جامعة السلطان قابوس
Sultan Qaboos University

كلية الهندسة
College of Engineering

Postgraduate Research Symposium

20th December 2023

Dr. Nabeel Al-Rawahi
Dean

Postgraduate studies within the College of Engineering serve as one of the vehicles for innovation, expertise, and socio-economic impact. In our postgraduate programs, we aspire to provide a crucial platform for students to specialize deeply within their chosen engineering disciplines. Through rigorous coursework and research endeavors, postgraduate students hone their skills, cultivate a profound understanding of complex engineering concepts, and emerge as experts in their fields. Moreover, the emphasis on research within these programs fosters propelling technological advancements and contributing substantially to the expansion of knowledge. Such initiatives not only elevate the institution's academic standing but also cater directly to the evolving national needs and those of industries, ensuring graduates are equipped with the specialized knowledge and practical skills essential for addressing contemporary challenges. The collaborative environment inherent in postgraduate studies encourages networking, collaboration, and interdisciplinary exchange. We hope that this symposium will result in fruitful networking and collaboration among our postgraduate students and faculty members and will attract our aspiring undergraduate students to pursue postgraduate education.

Dr. Nasser Al-Azri
Assistant Dean for Postgraduate Studies and Research

The college of Engineering at Sultan Qaboos University is currently offering six PhD programs and eleven MSc programs. These programs undergo continuous revision and modernization to optimize their learning outcomes with the international trends and national needs. Besides the review process, we find it imperative to sustain these programs through interdisciplinary research and by attracting outstanding intake from undergraduate level. The Postgraduate Research Symposium, which is part of the college’s 2023 operational plan, has been organized to publicize postgraduate research activities and, equally important, to encourage networking and collaboration amongst researchers in the college. We hope that this symposium will pave roads to new ideas for collaboration and advancement of research at the college. Finally, I would like to express my deep gratitude to my colleagues in the College Postgraduate Studies Committee who worked diligently for the success of this event. I also would like to thank our graduated and current postgraduate students who participated in this event.

Organizing Committee

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Abstracts

1. Civil and Architectural Engineering

Analysis of Drainage in the Wadi Adai in Muscat Governorate, Sultanate of Oman

Lamyaa Mohammed Al Shezawi

MSc Degree (Spring 2022)

Supervisor: Dr. Ahmad Sana

Abstract: This study aims to model and develop flood analysis for the Wadi Adai area using the Hydrologic Engineering Centre – River Analysis System (HEC-RAS) simulation software. The study area has a catchment area of more than 390 km^2 and the length of the main streamline is about 13 km starting near Bajariyah till Qurum beach. Whereas the present study focuses on the length of about 6.5 km of the main channel for simulation. The objective of the study could be achieved by using the Digital Elevation Model (DEM) of the area to prepare the geometric data, cross sections, and bank lines as well as the physical parameters and boundary conditions. As this study focuses on the hydraulic simulation, the input of flood peaks for the same catchment area was obtained from a study made at the Wadi Adai downstream. Obtained flood peaks for return periods of 2, 5, 10, 25, 50, and 100 years were used as inputs to the steady flow analysis. Water surface elevation and velocity of the inundation were obtained from the simulation model displayed in RAS mapper. The calibration of the model was performed considering the observed data of the Guno cyclone at Bajariyah gauge station along with the cross section on the same location. The calibrated Manning's n value was used to run the simulation model. Moreover, the HEC-RAS model was validated by choosing different events from the observed and recorded data at Bajariyah station. In addition, the sensitivity of the model was carried out by using various values of calibrated parameter, in which the inundation depth gets affected. The result showed that the model was very useful to predict the flood for different return periods and good estimate for inundation depths. This study will be useful for the design and management of urban drainage system in Wadi Adai catchment.

Keywords: HEC-RAS model, urban drainage system, catchment area, flood analysis

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Numerical Modelling on the Behavior of Concrete Filled Steel Tube (CFST) with Ferrochrome Slag (FCS) as a Fine Aggregate at Elevated Temperatures

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Abstract: Since laboratory testing is costly and requires considerable amount of time especially in concrete tests, numerical simulation becomes a matter of great interest in the last few decades. Finite element modelling method using computers permits the simulation of structural elements composed of concrete and high strength concrete. On the other hand, modelling the response of concrete containing waste materials and industrial by-products is difficult due to the deficiency in the definition of material properties contrasting normal and common types of concrete. Existing constitutive models for concrete materials do not account for the presence of aggregate replacement such as Ferrochrome slag (FCS). FCS is an industrial by-product of the ferrochrome manufacturing and one of the waste materials that is used in various construction applications. As experimental tests were already performed on FCS concrete that is used in concrete-filled steel tube (CFST) composite column, it is necessary to further investigate the behaviour of this type of concrete utilizing finite element modelling. This research focuses on the numerical simulation of concrete-filled steel tube (CFST) stub column with ferrochrome slag as a fine aggregate after exposure to elevated temperatures. The study aims to investigate the behaviour of such columns at ambient temperature and under fire conditions through finite element modelling and simulation. The numerical models were validated against previous experimental data, and parametric studies were conducted to assess the effect of various factors, such as steel tube thickness and concrete strength. Modifications on existing concrete stress-strain relations after cooling from high temperatures were proposed to consider confinement and FCS aggregate replacement. The results are matching well with experiment at normal and high temperature in terms of failure mode, ultimate load capacity and overall behaviour trend. The outcomes of this research can help in understanding the behaviour of concrete-filled steel tube stub columns with ferrochrome slag as a fine aggregate and aid in the design of exceptional/innovative fire-resistant structures that contains new type of materials.

Keywords: Concrete-filled steel tube (CFST), Finite element analysis (FEA), Concrete damage plasticity (CDP), Compressive response, Ferrochrome slag (FCS) concrete

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Modeling of Reinforced Concrete Buildings under Fire Using OpenSees

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Abstract: Fire poses a significant and persistent threat to buildings, and events like the September 11 incident at the World Trade Center in 2001 have highlighted the need to comprehend the behavior of structures under exposure to fire. Elevated temperatures caused by fire induce additional thermal stresses and reduce material strength, contributing to the potential failure of structural elements. To address these critical concerns, this research aims to gain a comprehensive understanding of the behavior of reinforced concrete buildings when subjected to various fire scenarios, different element sections, and load ratio. A 2-story reinforced concrete building, that represents a typical residential unit in Oman having a footprint of 13.91×22.5 meters, serves as the subject for investigation. The study employs OpenSees for Fire, utilizing non-linear static analysis, to model the buildings response to fire scenarios. To explore the effects of different fire locations on the structure's behavior under elevated temperatures, three fire locations are distributed on each floor, yielding a total of 15 fire scenarios. On the ground floor and first floor, the fire locations are strategically placed in three bays of sizes 5.3×3.6 meters, 4.4×4.1 meters, and 3.6×3.2 meters. However, on the first floor, the second bay has a different dimension of 4.2×4.1 meters due to changes in the layout. The ISO834 standard fire curve is applied as the thermal load during the analysis. Additionally, the results are compared for both direct and indirect effect conditions to comprehensively assess the structural response. Moreover, to investigate the effects of weak and strong columns and beams the study first reduced the beam sections by 0.5d and kept the columns as it is to have weak beams, after that we increased the sections by 1.5d kept the columns as it is to have strong beams, and the same thing has been done for the columns while the beams kept their original sections. To see the effects of load first the study reduced the loads by 50% and after that the load was increased by 150%. The study findings indicate that an increase in temperature directly affects the internal forces and deformations experienced by the beams and columns. This includes moments at spans and supports, axial forces, and deflections. The location of the thermal loading significantly impacts the displacement and bending moments in both spans and supports and the axial forces in spans. Closer members to the thermal loading location exhibit higher internal forces. Additionally, the thermal expansion of columns contributes to an upward displacement at the mid-point of the beams. The study also shows that increasing the depth of the elements results in reduced displacement, movement, and axial force values. Conversely, reducing the depth increases the displacement, moment, and axial force values. Similarly, increasing the load of the elements increases the displacement, moment, and axial force values, while reducing the load reduces the displacement, moment, and axial force values. The results demonstrate that reinforced concrete structures display remarkable strength under fire loads.

