experimental test rig is essentially a single cylinder 7.5Kw, four stroke diesel engine model CT100.22 developed by Gunt Hamburg (Figure 1). The test stand measures the output of the internal combustion engine through a data acquisition (DAQ) system of Model USB-AD16f (for analyzing the collected signals from the force sensor, thermocouples, fuel flow meter sensor, air flow meter sensor, speed sensor, charge amplifier and the proximity sensor), and onto a computer containing the Gunt software. An asynchronous motor serves as the braking unit, while a frequency converter allows torque and engine speed to be generated. The respective engine parameters are highlighted in Table 1.

Table 1. Diesel engine specification.

Engine parameters	Specification
Engine model	HATZ-1B30-2
Engine type	Single cylinder direct injection CI
Bore (mm)	80
Stroke (mm)	69
Crank length (mm)	34.5
Connecting rod length (mm)	114.5
Compression ratio	21.5:1
Rated power (kW/rpm)	5.4/3600
Idle speed (rpm)	1000
Displacement volume (cm^3)	347

The internal combustion engine generates emissions which are subsequently measured by the emissions analyser. The Bacharach model ECA 450 is used for this purpose, and can record the exhaust concentrations of O_2, CO, NOx, SOx and HC. However, CO_2 data from this equipment is mostly calculated, and therefore, is not considered in this study.

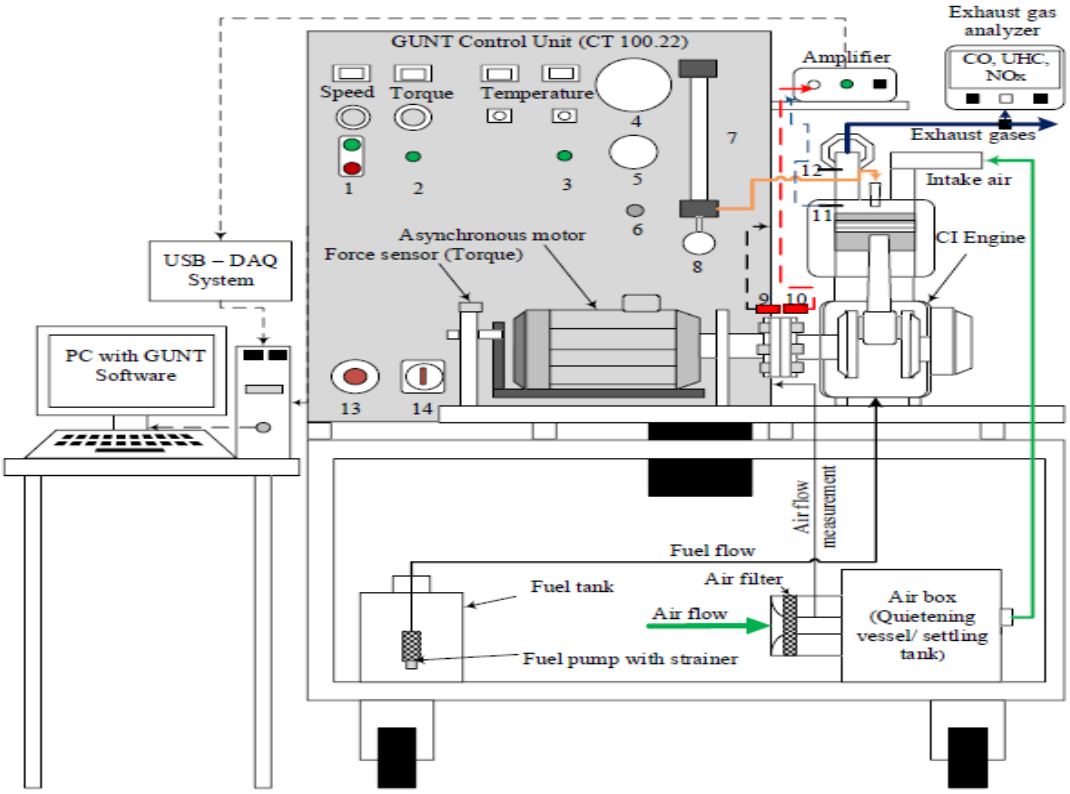

Fig. 1. Electric motor switch, 2 Ignition switch, 3 Coolant pump switch, 4 Air consumption gauge, 5 Intake (negative) pressure gauge, 6 Fuel pump switch, 7 Fuel measuring tube, 8 Fuel consumption meter, 9 Speed sensor, 10 TDC sensor, 11 Kistler pressure transducer, 12 Exhaust gas temperature sensor, 13 Emergency switch, 14 Main switch (Courtesy [15]).

