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OPTIMIZATION OF CONTAINER TERMINAL OPERATIONS USING RESPONSE SURFACE METHODOLOGY

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Abstract
Container terminals are essential for handling the growing container traffic resulting from global trade. Operation managers must either increase the number of handling components or improve the efficiency of existing equipment to meet the increasing demand. This paper employs the response surface methodology to obtain the optimal number of yard trucks (YTs) and rubber tyred gantry (RTG) cranes. First, a two-level full factorial design was employed to fit first-order regression models and assess the effects of the variables. Then, the second-order models were constructed with a central composite design to further explore the influence of key parameters on the response variables. The Derringer-Suich method was applied to identify the optimal levels of performance criteria such as operation time and cost. According to the implementation results, the average operation time was reduced from 303.25 minutes to 286.25 minutes, reflecting a 5.6 % improvement in operational efficiency. Furthermore, the total operating costs decreased by $315.72, from $2,331.59 to $2,015.87. This 13.5 % improvement highlights the operational cost advantages achieved by optimizing resources. 24 refs.
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Key Words: *Container Terminal, Double Cycling, Simulation, Response Surface Methodology, Derringer-Suich Method*

Pages 575-586

EVALUATION OF MEASUREMENT UNCERTAINTY CONTRIBUTIONS IN RING GAUGE CALIBRATION

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Abstract
Measurements are of paramount importance in industry and other areas of importance to society. They are used to determine the characteristics of processes and products, to control and regulate processes, to decide on the acceptable quality of products, etc. To ensure the quality of measurements, we have to calibrate measuring devices regularly. In our laboratory – the holder of the national length standard, we mainly calibrate high-precision standards from accredited laboratories. As the demands on the accuracy of measurements are constantly increasing, we are also forced to continuously improve the accuracy of our calibration procedures. This article presents the development of methods for calibrating the diameter of ring gauges, which represent an important standard for calibrating measuring instruments for measuring internal dimensions. The main objective of this development is to reduce the measurement uncertainty based on a scientific investigation of all influencing parameters. The presented study focuses in particular on the control and reduction of the influence of geometric anomalies of the calibrated rings on the measurement uncertainty during calibration. 17 refs.
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Key Words: *Measurement Traceability, Calibration, Measurement Uncertainty, Ring Gauge, Error Simulation*

Pages 587-598

PROCESS SIMULATE VERSUS INERTIAL MOCAP SYSTEM IN HUMAN MOVEMENT EVALUATION

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Abstract
There are various tools for evaluating physical ergonomics. Two main computer-assisted approaches can be recognized in the literature: analytical evaluation using simulation software like Siemens Jack or Process Simulate, and empirical evaluation by tracking human body movement. Both methods have their own advantages and disadvantages. This article compares an analytical method using Process Simulate software and an empirical evaluation using an inertial motion tracking system and highlights the strengths and limitations of both approaches. The information from the tracking system is processed by the Process Simulate software and an ad-hoc ergonomic analysis module developed in Unity. Given the limited license of Process Simulate, the ergonomic comparison is performed using two indices, RULA and OWAS. Other comparison metrics discussed in the article are the time required for the analysis, the additional functionality each solution offers and the possibility of augmenting the assessment with virtual or augmented reality solutions. The results show some limitations of using Process Simulate with the tracking data and the great versatility of the solution developed in Unity. 26 refs.
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Key Words: *Ergonomics, Simulation, Analytical Evaluation, Empirical Evaluation*

Pages 599-610

GA AND WOA-BASED OPTIMIZATION FOR ELECTRIC POWERTRAIN EFFICIENCY

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Abstract
This study presents an optimum vehicle architecture along with a design methodology that optimizes the motor power, battery capacity, and propulsion ratio for two different driving profiles using Genetic Algorithm (GA) and Whale Optimization Algorithm (WOA). A virtual electric vehicle model was created in MATLAB/Simulink and validated with real-world driving. The vehicle architecture was optimized with GA and WOA based on the cost, range, gradability, and maximum speed outputs obtained from the "hybrid driving" and "urban driving" behaviours. According to the results obtained in the study, it was found that GA optimization can create a vehicle architecture suitable for long-distance and high-performance driving and can provide shorter optimization times. On the other hand, it was seen that WOA optimization can create vehicle architectures with lower costs, higher maximum speeds, and improved gradability in urban driving. It was found that e-motor 4 and battery 2 can provide the most optimum vehicle architecture solution on a component basis. 33 refs.
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Key Words: *Electric Vehicle, Simulink, Design Optimization, Genetic Algorithm, Whale Optimization Algorithm*