Keywords: OpenSees for fire, Reinforced concrete buildings ,3D response, Finite element, various fire scenarios

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Adsorption Kinetics of Boron by Parthenium Hysterophorus and its Carbonized Form

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Abstract: The Parthenium hysterophorus is an invasive plant that can be found in abundance throughout Oman. Besides its rapid growth rate, it poses allelopathic characteristics that have been showing enormous hazardous risk impacts to human, animal, soil, agriculture, and the environment due to its allelopathic characteristics. A buildup of this weed can have severe environmental and economic impacts, and it is difficult to control and eliminate. Furthermore, boron is a pollutant found in a variety of water sources, including groundwater, surface water, and effluents. Boron concentrations in potable water can adversely affect human health, including reproductive and developmental issues. Due to its solubility and toxicity, removing boron from contaminated water is such a challenging task. Reverse osmosis and ion exchange are currently used to remove boron from contaminated water. However, these techniques are expensive and energy-intensive, making it necessary to develop a more sustainable, cost-effective, and effective procedure. In this study, an adsorbent was generated from P. hysterophorus, characterized, and evaluated for its efficacy in removing boron from aqueous solutions. Therefore, this study aims to: (i) assess how pyrolysis temperatures of 700 °C affect the physicochemical characteristics of the resultant biochar; (ii) evaluate the differences between PW and CPW characteristics, such as pH, electrical conductivity, point of zero charge, bulk density, particle density, porosity, and specific surface area; (iii) evaluate the viability of employing CPW as an economical and eco-friendly replacement for industrial adsorbents for the removal of boron from aqueous solutions at different contact times; (iv) analyze the boron adsorption kinetics onto PW-adsorbent and its carbonized form (CPW) and identify the rate-limiting phase; and (v)- examine the physicochemical properties of the adsorbents before and after boron adsorption to comprehend the adsorption mechanism. The findings has shown that P. hysterophorus was composed of 70.7% moisture, 10.5% volatile matter, 5.0. % ash, and 14.0% fixed carbon. Moreover, carbonized-PW exhibited a higher pH and point of zero charge compared to unmodified PW, indicating an increase in alkalinity and surface charge. A slight increase in particle density was observed after carbonization, as well as a decrease in electrical conductivity and mass density. Additionally, the carbonization of PW-biochar increased its porosity and specific surface area in comparison to its normal form. It was also found that contact time has a significant effect on the removal of boron in the study. Based on Method.2, maximum boron removal was achieved in the first minute for pristine PW and in three minutes for PW biochar. In terms of MPAE values, the pseudo-second order model provided the best fit with acceptable MPAE values. Finally, the physicochemical properties of the adsorbents indicate that B was successfully removed by P. hysterophorus.

Keywords: *P*. hysterophorus, carbonization, adsorption, wastewater, treatment

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Experimental and Numerical Study on the Behavior of Angle Connections under Tension

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Abstract: This research investigates the net cross-section capacity of bolted steel angles under tension, with a specific focus on the double bolt rows arrangement, an aspect currently unaddressed in the Eurocode-3. The aim is to develop a reliable equation for assessing the load carrying capacity of bolted connections in this configuration.The primary concern arises from the lack of provisions in the Eurocode-3 for the double bolt rows arrangement in bolted steel angles under tension. This gap in the code necessitates a thorough investigation to understand the behavior and strength characteristics of such connections and, consequently, develop accurate assessment methods. To address this, experimental tests were conducted on bolted steel angle specimens arranged in both single and double rows configurations. The resulting experimental data offers critical insights into the behavior and strength characteristics of these connections under different bolt configurations. Simultaneously, a numerical model utilizing a ductile damage material model was developed to simulate the behavior of bolted steel angles. The numerical model's accuracy and effectiveness were validated against the experimental results, ensuring its reliability in representing real-world scenarios. Eurocode-3 and BS5950 were found to underestimate the net cross-section capacity of bolted steel angles in the double bolt rows arrangement. The proposed equations Based on combined findings from experimental and numerical investigations aim to enhance understanding, leading to safer and more reliable structural designs in the construction industry.

Keywords: Steel Angle, Capacity, Bolt Arrangement, Numerical Simulation, Experiment.

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Analysis of Construction Waste Management System in Oman: A Circular Economy Approach

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Abstract: Construction and Demolition (C&D) waste management is becoming increasingly important due to the rising amounts of waste generated worldwide. In Oman, there has been a substantial increase in the amount of C&D waste received in dumping locations within just one year. Mitigating waste challenges requires proactive action at the early stages of construction projects. Adopting a circular economy approach requires clearly identifying C&D waste management components, quantifying the waste generated, and a monitoring system to oversee waste movement as an entity in the C&D management system. The study aimed to examine the existing system and its associated practices to understand and evaluate the current state of C&D waste management in Oman, including stakeholder identification and roles. The evaluation of the process included collecting and analyzing the existing construction waste data from Be'ah, Muscat Municipality and Environment Authority. The analysis provided insights into the quantity and characteristics of construction waste generated in Oman. The study is further extended to develop a data-driven model using a feedforward Artificial Neural Network (ANN) method. The model's main objective was to predict the construction waste that may have been generated from a project before construction. This model helps to quantify the expected waste entity in the C&D management system and support the decision makers to provide necessary actions to minimize illegal dumping of waste. The model was developed by identifying the main components contributing to the generated construction waste. A Principal Components Analysis (PCA) was used and identified the three features of plot area, built-up area, and number of floors as major input components for the ANN model. PCA results were further validated using Sensitivity Analysis (SA). The ANN model was built using a dataset of 75 instances split into a training set (80%) and a recall set (20%). Within the training set, it was further divided into three subsets: a second-order training set (70%), a validation set (15%), and a testing set (15%). The optimal model had one input layer with three neurons, three hidden layers with two neurons each, and one output layer with one neuron. The model achieved a good prediction accuracy translated by the coefficient of determination of 0.71. The study concluded that the area related features have the highest influence on the waste generation and proposed the utilization of the prediction tool prior to the issuing of building permits to achieve efficient handling, recycling, and monitoring of construction waste, incorporating principles of circular economy. To avoid illegal dumping, the proof of delivering the amount of estimated weight at a regulated dumping site is recommended to be a mandatory criterion to issue a completion certificate for any project.

Keywords: Artificial Neural Network ANN, Construction Waste Management CWM, Recycling. Principal Component Analysis PCA.

