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EFFECT OF TOPOLOGICAL OPTIMISATION ON THE KINETIC PROPERTIES OF THE KINEMATIC CHAIN

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Abstract
The paper addresses the importance of topology and shape optimisation on improving the performance of a device operating in a mine industry. The process of increasing the stiffness and the value of the first eigenfrequency of the load-carrying structure will be demonstrated. In order to satisfy both objectives simultaneously, two initial optimisation domain models were introduced. The first was the most commonly used optimisation model with full material, while the second was a model with an initial gyroid lattice structure in the optimisation domain. The results obtained by the optimisation of the load-carrying structure were used to analyse the effect of stiffness and eigenfrequency on the four-bar mechanism path of the coupler point and the reduction of the value of the joint forces of the most loaded links. 24 refs.
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Key Words: *Topology Optimisation, Shape Optimisation, Eigenfrequency, Kinematic Chain*

Pages 17-28

THE SIMULATION MODEL OF WAREHOUSE SPACES APPLYING MATHEMATICAL-STATISTICAL METHODS

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Abstract
This article explores the use of cluster analysis in designing warehouse spaces. Drawing on theoretical insights from cluster analysis and an examination of the supply processes in selected industrial enterprises, it introduces an algorithm for applying hierarchical clustering methods to the design of storage systems across various industrial production environments. The proposed methodology is experimentally validated, demonstrating its practical application as a mathematical-statistical approach for designing warehouse spaces in companies. 27 refs.
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Key Words: *Mathematical-Statistical Methods, Modelling, Warehouse, Dendrogram*

Pages 29-40

SIMULATION OF ROBOTIC INSPECTIONS BASED ON SYSTEMATIC DATA ACQUISITION AND ANALYSIS

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Abstract
Autonomous robots are of utmost importance across various research fields and have numerous practical applications. They can be used in scenarios such as rescue operations, security, safety management, and interventions in hazardous or hostile environments, among others. A key application of these robots is overcoming obstacles in extreme conditions, especially when human intervention is either impossible or not permitted. This paper presents modelling and simulation results based on a mathematical tool developed through systematic data acquisition and analysis, ensuring the safe operation of a robot designed to assist its pilot. The proposed predictive model is built using data collected from the robot's sensors, which are stored in a dedicated database. This data includes information on position, velocity, and acceleration, as well as their handling and processing in the presence of obstacles. The paper also includes a case study, with results that can serve as a predictive model applicable to similar conditions. 35 refs.
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Key Words: *Modelling, Simulation, Mobile Robots, Systematic Data Analysis, Obstacle Detection*

Pages 41-52

SIMULATION OF ELECTRIC MULTIPLE UNITS WITH VIRTUAL CONTROL UNITS

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Abstract
To effectively improve the overdependence of traditional simulation platforms on physical equipment, this study proposes a simulation platform based on a virtual central control unit (CCU) and a traction control unit (TCU). First, a traction system model was established, analysed and implemented. Second, the functions of CCU and TCU were designed, the data communication between the virtual model and physical equipment were implemented. Lastly, the operating effects of the simulation platform under operating scenarios were explored through simulation experiments and compared with the data of real vehicles. Results show that the simulation platform based on the virtual CCU is consistent with the existing simulation platforms in operating effect, meeting the needs of interconnectivity experiments. The simulation model requires 377 s to accelerate from 0 to 350 km/h, and the speed loss in neutral-zone passing is 22.1 km/h at most at the speed of 350 km/h, which is approximate to the real data. The obtained conclusions are of realistic significance for establishing an interconnected simulation test platform specific to electric multiple units of different models. 22 refs.
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Key Words: *Traction Drive System Simulation, Central Control Unit Simulation, Simulation Platform Construction, Neutral-Zone Passing*