Experimental procedure

In this work, three different nano particles were added to petro diesel at 50mg/l concentrations. The nano particles are GO, TiO_2 and GO-TiO_2. The dissolution of the particles is enhanced by using the UP400S, Hielscher GmbH ultrasonicator, at a frequency of 60Hz, with an amplification factor of 0.5. The hybrid fuel is subjected to ultrasonic mixing for a period of 30 minutes, after which all the nano particles are completely dissolved. The homogenous nano fuel is then introduced into the fuel tank, and the engine test is initiated. The current experiment was conducted at a constant engine speed of 2000 rpm, with a permissible full load of 15 Nm. Hence, within the context of this study, various engine loads of 20%, 40%, 60% and 80% of peak load were tested. At every loading situation, the in-cylinder pressure is recorded for fifty (50) cycles, at 0.5° crank angle interval. Furthermore, engine performance parameters including the brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature are obtained for forty cycles, directly from the Gunt software. Additional analysis on the obtained data in terms of pressure averaging and rate of heat release calculations are completed using a special in-house matlab code. The information obtained from this algorithm is eventually exported to Microsoft excel for visualization.

Theoretical background

The model used to evaluate the rate of heat release in a typical IC engine embraces the first law of thermodynamics. Hence, for a specific crank angle, the gross heat release rate from the intake valve closure, to the exhaust valve opening is given by [16].

$$\frac{dQ_{gross}}{d\theta} = \frac{1}{\gamma - 1}\left[\gamma p \frac{dV}{d\theta} + V\frac{dp}{d\theta} + (u - c_v T)\frac{dm_c}{d\theta}\right] - \sum h_i \frac{dm_i}{d\theta} + \frac{dQ_{ht}}{d\theta} \quad (1)$$

Equation 1 could be rewritten as [17]

$$\frac{dQ_{gross}}{d\theta} = \frac{\gamma(T)}{\gamma(T) - 1} p \frac{dV}{d\theta} + \frac{1}{\gamma(T) - 1} V \frac{dp}{d\theta} + \frac{dQ_{wall}}{d\theta} \quad (2)$$

Since heat loss through the cylinder walls is primarily by convection, the rate of heat transfer through the wall could be obtained as [5]

$$\frac{dQ_{wall}}{d\theta} = h_c A_{(\theta)}(T - T_{wall})\left(\frac{1}{6N}\right) \quad (3)$$

It is important to note that equation 1 is evaluated assuming that the charge introduced into the cylinder obey the ideal gas law. The variation of the cylinder volume, V, as a function of the crank angle θ, is evaluated using equation 4 [18]

$$V(\theta) = V_c\left[1 + \frac{C - 1}{2} + \left(R - \cos\theta - \sqrt{(R^2 - \sin^2\theta)}\right)\right] \quad (4)$$

The coefficient of variation (COV) is the term used to measure the level of uncertainty in the collected data. It uses the standard deviation of the data sample to investigate statistical dispersion of sensor values. In the case of indicated mean effective pressure, the COV is given by [19]

$$COV = \frac{\sigma_{IMEPh}}{IMEPh} \times 100 \quad (5)$$

Results and discussion

Combustion characteristics

Fig. 2 shows the in-cylinder pressures for the three different categories of nano fuels. The results suggest that introducing nano particles in the petro-diesel has a positive effect on the pressure, especially for the GO and TiO_2 fuel blends. This is because nano particles serve as catalyst by reducing the ignition delay of the fuel [20]. By lowering the ignition time, a significant portion of the atomized fuel remains undiluted by the surrounding air at conditions that are close to stoichiometric, thereby ensuring effective combustion [17].