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The Flexural Capacity of the Prefabricated Truss-Beam Slabs

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Abstract: This study investigates the flexural capacity of prefabricated truss-beam slabs as a cost-effective and time-saving alternative for constructing reinforced concrete buildings with lighter weight. The conventional methods of casting and curing slabs are time-consuming and costly. Therefore, the development of innovative slab types and construction techniques is necessary. The prefabricated truss-beam slabs consist of precast truss beams with lightweight blocks, such as polystyrene blocks, placed between them to reduce the self-weight of the slabs. The use of polystyrene blocks significantly reduces the weight, thereby reducing the size of structural elements and the amount of reinforcing steel bars. The system requires a lesser amount of formwork and stringer support for a shorter period during the construction process. Furthermore, the installation of precast beams on-site saves construction time and reduces costs. The study examines different aspects of the prefabricated truss-beam slabs, including flexural performance, the effect of stirrup configuration, reinforcement ratio, and span on deflection, and capacity. The results indicate that all prefabricated beams exhibit good flexural performance, and the stirrup configuration has minimal impact on their behavior. Longer spans result in increased deflection but decreased capacity. Higher reinforcement ratios lead to reduced deflection and increased capacity. Moreover, the cost analysis reveals that the prefabricated truss-beam system is more economical compared to solid slabs and polystyrene-filled ribbed slabs. Overall, this research demonstrates the viability of prefabricated truss-beam slabs as a lightweight and cost-effective solution for efficient roof construction in reinforced concrete buildings.

Keywords: Flexural strength, Prefabricated truss beam slab, Ribbed slab, deflection, cost comparison.

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Flexural Fatigue Life Analysis and Fatigue Life Distribution of Plain and Fiber-Reinforced Lightweight Aggregate Concrete

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Abstract: Lightweight aggregate concrete (LWAC) has received a lot of attention in the construction sector due to its distinct qualities and benefits. Moreover, the addition of fiber to the LWAC mix can enhance its mechanical properties, and the use of fiber-reinforced LWAC is increasing in the construction sector. This type of concrete is used in bridges, floor slabs in high-rise buildings, off-shore structures, highways, pavements and airport runways. In these types of structures, flexural stress is critical, so it is important to investigate the fatigue effect on this type of concrete structures that use this LWAC at various stress levels. When compared to normal concrete, lightweight aggregate concrete can significantly reduce self-weight in engineering structures. As per limited information in the literature, the fatigue performance of LWAC is not the same as normal-weight concrete. Therefore, it is important to conduct more studies on the fatigue performance of LWAC. This thesis investigates the flexural fatigue strength and fatigue life distribution of plain and fiber-reinforced lightweight aggregate concrete (LWAC) under various stress levels. The flexural fatigue test data for plain and fiber reinforced LWC is collected from published and unpublished sources. The fatigue performance of different types of LWAC was evaluated using conventional Wöhler fatigue equation and power relations (double logarithmic fatigue equations). The effect of different types of fibers (hook-ended fiber, twisted fiber, polypropylene fiber and mix fibers) on the fatigue performance was also evaluated. Probabilistic fatigue analysis was conducted on the collected fatigue test data to evaluate the fatigue performance for different failure probabilities. The analysis used two-parameter Weibull distribution (2PWD) and three-parameter Weibull distribution (3PWD) models. The probabilistic fatigue life of plain and fiber-reinforced LWAC was assessed at specific fatigue life, using and contrasting the 2PWD and 3PWD models. There are limited experimental studies conducted in this field for the LWAC. Therefore, the analyzed data were collected from two different studies. The results show that fiber reinforcing can significantly increase the fatigue resistance of LWAC. Both plain and fiber-reinforced LWAC's fatigue life follows the Weibull distribution, with shape and scale parameters that depend on the applied stress amplitude. By taking into account failure probability, the double and single logarithmic fatigue equations were developed to establish the fatigue life equation. It was found that the 3PWD represents the fatigue failure more accurately than the 2PWD because of its nonlinear curve, which is the real case of fatigue failure. Moreover, the results of stress level for two million cycles ($N=2\times10^6$) obtained using 3PWD were better than those obtained by 2PWD.

Keywords: flexural fatigue, 2PWD, 3PWD, Probabilistic fatigue analysis.

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Sabkha Soil Improvement Using Deep Soil Mixing Technique: Experimental and Numerical Study

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PhD Degree (Expected Spring 2024)

Supervisor: Dr. Yahia E.-A. Mohamedzein.

Abstract: Sabkha soil is prevalent across the world, especially in the Arabian Gulf region, and poses challenges to the stability of structures. The utilization of deep soil mixing (DSM) was favored as an improvement technique due to its economic principles and numerous advantages, in contrast to costly traditional deep foundation systems. The behavior of DSM columns in sabkha soil was modeled both experimentally and numerically to develop geometric and column strength designs. A specialized apparatus was created to implement DSM columns, replicating the in-situ construction sequence. The results revealed a close agreement between experimental and numerical models regarding settlement and stress distribution along the soil profile. Significant enhancements in bearing capacity reached up to 130%, and substantial settlement reduction was observed. The DSM column bore approximately 75% of the applied stress, while the remaining 25% was supported by the surrounding soil beneath the footing, both numerically and experimentally. Stress concentration ratios exhibited notable differences, ranging from 1.25 to 2.60 for experimental models and 2.25 to 3.50 for numerical models. This difference is attributed to variations in stiffness between the DSM column and the surrounding soil. Additionally, the increase in the area replacement ratio is significant as the applied stress increases. Also, the column floating ratio plays a crucial role when the applied pressure increases. Moreover, the column strength has a substantial effect on the improvement degree up to 2600 kPa but exhibits negligible improvement beyond this value.

Keywords: (deep soil mixing; sabkha soil; stress concentration ratio; experimental model; numerical model)

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2. Electrical and Computer Engineering

Characterization of Vegetation Land Cover Nearby Water Dams in Oman Using Remote Sensing Technology and Image Processing Algorithms

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MSc Degree (Spring 2022)

Supervisor: Dr. Mohammed M. Bait-Suwailam

Abstract: Water is a finite natural resource, and it requires continuous monitoring in order to implement strategies and policies that ensure its long-term viability. Further, water dams are used to reduce water shortage. In this thesis, with the support of remote sensing imagery data, geographic information system (GIS), and MATLAB image processing toolbox, a comprehensive numerical study is conducted to investigate and characterize the vegetation landcover as well as the water surface area in nearby water recharge dams in Oman. The study area is extracted from remote sensing satellite imageries. Four earth observation satellites were used exclusively in this study which are Landsat-5, Landsat-7, Landsat-8, and sentinel-2. Multiple methods are applied and tested using ArcGIS software to visualize the vegetation landcover and water surfaces. The main contribution of this research is the development of engineering high-speed and robust scripts to investigate the vegetation land cover as well as the water surface area in Oman over a long period. The developed computer scripts avoid unnecessary complex retrieval procedures and can be reused for multiple applications. Moreover, this research study is a time series analysis focused on the years between 1985 and 2020. In this study, several water dams are considered as case study areas, including three groundwater recharge dams, Naam, A'Rassah, and Uqiidah water dams. Those dams are located in a hot and drought region in Ash-Sharqiyah North Governorate, wilāyāt Al-Qabil, in Oman. From image processing techniques, the hue, saturation, and value (HSV) color representation is used for classification and segmentation. Moreover, MATLAB scripts are also developed to aid in numerically estimating the two types of land cover. Additionally, the spectral profiles of vegetation landcover nearby water dams are processed and analyzed. The achieved results show that the average vegetation landcover was around 4.2 km2 in the first 17 years from 1985 to 2002. In contrast, during the next seven years, from 2002 to 2009, the average land cover decreased approximately to 3.6 km2. Furthermore, the next four years, from 2009 to 2013, show a noticeable change in the average vegetation landcover to reach around 4.6 km2. In the last period, between the years 2013 and 2020, the average increased significantly to reach around 8 km^2. The findings from the analysis show the vegetation average land cover increased significantly by 89.9% compared with the average vegetation land cover for the years before the dams were constructed. Nevertheless, the mentioned water dams construction was done between 2009 and 2012. What stands out in this is that the statistics show a significant vegetation land cover growth after the water dams are constructed.