Pages 53-63

FUEL STRATIFICATION COMBUSTION CHAMBER ANALYSIS FOR FUTURE HYDROGEN COMBUSTION

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Abstract
Fuel stratification is one of the key technologies that helps to meet strict environmental standards as well as it increases efficiency of the internal combustion engines. Stratification of fuel is particularly useful at low and medium engine operational load where high engine power output is not required. To achieve long-term reliability in lean burn combustion, multiple technologies are currently under development. Creating fuel-rich zones inside the chamber, for example through fuel stratification, is the solution. As a result, a patented design, known as the "Combustion compartment with implementation of stratification and spark-controlled auto-ignition of the fuel mixture using compression", was created. The design was predicated on the idea that a stratified charge engine generates a leaner mixture in the combustion chamber as a whole and a richer mixture near the spark. A simulation analysis of the patented system verified its substantial contribution to reducing emissions. This technology is very important in development of hydrogen-powered combustion engines, where the goal is to optimize combustion process, to increase engine efficiency and to reduce engine emissions. 21 refs.
(Received in October 2024, accepted in January 2025. This paper was with the authors 2 weeks for 2 revisions.)

Key Words: *Fuel Stratification, Combustion Space, Piston, Simulation Analysis*

Pages 64-75

HEAVY METAL-CONTAMINATED SOIL REMEDIATION THROUGH EDEM BASED ON ROTARY TILLAGE

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Abstract
To address the technical challenge of the uneven distribution of passivator particles (more in the upper layer and less in the lower layer) during the chemical remediation of heavy metal-contaminated soil, this study proposed a method based on rotary tillage for mixing passivator particles with soil. Initially, the key structure of the rotary tiller was optimized, and the tillage process was numerically simulated using the Enhanced Discrete Element Method (EDEM). Taking the mixing uniformity of passivator particles and soil particles as the core evaluation metric, and under a fixed tillage depth of 25 cm, the travel speed of the rotary tiller and the blade roller speed were selected as key variables. Results demonstrate that when the travel speed of the rotary tiller is maintained at 2 km/h and the blade roller speed is set to 250 r/min, the mixing uniformity of passivator and soil particles reaches 82 % after secondary tillage, representing 61 % improvement compared to primary tillage. The proposed method provides a crucial evidence for the optimization of soil remediation processes, which has significant academic and practical implications. 31 refs.
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Key Words: *EDEM, Rotary Tillage, Passivator, Soil Remediation, Simulation*

Pages 76-86

A MODELLING APPROACH FOR ASSET DEGRADATION: ADVANCING DIGITAL TWIN IN MAINTENANCE

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Abstract
Recently, a considerable literature has grown up around the theme of maintenance applications in Industry 4.0. Optimizing complex maintenance systems in particular poses a challenge as modern manufacturing systems involve numerous dependencies and interactions. Simulation has shown success in modelling comparable problems in other fields. This study introduces a novel discrete event simulation method for modelling stochastic asset degradation, which facilitates seamless integration into digital twin frameworks for maintenance systems. Rather than modelling the mean time between failures or predicting the remaining useful life, generating accurate and live asset degradation profiles enables the development of a digital twin that optimizes maintenance strategies in real time. However, assuming the asset health index does not improve without maintenance interventions makes these findings less generalizable. We apply the proposed methodology to a maintenance problem in a published study. Further research might explore the effectiveness of integrating real time optimization. 29 refs.
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Key Words: *Simulation, Maintenance, Modelling, Stochastic, Degradation*

Pages 87-98

REFLOW PROCESS OPTIMIZATION OF TINNED COPPER STRIP BASED ON FSI-THERMAL SIMULATION

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Abstract
The reflow process of tinned copper (TC) strips is critical for meeting the high metal surface quality standards in electronic devices. A significant challenge is obtaining high-quality reflow-derived tinned copper (R-TC) through the remelting of the tin layer. The fluid–solid thermal (FSI-Thermal) coupling in this process is crucial for tin plating quality. This study proposes an effective method to address local yellowing on the R-TC surface by developing an FSI-Thermal model and optimizing the reflow process. At the feed rate of 0.1 m/s, heat flow of 925 K, and inlet velocity of 10 m/s, the force borne on the TC surface is even, and the minimum temperature approaches 532.4 K (> 505.05 K), accompanied by the thermal stress-induced deformation. However, the TC surface temperature is distributed unevenly in the external chamber. Reflow test is performed based on simulated parameters. Results show that due to the thickness difference of surface oxides, local yellowing takes place on the R-TC surface, and the optimized reflow process substantially reduces the nonuniformity of the tinned oxide layer and realizes the high-quality sedimentation of the clad layer. 28 refs.
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Key Words: *Reflow, Tinned Copper, Reflow-Derived Tinned Copper, Fluid-Solid Thermal, Process Optimization*