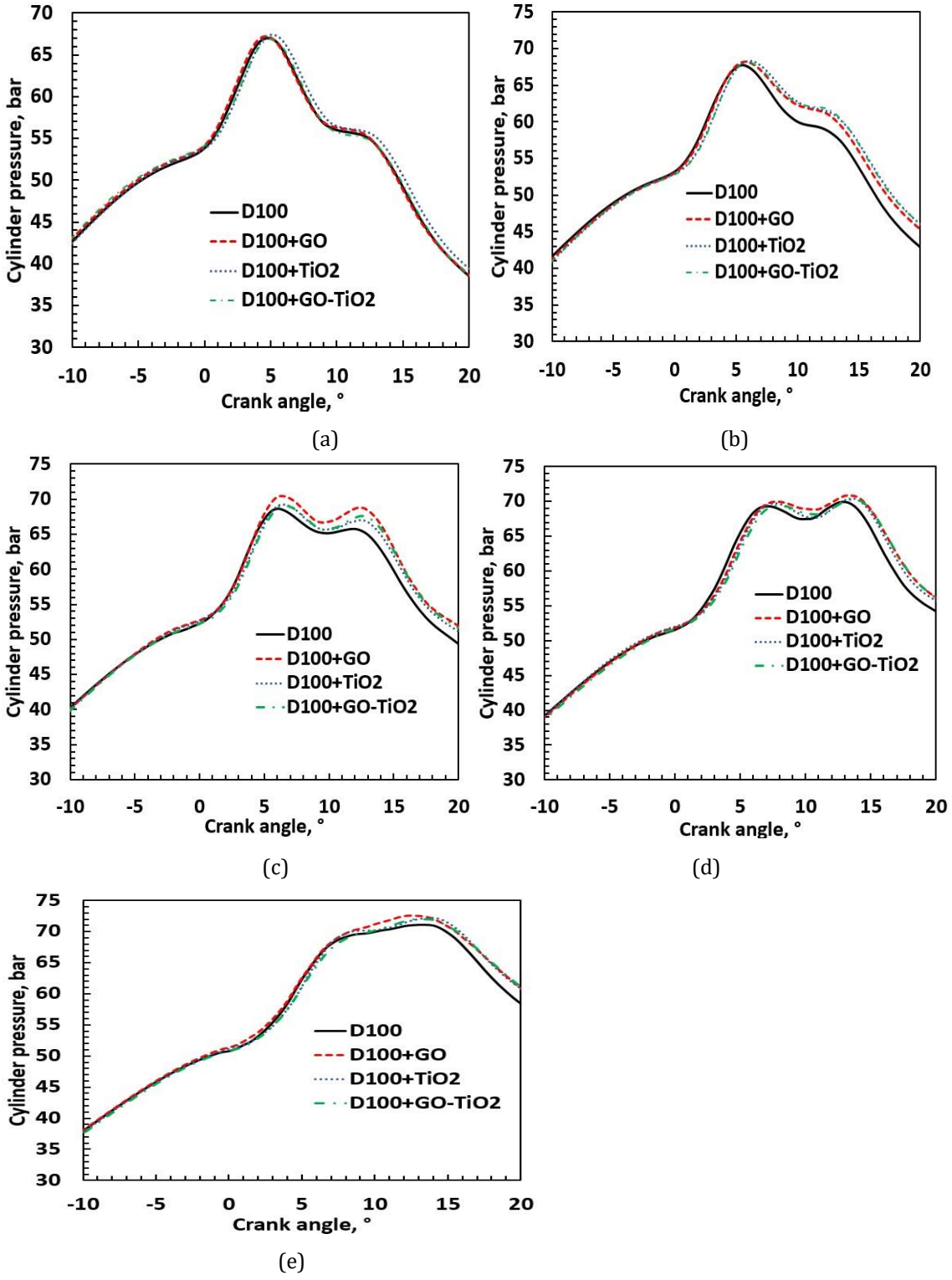

Fig. 2. The average cylinder pressure profile at different engine loads and engine speed of 2000 rpm. (a) No load; (b) Engine load = 3 N.m; (c) Engine load = 6 N.m; (d) Engine load = 9 N.m; (e) Engine load = 12 N.m.

The combustion is often accompanied by a surge in temperature, and consequently, high cylinder pressure values, along with heat. This trend is supported by the graph of the heat release rate at various crank angles as highlighted in Fig. 3.