Keywords: Remote sensing, GIS, drought region, band composite, NDVI

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Design of Wearable Patch Antennas with Polarization and Frequency Reconfigurability for Body Centric Wireless Networks Applications

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Abstract: Body Centric Wireless Networks (BCWN) communication systems are attracting the attention of many researchers, due to their importance in many aspects. It covers an extensive range of applications that are associated with many services. The fast development in 5G, 6G, and the Internet of Things (IoT) make investment and research in this area valuable. BCWN covers a wide range of applications such as Bio-medical and health care, tracking, sports, security, entertainment, military, etc. This thesis focused more on the design and optimization of the wearable reconfigurable antenna. In this case, a single antenna can operate at multi-bands, polarizations, or both by using multiple switching devices that change the status of the antenna by changing its size, instead of using several antennas that make the system complex and large in size. The antenna used in the thesis is a rectangular patch antenna with cuts at the corners connected by PIN (Positive- Intrinsic-Negative) diodes. By turning the diodes ON and OFF, different statuses are achieved. In this design only, by changing the statuses of the PIN diodes, three different polarizations and four different bands of frequencies can be achieved. The first case is when all diodes are in OFF status, the resonating frequency is at 2.45 GHz, with a bandwidth of 250 MHz (10.2%), and a gain of 4.61 dBi. The second case is with all PIN diodes being ON states. The resonating frequency shifted to 2.2 GHz with a gain of 2.91 dBi. Both the above-mentioned cases have linear polarization. In Cases three and four, half of the PIN diodes are ON and half are OFF, which can achieve resonating frequencies at 2.38 GHz and 2.37 GHz, with a gain of 4.19 dBi and 4.15 dBi respectively. The matching bandwidth for both bands are 380 MHz (16.5%) and 390 MHz (17%) respectively. The antenna has linear polarization at the resonating frequencies of 2.38 GHz and 2.37 GHz, and circular polarization at frequencies of 2.16 GHz, and 2.15 GHz for case three (RHCP) and case four (LHCP) respectively. Another improvement has been achieved by introducing a slot to the first case when all PIN diodes are in OFF status. The antenna resonating frequency shifts to the Super High Frequency range (SHF), resonating at 3.48 GHz with a gain of 7.61 dBi. A third antenna design was proposed as well by introducing PIN diodes to the slot gaps, seven other cases were presented and analyzed.

Keywords: BCWN, Antenna, Wearable, Reconfigurable

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Finding the Optimal Location and Size of Static VAR Compensator to Enhance System Voltage Profile at Muscat Governorate

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Supervisor: Prof.Abdullah Al-Badi

Abstract: Over the past three decades, the electricity demand has risen dramatically. Therefore, transmission lines operated at maximum capacity near thermal limitations to meet the load requirements. Consequently, electrical utilities are more focused in controlling and regulating the power flow via the main transmission lines. Flexible Alternating Current Transmission System (FACTS) equipment can be used to expand transmission capacity, improve dynamic behavior and stability, and limit power quality issues. Oman electricity demand increases as well as global demand, which leads to operate the transmission lines near thermal limitations. Therefore, the operating voltages of transmission lines should be maintained within grid code limits which require both active and reactive power flow control. A static VAR compensator (SVC) is one of the FACTS devices used to improve voltage profile. This thesis studies the Oman Main Interconnected System (MIS) with main focus on the Muscat governorate and demonstrates the effect of SVC devices on the voltage profile of the system. This study aims to find optimal locations and sizes of SVC by using Particle Swarm Optimization (PSO) which will improve the voltage profile at the area using MATLAB software. Simulation results show that the voltage profile improved, and total system losses decreased. In addition, this thesis investigates the dynamic behavior of SVC on the MIS using DigSILENT software. Therefore, load flow, voltage profile, harmonics and stability were investigated. The simulation results show that integrating SVC in the MIS improves the voltage profile and decreases losses. Also, system stability improved since the system response due to connecting SVC become faster. However, due to nonlinearity of SVC harmonics increased but still they are within limits of the grid. Also, the loading of the system increased when SVC was connected to the system as per reactive power to voltage (QV) curve simulation. Therefore, SVC can be one of the solutions that improves voltage profile and enhances system loading and stability.

Keywords: optimal location; voltage profile; stability; static var compensators

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Design and Performance Assessment of Microwave Antennas for Soil Moisture Sensing

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Supervisor: Dr. Mohammed M. Bait-Suwailam

Abstract: The world population has reached nearly 8 billion. This presents significant challenges in meeting the growing demand for food and clean water. With agriculture accounting for over 70% of global water usage, efficient water management is crucial for sustaining food production. Finding the optimal soil moisture content is vital, as it influences nutrient transport for plant growth, soil temperature regulation, and the prediction of natural events like droughts and forest fires. Accurate soil water content estimation is therefore essential in fields ranging from agriculture and hydrology to geotechnical engineering and the food industry. This work introduces a novel soil moisture sensor approach that uses a microstrip transmission line resonating at 1.4GHz, designed to enhance the accuracy, durability, and environmental compatibility of soil moisture measurements. Central to this study is the fact that soil moisture significantly influences the soil mass's biological, hydrological, and geophysical characteristics, relevant to diverse fields like agronomy, engineering, and ecology. The sensor used in this work employs a microstrip antenna, placed on the soil, to detect variations in electromagnetic (EM) wave velocity, which correlates with soil permittivity and its moisture content. Simulation results reveal that increased soil moisture consistently leads to a decrease in resonant frequency across various depths, with the reflection coefficient (S11) inversely related to EM wave penetration. At a 5mm depth, a noticeable frequency shift of 1.82% to 7.64% was observed for moisture levels from 5% to 20%, with this trend becoming more pronounced at greater depths, up to a 13.92% shift at 20mm depth. Empirical testing on sandy loam soil corroborated the simulation findings, demonstrating a clear relationship between increased soil moisture, lower frequency, and higher reflection coefficients, indicative of greater soil reflectivity. Given its depth-sensitive nature, the study suggests the potential development of multi-frequency sensors to acquire comprehensive soil moisture profiles.

Keywords: Soil moisture measurement, microstrip antenna sensor, sustainable agriculture, water management

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Robust 3D Dynamic Region Reaching with Obstacle Avoidance for Quadrotor-type UAV

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Abstract: This thesis provides an extensive investigation of quadrotor dynamics control, specifically emphasizing translational and attitude control through the implementation of various advanced techniques. The quadrotor system is represented as a sophisticated multi-input multi-output (MIMO) system, with distinct sets of equations governing the dynamics of translation and attitude. A novel control technique is presented for translational dynamics, incorporating backstepping, region-reaching strategies, and obstacle avoidance. Backstepping is employed to develop a stable control law that ensures convergence to a predefined region in three-dimensional space while avoiding obstacles. The proposed control strategy employs artificial potential functions to guide the quadrotor through a dynamic environment safely. Based on the backstepping method, the region-reaching controller exhibits the capability to accurately follow desired trajectories while effectively avoiding potential obstacles, thereby guaranteeing the safety and dependability of quadrotor navigation. A modified terminal sliding mode control approach is used in attitude dynamics. Integrating a Radial Basis Function (RBF) neural network enhances this technique by effectively handling uncertainties and disturbances. The revised terminal sliding mode controller guarantees the quadrotor's stable control over its attitude, even when faced with external disturbances and uncertainties in the model. The RBF neural network is employed to adjust the control inputs, allowing the quadrotor to achieve accurate attitude control, which is crucial for tasks such as aerial photography, surveillance, or any other application requiring stable positioning. The simulations are performed utilizing MATLAB/Simulink, which offers a virtual setting for testing and verifying the suggested control methods. The results indicate that the backstepping-based region reaching and modified terminal sliding mode control strategies are effective and robust. This suggests that these strategies have the potential to be applied in real-world quadrotor systems. This study makes a valuable contribution to the progress of quadrotor control systems by introducing novel methods to handle translational and attitude dynamics. The research places a significant focus on ensuring safety and achieving high levels of accuracy.