Pages 611-621

HYBRID DYNAMIC ANALYSIS OF THE MANUFACTURING PROCESS OF LIGHTWEIGHT BRICKS

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Abstract
In this study, the hybrid simulation approach was adapted using the System Dynamics methodology to characterize continuous and discrete variables in the lightweight brick manufacturing process. Vensim® software was used to evaluate the effects of delays in production flows at specific time intervals, and the continuous impact of variability in the stages of the process was established. The results demonstrate that carrying out a continuous evaluation of the input flow of raw material does not impact the accumulation of material. However, when assessing the monitoring of delay times in a discrete approach, there is a direct impact on batch formation and production capacity fulfilment, resulting in an 8.54 % increase. In conclusion, it is crucial to not only characterize the variables but also to assess their impact using an overarching indicator, such as production capacity, rather than focusing solely on subsequent stages. This comprehensive approach enables strategic decision-making to identify areas of opportunity within the process. 22 refs.
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Key Words: *Manufacturing Process, Discrete Behaviour, Continuous Behaviour, Hybrid Simulation, System Dynamics*

Pages 622-633

PARAMETER OPTIMIZATION AND ANALYSIS OF PLASTIC SEPARATOR BASED ON EDEM-FLUENT

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Abstract
The rapid and efficient separation of polyethylene terephthalate (PET) materials from the crushed beverage bottle mixture is one of the current technical difficulties. In this study, a gas–solid phase flow model of broken beverage bottle materials was established, and a simulation analysis of winnowing separation process of the broken beverage bottle mixed material was performed utilizing the engineering data exchange model (EDEM) and the computational fluid dynamics (CFD). A four-factor and three-level response surface method (RSM) was designed to investigate the influences of material feed weight (*A*), wind velocity (*B*), wind velocity angle (*C*) and initial material feeding velocity (*D*) on the separation effect. The PET material content (C_{PET}) after separation was applied as evaluation index to determine the optimal winnowing parameters. Results show that the EDEM-Fluent coupling simulation can reflect the impact of fluid parameters on movement paths of the mixed material. The influencing strength of factors on separation rate was concluded as follows: $B > D > C > A$. The results obtained with optimized parameters showed that the C_{PET} approaches 99.99 % accuracy. 27 refs.
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Key Words: *Plastic Recycling, PET, Winnowing Separation, EDEM-Fluent Coupling, Response Surface Method*

Pages 634-643

APPLICATION OF MACHINE LEARNING TO REDUCE CASTING DEFECTS FROM BENTONITE SAND MIXTURE

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Abstract
One of the largest Slovenian foundries (referred to as Company X) primarily focuses on casting moulds for the glass industry. In collaboration with Pro Labor d.o.o., Company X has been systematically gathering defect data since 2021. The analysis revealed that the majority of scrap caused by technological issues is attributed to sand defects. The initial dataset included information on defect occurrences, technological parameters of sand mixture and chemical properties of the cast material. This raw data was refined using data science techniques and statistical methods to support classification. Multiple binary classification models were developed, using sand mixture parameters as inputs, to distinguish between good casting and scrap, with the *k*-nearest neighbours algorithm. Their performances were evaluated using various classification metrics. Additionally, recommendations were made for development of a real-time industrial application to optimize and regulate pouring temperature in the foundry process. This is based on simulating different pouring temperatures while keeping the other parameters fixed, selecting the temperature that maximizes the likelihood of successful casting. 15 refs.
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Key Words: *Gravity Casting, Machine Learning, Defect, Classifier, Data Science*