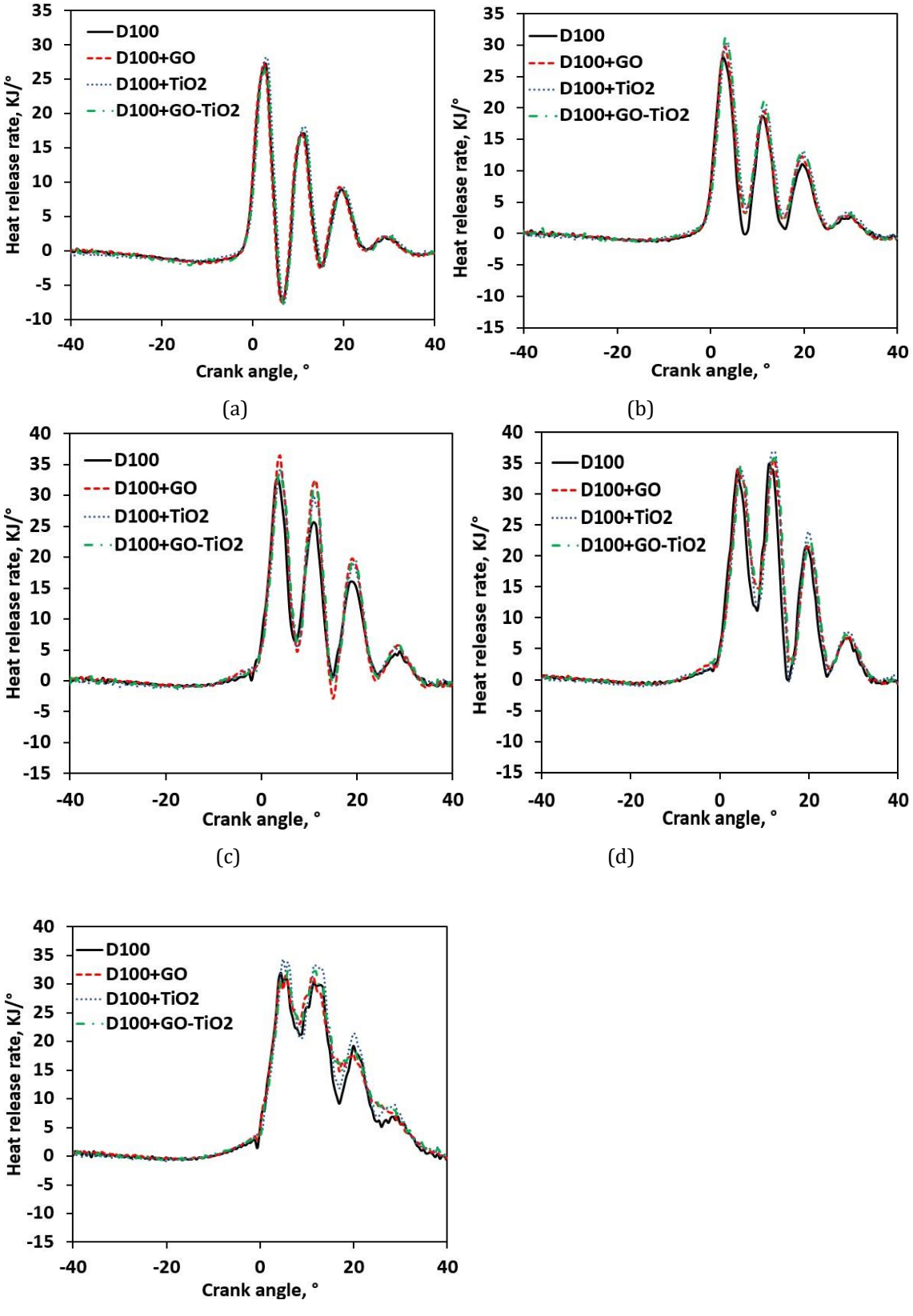

Fig. 3. The average heat release rate at different engine loads and engine speed of 2000 rpm. (a) No load; (b) Engine load = 3 N.m; (c) Engine load = 6 N.m; (d) Engine load = 9 N.m; (e) Engine load = 12 N.m.

The no load situation is usually associated with engine instabilities characterized by erratic variations in the engine speed, and is included here for observation purposes only. The main interest in this case lies at 6Nm,

9Nm and 12Nm engine loads, where the nano fuels display high heat release periods, at least at 0° and 15° crank angles.

Engine performance

The engine performance characteristics could be represented in terms of the Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTE), Fuel Mass Flow Rate and Exhaust Temperature. The BSFC is lowest at the highest loading condition due to the huge power supplied by the engine at high torque.