Keywords: Quadrotor, Region reaching controller, Obstacle avoidance, RBF neural network, Terminal sliding mode controller

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AI-Based Path Loss Characterization for Future Mobile Network Links

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Supervisors: Dr Zia Nadir

Abstract: The study aims to characterize path loss propagation models in wireless communication systems, particularly at 4G/5G and TETRA systems, using artificial intelligence (AI) techniques. Traditional methods for predicting path loss are based on empirical models created from measurements of the wireless channel. However, AI has been suggested as a substitute methodology to overcome these limitations. The characterization of path loss propagation models in these systems is essential due to their unique characteristics and requirements. New developments in AI and machine learning show promise for ways to make path loss predictions more accurate by taking into account more factors and non-linear relationships. This study looks into and compares how well traditional empirical models and AI can describe path loss for 4G, 5G, and TETRA frequencies. The main purpose of this study is to look into and define path loss propagation models in wireless communications, especially in 4G/5G and TETRA systems. They will do this by using both artificial intelligence (AI) and standard empirical models, and they will then compare how well they describe path loss. The findings of this research will contribute to narrowing the existing knowledge deficit and ultimately enhancing the effectiveness, extent, and capability of wireless communication systems through facilitating the development of more dependable and efficient microwave connection designs. The examination of path loss prediction models for GSM and TETRA systems, encompassing the utilization of identical datasets for both training and testing, provides significant findings regarding their individual performances. A significant observation is the consistent dominance of Artificial Neural Networks (ANN) in path loss prediction, irrespective of the wireless communication system, as compared to Support Vector Regression (SVR). The research also explains the diverse performance of empirical models in different locations and systems, and proposing suitable methodology in choosing models that takes into account specific environmental attributes. The empirical models' outcomes provide vital insights into the comprehensive panorama of path loss prediction, hence complementing the conclusions derived from machine learning models.

Keywords: AI, TETRA, GSM, Path, Empirical

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Adaptive Protection Schemes for Transmission Line Connected with Renewable Energy Sources

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Abstract: Integrating inverter-based renewables in electrical power systems introduces several challenges to different power subsystems. One of these is the protection system. The conventional protection system functions may not properly function for different fault scenarios due to the inverters' behaviors. The protection system elements of the transmission lines connected to inverter-based generators need to be designed to cope with the different changes experienced by the power system, such as the penetration level, the reduction of inertia, the lack of zero and negative-sequence components, and the changing source impedance. Different techniques can be used to mitigate these changes. Adaptive protection schemes are the most common of these. The proposed adaptive schemes in this research are Machine Learning (ML)-based. They are mostly related to detecting and classifying electrical faults in the transmission lines connecting inverter-based generators, namely photovoltaic (PV) systems and doubly-fed induction generator (DFIG) wind turbines. The 39-bus power system was used as the transmission system network and to extract the power signals. Two adaptive methodologies were considered. The first selects the appropriate pre-trained and pre-optimized classifier by monitoring the circuit breaker status and the active power of the generators' outputs behind the protected transmission line to identify the power system topology. This is basically a lookup table approach that inputs the circuit breaker's status and the output active power of the generator. The second adaptation scheme uses incremental learning as an adaptation mechanism. The incremental learning process uses the measured voltages and currents online (data stream) to update the parameters of the classification model associated with data drift detection and self-labeling models. This data-driven approach is used to minimize the time in the updating mode, which reduces computational complexity and increases the speed of detection and classification. The main aim of the incremental is to maintain the efficiency of the fault detector in the face of changing the statistical characteristics of the data and to do that without human interference. This work utilizes a wide range of ML algorithms to detect and classify different types of faults in transmission lines connected to IBGs. Furthermore, it investigates the impact of data imbalance, which is essential when considering power system faults as minority events. It also proposes two fault detection and classification techniques for adaptive protection design approaches considering the ML algorithms. Finally, it deals with data streams by having data drift detection and labeling using Hoeffding's inequality theory and self-training self-labeling semi-supervised model as part of the ML-based power system protection scheme. When compared to similar methodologies from the literature, the findings demonstrated a competitive performance. The incremental learning strategy with the suggested fitting and updating criteria has exceptional performance in terms of retraining time and detection and classification accuracy.

Keywords: Adaptive protection, Machine Learning, Renewable Energy Sources

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A Sub-6 GHz Single Ring Slot Antenna for 5G Mobile Phone Handsets

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Abstract: In this work, a single circular ring slot antenna designed for 5G mobile applications is presented. The design is composed of a concentric single-ring slot antenna to achieve dual band and linear polarization which is simulated using a high-frequency structure simulator (Ansys HFSS). A perturbation technique was added as a horizontal and vertical cut to achieve circular polarization. The proposed antenna was also designed with a 50-ohm microstrip dual feed line and the simulated results of multiband and wideband features of sub-6GHz are presented. The antenna shows a gain at 4.3dBi and 4.1dBi at 3.5GHz and 6GHz respectively. Also, adding a single split ring resonator enhances the frequency bands and shifts the second band from 6GHz to a higher frequency of 6.75GHz while maintaining the lower frequency band constant at 3.5GHz.

Keywords: circularly polarized (CP) and linearly polarized (LP), ring slot antenna, split ring resonator.

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3. Mechanical and Industrial Engineering

Develop an Efficient Cooling System Using Phase Change Materials for Thermal Management of a Central Processing Unit (CPU)

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Abstract: The dissipated heat per unit area associated with the small size of electronic components requires a proper thermal management to prevent premature failure as well as keep components within permissible operating temperature limits. This study is devoted to developing a practical and feasible solution to improve the thermal performance of the existing cooling system using passive and active cooling techniques that include the utilization of phase change materials (PCM) to enhance the thermal management of the CPU of the personal computer. The PCM has a high latent heat of fusion, meaning it can absorb a large amount of heat while undergoing phase change, making it ideal for applications where high amounts of heat are generated as well as space and weight are limited. Design concepts were generated using the literature review and then the best concept was selected by identifying the most important parameters. The new cooling system was manufactured and experimentally investigated. The experimental part was then carried out to investigate the effect of two parameters on the cooling performance: the amount of PCM (four PCM amount values were used: 20g, 40g, 60g, and 80g), and the supplied power at the CPU(10W, 20W, 30W,40W and 50W). The temperature profile of the system was detected by measuring the CPU surface temperature and the PCM temperature every 30 seconds in six different locations. The results demonstrated a significant difference in CPU surface temperature value between operating and not using the cooling system, e.g., the CPU surface temperature reached 230°C after 20 minutes under 40W of supplied power, compared to 55°C when the system is cooled. In addition, the CPU surface temperature was found to be inversely proportional to the amount of PCM, whereas it was directly proportional to the amount of supplied power. The PCM-type RT35HC provided better thermal performance for the CPUs. 60-80g of PCM developed an optimum thermal performance for the CPU at a low level of dissipated heat and an acceptable working performance at a high level of dissipated heat. In case of using PCM-type RT64HC the optimal amount was found 60g of PCM under passive and active cooling approaches. Even when more power than the CPU's thermal designed power dissipation (TDP) was applied, the CPU surface temperature remained within the ideal operating temperature range or even lower. Generally speaking, it was concluded that even when more power was supplied than the CPU's thermal designed power dissipation (TDP), the CPU surface temperature remained within the ideal operating temperature range or even lower, indicating that the modified cooling system is efficient and reliable.