Pages 99-110

DEVELOPING ROUTES USING HYBRID SIMULATIONS: PUBLIC TRANSPORT VS. BIKE SHARING

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Abstract
This study compares implementing a bicycle-sharing system with the current bus transport system in Belo Horizonte, Brazil. We developed a hybrid simulation model, combining Agent-Based Modelling and Discrete Event Simulation, using AnyLogic software. The model's environment was constructed with Geographic Information System (GIS) tools integrated into the software, enabling the mapping of urban routes and facilitating agent decision-making. Based on the validated and statistically verified model, we created nine scenarios to compare travel times between bicycles and public transport. The scenarios considered key variables such as average speed, number of users, weather conditions, and infrastructure quality. The results showed that bicycles offer a more efficient alternative for the final leg of travel, significantly reducing travel times. This research highlights the potential benefits of bicycle-sharing systems and provides valuable insights for decision-making in urban transport infrastructure planning. 32 refs.
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Key Words: *Urban Mobility, Transport Infrastructure, Agent-Based Simulation, Discrete Event Simulation*

Pages 111-122

INTEGRATION OF SIMULATION AND HIERARCHICAL APPROACH TO SUPPORT LEAN IMPLEMENTATION

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Abstract
This study develops and implements a tool to support Lean practices through simulation integrated with a hierarchical approach using Moore-Hodgson algorithm and Genetic Algorithm (GA). The approach assesses the performance impact of Lean practices in a textile manufacturing system, focusing on material handling and setup time. Discrete Event Simulation (DES) is used to test scenarios, optimize decisions, and evaluate improvements. Integrated with hierarchical methods and GA, DES helps guide production scheduling, aiming to reduce waiting and setup times. Applied in a case study of a raffia packaging plant, the tool optimizes operational management decisions by introducing new equipment and scheduling strategies to improve material handling and setup processes. Several scenarios were tested, resulting in improved operational efficiency and higher output without affecting delivery timelines. 28 refs.
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Key Words: *Lean Manufacturing, Simulation, Hierarchical Approach, Moore-Hodgson, Genetic Algorithm*

Pages 123-134

A SIMULATION-BASED OPTIMIZATION APPROACH TO ENHANCE DRIVE SHAFT FATIGUE STRENGTH

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Abstract
This study presents a novel simulation-based optimization approach to enhance drive shaft fatigue strength using Bayesian-Kriging surrogate model. The methodology incorporates three key innovations: (1) a Python-based parametric model development using ABAQUS, (2) an entropy weight TOPSIS method for dimensional contribution analysis, and (3) a Bayesian Expected Improvement (BYEI) strategy for enhanced Kriging model performance. The proposed method significantly reduces computational cost while maintaining accuracy through intelligent sampling and model updating strategies. Validation using three test functions demonstrates superior convergence speed, stability, and accuracy compared to traditional methods. Application to drive shaft optimization achieved a 56.11 % improvement in fatigue life while maintaining structural constraints. Compared with the other two models, Bayesian-Kriging model has obvious advantages in prediction accuracy. The results demonstrate the method's effectiveness for complex mechanical component optimization, particularly in scenarios requiring balance between computational efficiency and accuracy. 13 refs.
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Key Words: *Entropy Weight TOPSIS, Kriging, Simulation, Optimization Design*