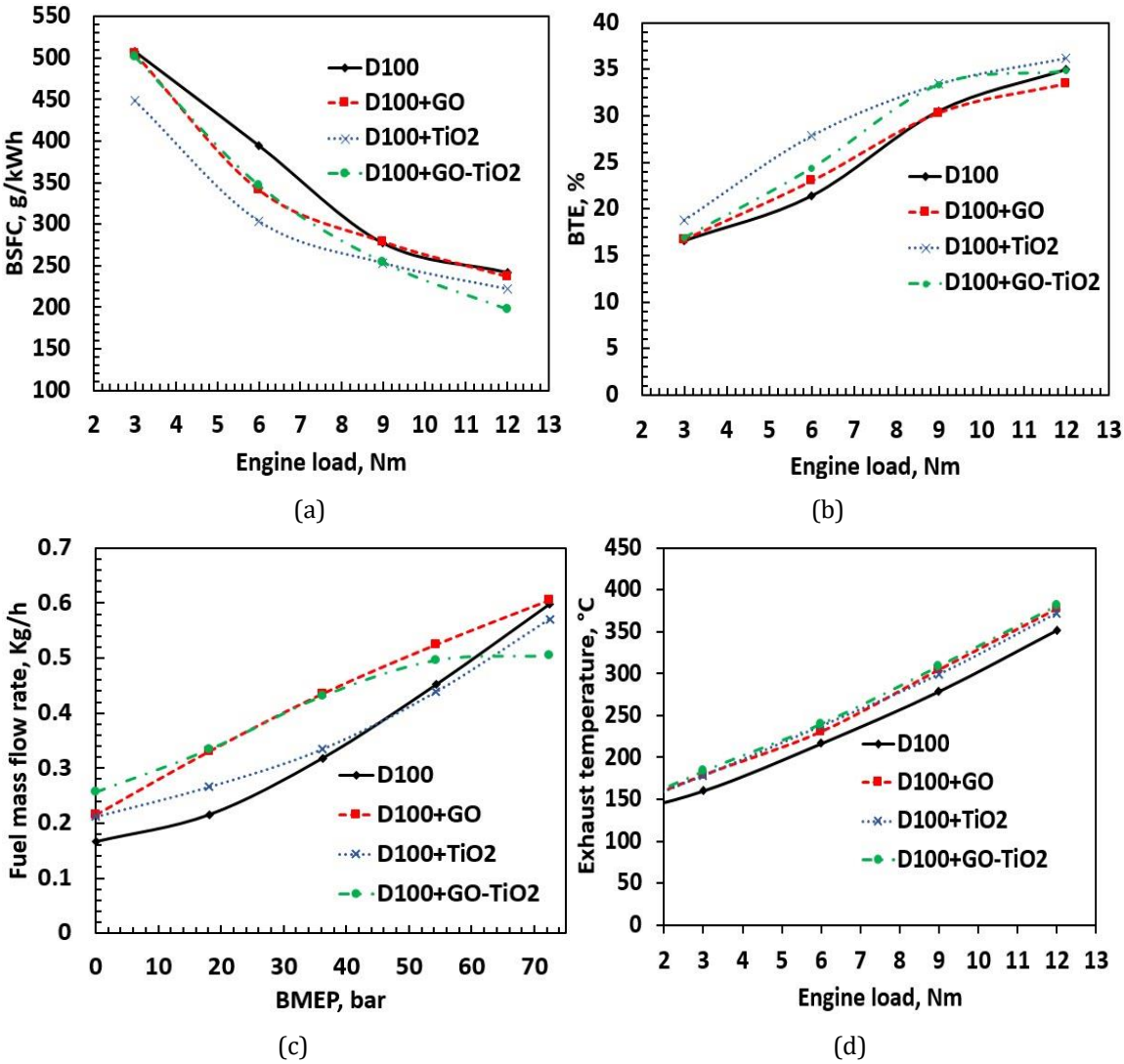

Fig. 4. The variation of engine performance parameters with load at a speed of 2000 rpm: (a) BSFC; (b) BTE; (c) fuel mass flow rate; and (d) exhaust gas temperature.

The TiO_2 and$GO\text{-}TiO_2$ fuel blends could be preferred to the petro-diesel, a situation further collaborated by their superior thermal efficiencies at most loads. In fact, it could be argued that the combustion quality of the nano fuel blends is better than pure diesel particularly when we consider the associated exhaust gas temperatures. A high temperature could indicate significant fuel burning due to the ignition delay properties of the nano particles, thereby achieving better combustion. Unfortunately, with the high compression ratio of the diesel

engine, a very short ignition delay is not always desirable, and could be considered as a precursor for dangerous operating conditions, leading to a catastrophic engine failure. Hence, extra care must be ensured when applying nano particles to boost engine performance.