Keywords: Phase Change Materials, CPU, Passive Cooling, Thermal Management.

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Design, Optimization, and Testing of a Battery-Powered In-Pipe Inspection Robot

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Abstract: In-Pipe Inspection Robots (IPIRs) have been a common alternative to human and endoscopic visual pipeline inspection for the past 3 decades. In addition to inspection, these robots are also capable of other tasks, such as drilling, data logging, and object retrieval. The ability of an IPIR to perform such demanding tasks is typically contingent on its payload capacity, radial range, along with its in-pipe steerability. In this study, a new IPIR is proposed with a design aimed at expanding its potential applications beyond inspection. The methodology espoused to address the aforementioned issues commences with the development of a parametric design of a Wall-Pressing IPIR, the sizing of a number of whose parts is determined based on the optimization problem formulated in this work. The optimization problem maximizes two contradictory objective functions, the robot's payload capacity, and its radial range. The optimization problem in this study is formulated as a Multi-Objective Optimization Problem (MOOP). The problem's Pareto front is solved for using the NSGA-II implemented by MATLAB's *gamultiobj()*. A single solution is selected from the obtained Pareto front and is validated for implementation as the final design of the proposed robot with a theoretical payload capacity of 11 kg and a radial range of 32.4 mm. The robot is then manufactured and tested to validate the results obtained theoretically in terms of its payload capacity and radial range. The experimental results are found to be consistent with the theoretically reported ones with a maximum percentage difference of 3.84%. Finally, a number of recommendations are suggested in response to issues encountered during the testing of the robot. Furthermore, other recommendations are made which aim to introduce improvements over the achievements of the present work pertaining to the automation of the proposed robot's control, its in-pipe steerability, as well as its applicability to active pipelines.

Keywords: In-Pipe Inspection Robots, Wall-Pressing Mechanisms, Multi-Objective Optimization, Genetic Algorithm

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Energy Performance Assessment of a Zero-Energy House

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Abstract: With the continuous economic and population growth and with the implementation of Cost Reflective Tariff (CRT), the building sector is forced to implement new strategies to reduce energy consumption. This research aims to develop design guidelines for residential buildings for the three main predominant climates (Hot-dry, Hot-humid, and Warm-humid) in the Sultanate of Oman. Using an existing 210 m2 eco house instead of a local house and studying the energy performance against nZEB performance metrics. The research methodology consisted of four main phases, firstly, a data collection phase for all necessary information related to the house. Secondly, an audit phase to confirm as-built drawings and survey building systems. Thirdly, an energy analysis phase where the house was modelled in DesignBuilder software followed by a validation phase using previous experimental data. The calibrated model was then used to assess the energy status, were results showed that the current performance can be further improved. Fourthly, different energy efficient measures were tested, and backward analysis was performed by comparing the currently applied passive and active systems with those of a local Omani house to study their effectiveness. In addition, a sensitivity analysis was performed for the cooling thermostat setpoint to reduce the design parameters tested. Followed by a solar water heater effectiveness test. Finally, results showed that the currently applied HVAC system can be improved by using either high performance Split ACs or a variable refrigerant volume system and that the energy saving can reach up to 62.8% depending on the climate. The results of these tests were used to develop building guidelines per climate. Overall, this research contributes to the field of sustainable architecture by providing valuable insights into the energy performance of eco houses in diverse climates. The guidelines derived from this study offer practical recommendations for designing and constructing energy-efficient houses, ultimately contributing to the transition towards more sustainable and environmentally conscious building practices.

Keywords: Zero-energy building, Energy efficient measures, residential building, DesignBuilder, Oman, Eco house

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Precipitation Hardening of the Aluminum Alloy 6201

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Abstract: The aluminum-magnesium-silicon alloy 6201 is a popular electrical conductor, widely used for overhead distribution and transmission lines. It has a mass conductivity twice that of copper, due to its low density of 2.7 g/cm^3, which is less than one third of that of copper. It also has one of the highest strength-to-weight ratios among structural alloys in addition to an excellent corrosion resistance. Its tensile strength varies between 255 to 330 MPa and has an electrical conductivity in the range 52-57 % IACS. The alloy makes up the homogenous overhead conductor All Aluminum Alloy Conductor (AAAC). AAAC, however, experiences corrosion, creep, erection, power loss, and other drawbacks. Therefore, it has been essential for manufacturers to improve its mechanical and electrical properties by improving the alloy performance. A simultaneous improvement of both strength and electrical conductivity has been a challenge to researchers; the improvement of one of them would decrease the other. Precipitation hardening is performed during processing to improve mechanical properties, which is considered as one of the metallic strengthening mechanisms; solid-state-transformation is another expression for precipitation. This thesis investigates the precipitation phenomenon in the aluminum alloy 6201. To nucleate second phase particles (precipitates), two different heat treatment methods are introduced: a heat treatment designation which includes in order, solution heat treatment, quenching, and artificial aging, respectively (also known as T6-temper) and the commercially adapted heat treatment (throughout this thesis, it will be referred as the AL3 processing/ wire) is performed as well, for comparison. The latter method excludes the intermediate solution heat treatment and quenching. A microstructure-property relationship is investigated as well; the microstructure features precipitate density, dislocation density, precipitate mean radius, and precipitate phase fraction are predicted, which are then correlated with the measured mechanical properties and electrical conductivity. The results of the study show that the electrical conductivity was remarkably high after performing the T6-temper heat treatment; it exceeded the values of the previous studies as well as that of the 1350 alloy (EC wire), 61% IACS. Tensile strength was retained during artificial aging at the low temperatures 150 and 155 °C and significantly reduced during artificial aging at higher temperatures. A significant amount of the second phase particle β″-precipitate must have nucleated (precipitation), which would explain the retainment of tensile strength, as in the case of the sample artificial aged at 155 °C for 30 h, with the remarkable increase in electrical conductivity. Precipitates are made up from alloying elements; therefore, a high number of precipitates results in low number of alloying elements; the previous is responsible for such strength retainment (after the reduction during solution treatment) and the latter is responsible for the high electrical conductivity. In the case of the AL3 type heat treatment, high strength of 340 MPa and medium conductivity of 56 %IACS were obtained.