Pages 644-655

A SIMULATION METHOD FOR FIREPROOF SPACE DESIGN IN AVIATION AIRPORT TERMINALS

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Abstract
To scientifically design a fireproof space system for general aviation airport terminals, a simulation method was proposed by comparing smoke spread, temperature, visibility, and evacuation time. Taking the civil aviation airport of Luoyang, China as an example, four fire scenarios were set in the business and baggage areas through fire zoning, and the evolution of visibility and temperature under different scenarios was analysed. Then, the safe evacuation time and the available evacuation time under each scene were comparatively discussed, and the spatial optimization layout effect and the safety of personnel evacuation in the terminal on the fire scene were verified through simulations. Results show that the available safe evacuation time in the baggage area and business area increases from 401.5 seconds and 388.3 seconds to 524.2 seconds and 424.5 seconds, respectively, after the addition of the smoke control system and fire zones in the terminal. The required safe evacuation time in the event of a fire is 300 seconds, which is shorter than the available safe evacuation times. The obtained conclusions provide a novel method for developing efficient emergency evacuation strategies for airports. 21 refs.
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Key Words: *Performance-Based Fire Protection Design, Fire Simulation, Emergency Evacuation*

Pages 656-667

CUTTING VIBRATION RESPONSE OF A SHIELD-TYPE TUNNELLING ROBOT SYSTEM

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Abstract
To improve the tunnelling-cutting efficiency, enhance the overturning stability of the tunnelling-cutting system, a shield-type tunnelling robot system was proposed, a load model of the cutting drum was established, and the cutting and tractive resistance were obtained. Force and overturning stability models were constructed. The stability coefficient was put forward, a multirigid-body dynamic model was built, and a model of the conditions for maintaining stability and a model of the vibration displacement response law were established. A simulation experiment and an underground on-site coal and rock section cutting test were performed, and the overall system stability and the vibration displacement response of each component were compared to verify the correctness of this study. Results prove that the proposed stability coefficient can significantly improve the overall stability by giving the shield the force to adapt to the cutting load. The transverse and longitudinal vibration displacement responses of the cutting drum to upper and lower shields decrease successively. The maximum transverse and longitudinal displacements are 9.27 and 11.68 mm, respectively. 31 refs.
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Key Words: *Shield Type, Cutting Robot, Multirigid-Body Model, Stability, Vibration Response*

Pages 668-679

PARCEL FLOW-SIMULATION TOOL OF PARSEC SYSTEM-OF-SYSTEMS' SCANNING TECHNOLOGY ARCHITECTURE

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Abstract
The rapid growth of e-commerce has led to an unprecedented increase in parcel volumes, posing significant challenges for secure and efficient cross-border parcel delivery. This paper presents a preliminary study on the development of the PARSEC flow-simulation tool, which aims to improve parcel flow management for customs by integrating advanced detection technologies into parcel handling processes. The simulation model incorporates three scanning technologies into a system-of-systems approach. Initial results demonstrate the potential for high detection rates and reduced false alarms, thereby minimizing costly and time-consuming manual inspections. By addressing important issues in parcel management flows, this tool could significantly enhance decision-making for secure and efficient parcel processing, making it adaptable to different facility sizes and operational conditions. 16 refs.
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Key Words: *Parcel Flow, Simulation Tool, Scanning Technology, Safety and Security, Customs, Performance Analysis*

Pages 680-691

A SIMULATION STUDY ON INLAND CONTAINER AND TRUCK SCHEDULING OPTIMIZATION

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Abstract
Inland container transportation, as a continuation of sea transportation, is crucial for ensuring the efficient flow of cargo entering and leaving ports. Optimizing the configuration of the inland transportation network and the organization of container dispatching services is vital for container shipping companies to ensure high-quality "door-to-door" service. This paper develops a container transportation network model incorporating an Inland Container Depot (ICD), then, establishes an inland container-truck scheduling model. A mixed integer programming model is developed to address the scheduling of imported empty containers, imported full containers, exported empty containers, exported full containers, and trucks. The model is validated using real data from a container shipping company, and the Variable Neighborhood Search (VNS) algorithm is proposed to solve the model efficiently. The simulation results indicate that establishing ICDs and planning truck and empty container scheduling within this transportation network can effectively reduce drayage transportation costs. 23 refs.
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Key Words: *Container Scheduling, Vehicle Routing Problem, Transportation Network, Inland Container Depot, Variable Neighborhood Search*