Pages 135-146

MANUFACTURING PROCESS BASED ON RECOGNITION RULES AND BAYESIAN NETWORKS

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Abstract
This study presents an optimization scheduling approach for automotive manufacturing processes using recognition rules and Bayesian networks (BN) to balance cost, time, and quality. The methodology includes a workflow model and a serial workflow scheduling algorithm, focusing on cost and quality within a set timeframe. The Bayesian Process Scheduling Optimization Algorithm (BPSOA) is evaluated against other algorithms, showing superior performance with an *MAE* of 0.1 and an *RMSE* of 1.2 after 20 iterations. Key results include process costs from 86,543 to 178,765 CNY, quality scores of 76.54 to 92.34, and handling times of 2.23 to 4.57 hours, with a resource utilization rate up to 95.43 % and failure rates between 1.23 % and 5.12 %. The study contributes to intelligent manufacturing by enhancing process adaptability and efficiency under uncertainty. 29 refs.
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Key Words: *Automotive Manufacturing Process Flow, Optimization Scheduling, Bayesian Network, Multi-Objective Optimization, Workflow Model*

Pages 147-158

SUPPLY CHAIN PRODUCTION PLANNING AND SCHEDULING COORDINATION USING DISCRETE EVENT SIMULATION

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Abstract
Effective coordination of multi-echelon supply chains is vital in dynamic markets, yet traditional methods fail to address inherent complexity and uncertainties. This study proposes a novel discrete event simulation (DES) and genetic algorithm (GA) integration to optimize production planning and scheduling. The DES model simulates real-world dynamics, including demand fluctuations and delays, while the GA optimizes critical decisions (production schedules, inventory levels) through iterative learning. A hierarchical framework combines mathematical supply chains modelling, DES-based scenario testing, and GA-driven decision refinement. Experimental results demonstrate significant improvements: 15–22 % cost reduction, 10–18 % shorter lead times, and 12–20 % higher service levels compared to conventional methods. This approach advances supply chain management by bridging dynamic simulation with metaheuristic optimization, offering enterprises a scalable tool for adaptive decision-making under uncertainty. The work underscores the value of integrating simulation and AI to tackle complex supply chain challenges. 21 refs.
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Key Words: *Multi-Level Supply Chain, Production Planning, Scheduling Coordination, Discrete Event Simulation, Genetic Algorithm*

Pages 159-170

VENTILATION SOLUTIONS SIMULATION FOR URBAN RESIDENTIAL AREAS

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Abstract
Rapid urbanization intensifies air quality and ventilation challenges in densely populated areas, impacting residents' health and comfort. While healthy ventilation systems regulate airflow, temperature, humidity, and pollutants, their design remains complex due to space constraints, dense structures, and climate variability. This study addresses two aspects: (1) evaluating ventilation effectiveness across diverse conditions using airflow analysis, and (2) proposing a multi-objective optimization framework integrating air quality, energy efficiency, and comfort metrics. Results show optimized strategies enhance environmental performance while maintaining energy savings and comfort. The research provides actionable insights for adaptive ventilation design and advances sustainable urban planning frameworks. By merging practical challenges with data-driven optimization, this work offers scalable solutions to improve living conditions in dense cities. 21 refs.
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Key Words: *Urban Densely Populated Residential Areas, Healthy Ventilation, Airflow Organization, Multi-Objective Optimization, Architectural Design*

Pages 171-182

RESILIENCE OF TECHNICIAN ALLOCATION IN MULTI-AGENT SIMULATIONS

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Abstract
As industrial and service systems become more complex, effectively scheduling technicians to boost system resilience is crucial. Traditional scheduling methods often prioritize efficiency but lack adaptability in dynamic environments, highlighting the need for multi-objective optimization. Multi-agent simulation offers a novel approach to enhance the resilience of technician allocation by simulating dynamic collaborations and task distributions more accurately. This method optimizes scheduling strategies and improves adaptability and emergency response capabilities in uncertain conditions. Current methods fall short in managing unexpected events and coordinating multiple tasks. To overcome these limitations, a new technician allocation model using a multi-agent simulation framework has been developed, integrating advanced scheduling optimization techniques to enhance resilience. This approach, supported by a multi-objective optimization algorithm, improves the efficiency, stability, and adaptability of technician scheduling, thereby strengthening system resilience. 18 refs.
(Received in October 2024, accepted in February 2025. This paper was with the author 2 months for 2 revisions.)

Key Words: *Technician Scheduling, Allocation Resilience, Multi-Agent Simulation, Scheduling Optimization, System Robustness, Multi-Objective Optimization*