Keywords: aluminum alloy 6201, artificial aging, electrical conductivity, α-and β-AlFeSi intermetallic particles, β″/β′/β-precipitate

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Potential of Nano Date Palm and Nano Titanium Particles to reinforce recycled polymers with Mechanical Characterization

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Abstract: This research work is about characterization of the mechanical properties of two newly developed nanocomposite materials. The produced composites are made by mixing either Nano date palm particles (NDPP) or Nano Titanium Dioxide particles ($NTiO_2P$), as a reinforcement filler, with recycled polypropylene (rPP). Particularly, downsizing the date palm microfibers generated from waste to Nano-sized lignocellulose fillers has been accomplished by ball milling machine. The powdering process is done at a high speed of 12 cycles per minute for four cycles. The manufacturing process involves making composite sheets using a twin-screw extruder in a hot melt state followed by compression molding. After that, test specimens are prepared following ASTM standards and then tested in Universal Testing Machine (UTM) setup. Experimental results showed that the highest tensile strength of the reinforced polymer can be accomplished at 3% wt. NDPP and 6% wt. NTiO2P. These filler loadings increased the tensile strength by 48% and 63% over the neat rPP, respectively. Moreover, the flexural strength of NDPP based nanocomposite increased by 30% at 3% wt. while the strength of $NTiO_2P$ based composite was improved 33% at 6% wt. over the neat polymer. Due to the soft nanofillers, both Nano particles exhibit a slight decrease in Young's modulus; 10.7% and 7.8% at 3% wt. NDPP and 6% wt. $NTiO_2P$, respectively. Similarly, the increase in elongation at break and flexural modulus for both nanocomposites contribute to improve the ductility of the neat polymer. The results from the morphological analysis using Field Emission Scanning Electron Microscope (FESEM) revealed that NTiO2P with 6% wt. has better interlocking with the polymeric matrix and better filler distribution over 3% wt. NDPP. Results showed that viscosity of NDPP based nanocomposites exceeded that of $NTiO_2P$ nanocomposites while density was less. This study confirms that nanocomposites produced from NDPP are economically viable and ecologically friendly materials that have a high potential to be utilized in a variety of industrial applications.

Keywords: Nanocomposites, Bio-composites, Mechanical properties, Nano date palm, Particle size effect

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4. Petroleum and Chemical Engineering

Multi-Channel Flow Reactor Design for the Photocatalytic Degradation of Harmful Dye Molecules

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Abstract: Textile industries consume large amounts of water and generate large quantities of wastewater daily. Globally, around 700,000 tons of dyes are synthesized, and about 280,000 tons of textile dyes are discharged into water bodies annually. Textile wastewater contains several complex and hazardous materials. Therefore, new, costeffective, and environmentally friendly technologies are needed to treat textile wastewater effluents. This study investigates the design of a serpentine continuous photocatalytic reactor for the degradation of methylene blue (MB) dye as a model contaminant of the synthetic textile wastewater under natural sunlight irradiation using zinc oxide nanorods (ZnO NRs) as a supported catalyst. ZnO NRs catalysts were fabricated on glass substrates using the microwave-assisted hydrothermal method and characterized by different techniques. The characterized results show that wurtzite crystal structure ZnO NRs has native defects in the visible region. Water contact angle measurement shows the highest wettability of ZnO NRs surface at pH 8. Photocatalytic degradation was conducted with MB dye under natural sunlight in a batch system followed by a continuous flow reactor. In the batch reactor, three different concentrations of 10, 50, and 100 ppm MB were examined under natural sunlight. MB degradation reached 100 %, 83 %, and 62 % under natural sunlight for 10, 50, and 100 ppm, respectively, after 3 hours of irradiation. In the continuous flow reactor, 100 ppm MB was degraded 80 %, 67 %, 58 %, and 46 % at flow rates of 1.5, 2.5, 4.5, and 6 ml/min, respectively. Furthermore, a multi-step process using a continuous flow reactor achieved ~ 90 % MB degradation after five repeated steps. The supported ZnO NRs in a continuous flow reactor can effectively degrade MB dye and are suitable for degrading industrial textile wastewater.

Keywords: Photocatalysis; Zinc oxide nanorods; Methylene blue; Continuous flow reactor

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Developing an ESP Lifespan Predictive Model Using Artificial Intelligence: a Case Study on an Omani Oilfield

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Abstract: The Electrical Submersible Pump (ESP) is the most effective and consistent artificial lift method for medium to high production rates. Although the capital cost of ESP is high, it pales in comparison to the production losses resulting from its failure. Recently, Machine Learning (ML) has gained significant attention in the oil and gas industry due to its predictive power. This paper aims to develop a ML model to predict ESP lifespan and identify the key features that influence its longevity. The study reviewed the failure history of more than 100 wells from an Omani oilfield, with 132 ESP failures attributed to sand and scale accumulation. The dataset includes 36 static features related to ESP design, installation, commissioning, failure, pull-out, and teardown. Three algorithms, namely Support Vector Regressor (SVR), Random Forest Regressor (RFR), and Extreme Gradient Boosting Regressor (XGBR), were selected. Hundreds of tests were performed on each algorithm to optimize the parameters and hyperparameters, based on mean absolute error, average residual, and determination coefficient. The study developed a model with two levels to predict the lifespan of ESP before installation and after the last valid well test. The model had a mean absolute error of 25 days and 8 days for the first and second levels, respectively, with a determination coefficient of 60% and 73%. The model showed that certain factors related to pump and motor design have the most significant impact on the longevity of the ESP before installation. Pump discharge pressure and flow rates of oil and water are crucial to monitor and control during its operational lifespan. The findings emphasize the importance of careful selection and design of ESP components to ensure a long-lasting lifespan. By scheduling ESP maintenance before failure, these findings can help mitigate capital costs, while preparing the necessary hoist, rig, and materials for ESP replacement can avoid deferred operational costs.

Keywords: ESP, ML, SVR, RFR, XGBR

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Surface Tension of Binary Crude Oil Blends: Measurement and Correlation

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Abstract: Surface tension of mixtures is an important property in various chemical industries especially in oil and gas processes, including distillation, liquid-liquid extraction, absorption, and separation due to its considerable effects on heat and mass transfer at the interface of the fluid mixtures, in addition to its essential role in fluid flow behaviors in two-phase pipelines. Several approaches have been proposed in the literature for modeling the surface tension of mixtures based on the experimental surface tension of pure components or their critical parameters or by experimental fitting parameters. This study aims to investigate which models proposed in the literature are the most suitable to predict surface tension of binary crude oil blends. Surface tension (σ), density (ρ) and dynamic viscosity (μ) of eight crude oil samples with API gravity range of 15.85 – 39.49 and twenty binary crude oil blends were measured at various temperatures. Surface tension of the crude oil blends was measured at temperatures of 293.15, 298.15, 303.15, 308.15 and 313.15 K at atmospheric pressure and different mole fractions. DuNouy Ring method was used to measure surface tension of crude oil samples and blends. The models in this study were classified into two main approaches: the first approach based on predictive nature of models, and the second approach based on correlations with experimental fitting parameters. The experimental results were compared to theoretical values obtained from thirteen different models. For the first approach, the lowest absolute relative deviation percent (AARD %) obtained for Vakili-Nezhaad et al., Brock-Bird and Goldsack-Sarvas models were 5.85%, 3.57% and 1.23% respectively. In the second approach, Eberhart and Connors-Wright models gave the most accurate results with AARD% of 0.95% and 0.86% respectively. However, these two models are less applicable since they require experimental fitting data to calculate fitting parameters. A new model is developed and suggested for binary crude oil blends based on their pure components surface tension values with an overall average absolute relative deviation of 0.95%. The new developed model is a modified version of the Vakili-Nezhaad et al. model with the new constant of (-1) instead of (25/3). Among models with no fitting parameters required, the new proposed model shows the best agreement with experimental values.