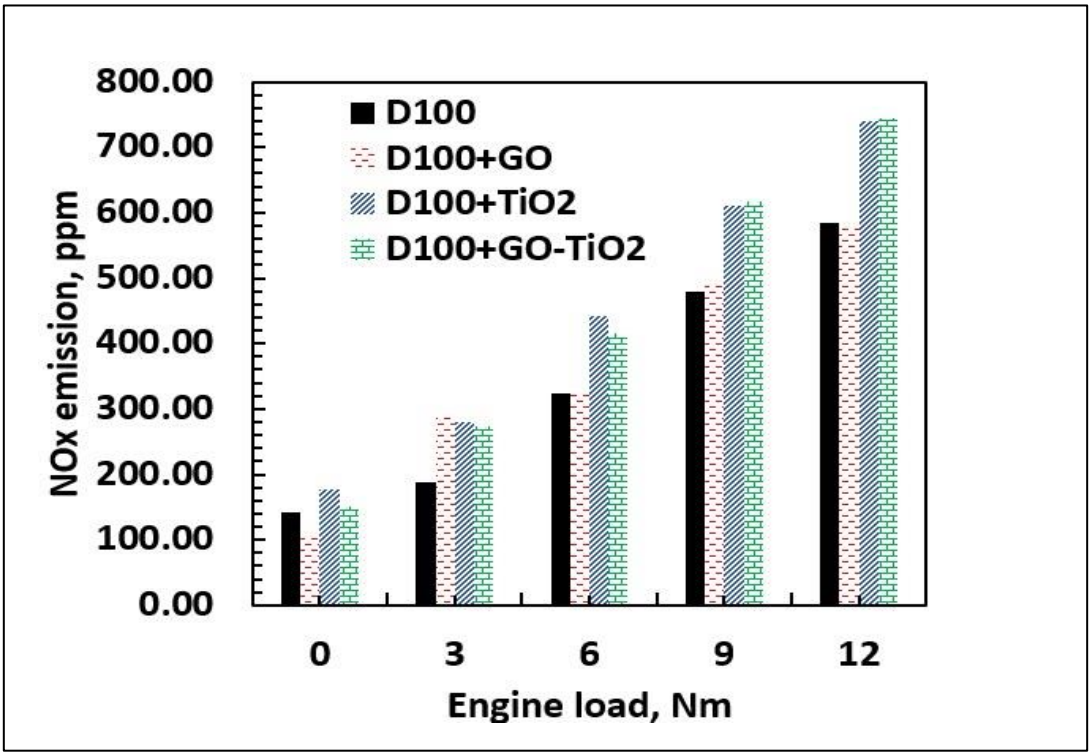

Fig. 5. The engine emissions at different loads for different fuels at a speed of 2000 rpm.

At high combustion temperatures, the graphene and titanium based nano fuels are unable to significantly reduce the ensuing NOx pollution (Fig. 5). Hence, a different case of CeO nano particles or Naphata based fuel blends could lead to remarkable improvements on emission levels.

Conclusion

This work observed the effect of 50 mg/l of three different nanoparticles (GO, TiO_2 and GO-TiO_2) on the combustion and performance characteristics of petro-diesel. The additives largely maintained a catalytic effect of the base fuel, leading to an increase in the peak pressure and heat release rate inside the combustion chamber, relative to pure petro-diesel. The following points are highlights of the study:

- It could be seen that the addition of any of the considered nanoparticles to diesel fuel decreases the BSFC which means enhancement of engine power for the same fuel consumption.
- The TiO_2 showed the lowest BSFC at low-medium engine loads while the GO-TiO_2 was shown to give the highest fuel economy at high loads.
- The GO nanoparticles led to comparable levels of NOx to those for neat diesel while TiO_2 and GO-doped-in- TiO_2 enhanced the formation of NOx.

Nomenclature

Q_{gross}	Gross heat release
γ	Specific heat ratio
θ	Crank angle
V	Cylinder volume (m3)
p	Instantaneous cylinder pressure (bar)
u	Specific internal energy
c_v	Specific heat at constant volume
T	Mean charge temperature
m_c	Mass of the cylinder charge
$\sum h_i\, m_i$	Enthalpy flux across the system boundary
Q_{ht}	Charge-to-wall heat transfer
Q_{wall}	Heat loss through the cylinder walls
h_c	Convection heat transfer coefficient
N	Engine speed (rpm)
V_c	Clearance volume
C	Engine compression ratio
R	Ratio of connecting rod to crank radius
σ_{IMEPh}	Standard deviation in IMEPh
$IMEPh$	Indicated mean effective pressure calculated by considering only the work delivered to the piston over the compression and expansion strokes (bar)

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