Pages 692-703

OPTIMIZING PRODUCTION WITH DEEP REINFORCEMENT LEARNING

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Abstract
The optimization management of complex production processes is the key to enhancing the competitiveness of enterprises in modern manufacturing. Traditional optimization methods often struggle to manage the dynamic and intricate nature of production environments, highlighting the need for more intelligent and efficient approaches. As an advanced technique in artificial intelligence, Deep Reinforcement Learning (DRL) has demonstrated significant potential in addressing high-dimensional, nonlinear dynamic system optimization through interactive learning with the environment. However, current research approaches face limitations in handling the diversity and dynamism inherent in complex production workflows. In this study, a simulation model was constructed to accurately represent real-world production processes, which was subsequently employed as the basis for DRL-driven optimization. Results indicate that this method effectively enhances the overall performance and adaptability of production systems, providing robust support for advancements in smart manufacturing and Industry 4.0. 21 refs.
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Key Words: *Complex Production Processes, Deep Reinforcement Learning, Simulation Model, Optimization Design, Smart Manufacturing*

Pages 704-715

A SIMULATION STUDY ON PLACEMENT OPTIMIZATION FOR USED CLOTHING RECYCLING BINS

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Abstract
This study addresses the inefficiencies in the placement and utilization of used clothing recycling bins in Connecticut. By incorporating user donation preferences, social network dynamics, and available recycling bin locations, a site selection optimization model is proposed. This model uses a network-based approach, linking users' current locations and their social activity nodes to various recycling bin options. By analysing user preferences and alternative bin locations, the study seeks to maximize user satisfaction through optimal bin placement. A decision-making framework is developed to identify the best recycling bin locations for clothing donations. To validate the model, simulation experiments were conducted using geographic data from Connecticut. The findings offer actionable solutions for improving the efficiency and user-centricity of recycling bin siting strategies. 24 refs.
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Key Words: *Used Clothing Recycling, Placement Optimisation, User Characteristics, Optimisation, Simulation*

Pages 716-727

OPTIMIZING HUMAN-MACHINE SYSTEMS IN AUTOMATED ENVIRONMENTS

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Abstract
With the rapid advancement of industrial automation technologies, human-machine collaboration systems have become critical for enhancing productivity and safety in highly automated environments. However, current human-machine collaboration systems still face numerous challenges in practical applications, especially in dynamic and complex work scenarios, ensuring safety and efficiency in the human-machine collaboration process lacks a systematic solution. To address this issue, this paper proposes a braking control method based on discrete-time model prediction and an adaptive human-machine safety distance prediction model using a multilayer perceptron (MLP) network. By modelling and predicting the system's dynamic data, this research aims to improve the efficiency and safety of human-machine collaboration, providing theoretical support and practical guidance for the design and management of automated systems. 23 refs.
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Key Words: *Highly Automated Environments, Human-Machine Collaboration, Discrete-Time Model, Multilayer Perceptron (MLP), Safety Distance Prediction, Braking Control*

Pages 728-739

COORDINATION OF PRODUCTION PLANNING IN MULTI-ECHELON SUPPLY CHAINS: A SIMULATION APPROACH

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Abstract
Driven by globalization and diverse market demands, modern multi-echelon supply chains face significant challenges. Effective coordination of resources and information flows between levels is crucial for improving supply chain efficiency and competitiveness. Traditional scheduling methods often fail to capture inter-level synergies and struggle with the dynamic changes and uncertainties in supply chains. To overcome these issues, a coordination strategy based on discrete event simulation was proposed. This strategy includes a multi-objective optimization model that focuses on production efficiency, inventory cost, and delivery time. Discrete event simulation models the production and scheduling processes, enhancing decision support for complex environments. This approach aims to boost the overall operational efficiency and flexibility of the supply chain, providing substantial theoretical and practical benefits. 17 refs.
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Key Words: *Multi-Echelon Supply Chain, Production Planning, Scheduling Optimisation, Discrete Event Simulation, Multi-Objective Optimisation*