Keywords: Crude oil, surface tension, density, binary blends, surface tension prediction

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Dynamic Reservoir Modelling of Carbon Dioxide Storage in Depleted Dry Gas Reservoir in Northern Oman: Case Study

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Abstract: Carbon capture, utilization, and storage (CCUS) is one of the essential technologies that needs to be addressed to reduce the different anthropogenic greenhouse gases (GHGs) emissions in the atmosphere especially carbon dioxide (CO_2) emissions. This GHGs emissions have shown an increased in trend over the last few decades and affects the global temperature and threaten the lives of organisms. Therefore, CCS is considered nowadays as an emerging technology that needs to be studied and investigated to ensure safe and large- scale sequestration of the CO_2 in the underground storage area. These various underground storage areas were suggested by scientists to be used for geological CO_2 storage purposes beneath the subsurface. Technically, using the depleted gas reservoir for ensuring large and safe storage of atmospheric CO_2 is suggested by different researchers for mitigate the level of the anthropogenic CO_2. However, inside the reservoirs, various trapping mechanisms will take place and this mechanism play an important role to ensure safe trapping of the injected CO_2. This study aims to investigate the impact of different parameters like connate water saturation, permeability, and wettability on physical trapping mechanisms. In addition, investigate the effect of Henry's law constant, and salinity in chemical trapping mechanisms in dry gas fields named as N-field. This N-field is part of Haban cluster area in Sultanate of Oman. RFD tNavigator which is a three-dimensional simulator has been used to investigate these various parameters impacts during CCUS process.

The results obtained from simulation indicate that, RFD Tnavigator was able to successfully used to predict the behaviors of injected CO_2 for storage purposes inside depleted gas reservoirs. Regarding physical trapping mechanism, as the connate water saturation increases the amount of CO_2 stored in the depleted gas reservoir increases and more amount of CO_2 will be stored and retained inside the depleted gas reservoir with time. Simulator also show that, as permeability values decreases, more amount of CO_2 will be retained inside the reservoir due capillary trapping mechanism. In addition, as the rock is more water wet system, more amount of CO_2 will be retained in the reservoir according to the results. moving into chemical trapping mechanism, the solubility of CO_2 in water increases when henry law constant decreases as other factors kept constant during the simulation run period. Also, results proved that, more amounts of CO_2 will be soluble inside the reservoir as time passes and hence more amount of CO_2 will be trapped as soluble in brine. In addition, higher values of salinity inside the brine in reservoirs will lead to impact the stored amount of CO_2 as soluble phase and hence the solubility of CO_2 in brine tends to decrease with increasing salinity. The findings of this study can aid to give an indication of the feasibility of using this depleted gas reservoir for CO_2 storage purposes to mitigate the level of anthropogenic GHGs emissions from the atmosphere which can help in limit the increase of global temperatures and save the life of organisms.

Keywords: CO_2 Storage, CCUS, CO_2 behavior inside Gas reservoir, Wettability, Pc and Permeability impact, CO_2 sequestration

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Application of Machine Learning Techniques for Inorganic Scale Precipitation Prediction in a Sandstone Reservoir

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Abstract: In the realm of the oil and gas industry, the emergence of inorganic scale formations has emerged as a significant concern, profoundly affecting flow assurance and the overall efficiency of oil and gas fields. These precipitates, with their potential to inflict damage on reservoirs, well completions, and surface facilities, present formidable challenges to petroleum engineers, production specialists, and facility managers alike. Despite the existence of numerous commercial computer applications designed to forecast inorganic scale formations with a degree of precision, a major drawback lies in their inherent limitations, which can detrimentally affect the accuracy and efficacy of these predictions. In recent years, there has been a considerable surge in the application of machine learning (ML) within the oil and gas sector. This study aims to delve into the utilization of machine learning algorithms as a fresh and innovative avenue for predicting the occurrence of inorganic scale precipitations specifically within carbonate formations in the oil and gas industry. The methodology employed in this present study revolves around the collection of both input and output data. This dataset encompasses a wide array of variables including pressure, temperature, artificial lifting method, target formation, water ionic composition, water cut, pH levels, total dissolved solids (TDS), and the propensity of each well to precipitate inorganic scale. For the purpose of prediction, a selection of machine learning algorithms has been made. These include Naive Bayes (NA), Neural Network classifier (NN), Logistic Regression (LR), Random Forest (RF), Decision Tree (DT), Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). The evaluation of these algorithms will be primarily based on metrics related to accuracy and other pertinent classification performance indicators. The outcomes of the model evaluations demonstrate that Gaussian Naive Bayes, Logistic Regression, and Neural Network emerge as the most proficient classifiers regarding prediction accuracy, boasting an impressive score of approximately 90%. The adoption of the suggested model promises numerous advantages. This includes the efficient allocation of well intervention resources, mitigated oil deferment arising from pump failures attributed to scale precipitation, and a reduction in budgetary overruns stemming from unforeseen malfunctions in pumps, valves, or even surface facilities. Consequently, the application of this model not only enhances the operational efficiency of oil and gas production but also contributes to substantial cost savings and improved flow assurance.

Keywords: Machine learning, Scale, Algorithms, Pump failures, Sandstone

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Improving the Performance of Membrane Distillation for Water Desalination Using Functionalized Carbon Nanotubes Derived from Local Biomass

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PhD Degree (Spring 2023)

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Abstract: The current work addresses the utilization of AC as a supporting substrate combined with NaCl as a novel green catalyst for the synthesis of carbon nanotubes (CNTs) via a catalyzed chemical vapor deposition (cCVD) method. The effect of different AC-NaCl ratios on CNT growth was investigated. The nano-particle yield was estimated and samples were characterized by BET, Electron microscopy (SEM and TEM), XRD, FTIR, and TGA analyses. The asymmetrical porous structure and high surface area of the AC clearly offer excellent uniform NaCl dispersion properties on the surface, resulting in a high catalyst-transition metal free-yield of CNTs forest growth. The results showed higher mass yield in the order AC-NaCl 1:2 > AC-NaCl 1:1 > AC-NaCl 1:3 ratios. AC and NaCl are excellent choices as substrate and catalyst combinations for the synthesis of metal-free MWCNTs as they are cost-effective and environmentally friendly. Acid functionalization was conducted using an acid mixture of H_2SO_4:HNO_3 at different volume ratios to improve the CNTs dispersity and to eliminate contaminants from their surfaces. Functionalized carbon nanotubes (f-CNTs) were then employed to prepare composite membranes for saline water desalination via direct contact membrane distillation (DCMD). Different f-CNT loadings were tested. All produced membranes were subjected to various characterization tests including porosity, SEM, ATR-FTIR, TGA, Contact Angle (CA) and Tensile strength tests. The results showed that the inclusion of f-CNT structure could improve hydrophilicity, porosity, thermal stability, and mechanical strength of the composite membranes. The DCMD process was also improved using f-CNTs compared to other membranes as the f-CNTs offered additional pathways for water vapor transport. In the DCMD experiments, the highest permeate flux reached was 19.6 kg/m^2.hr and > 99% salt rejection at 80 ^oC feed and 20 ^oC permeate temperature. This was achieved with 78.8^o contact angle, 56% porosity and thermal stability higher by more that to 11 °C compared to pristine PVDF. Overall, the results show that PVDF-f-CNTs membranes offer a potential and encouraging alternative to existing membranes. Optimization of operating conditions was conducted to maximize permeate flux within the range. A desirability of 0.776 was achieved at a feed temperature of 80 ^oC, feed flow rate of 75mL/min and 0.4 M feed concentration in which a flux of 19.472 kg/m^2.hr was obtained. Another optimization study was conducted at wider ranges and maximum flux of 31.078 kg/m2.hr could be found at 90 ^oC feed temperature, 80mL/min flow and 0.4 M NaCl feed concentration. A permeate flux of 29.7 kg/m^2.hr was achieved by the validation experiments, which indicates the reasonable accuracy of the predicting model.

Keywords: Nanotubes, Activated carbon, Sodium, Functionalization, Membrane distillation

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