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AUTONOMOUS ENTITIES: A HYBRID MODEL AND ITS EFFECTS

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Abstract
A good simulation model is one in which a real system is adequately represented. It is known that the level of accuracy of a simulation model is related to the complexity (scope and level of detail) that this model has. Given this, in the context of Modelling and Simulation (M&S), what are the effects when adding more detail to a simulation model? Are such effects the same when two different simulation approaches are combined? In order to answer these questions, this paper presents a method in which it is possible to (i) analyse the elements in a simulation model and (ii) analyse the nature of the connections among them. From the application of this method, the structure of three simulation models was represented by graphs. By analysing the graphs, the effects generated when adding a higher level of detail to the entities are perceptible. Such effects are more noticeable when comparing the simulation approaches. The use of Hybrid Simulation allows the creation of simpler and more robust connections. 25 refs.
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Key Words: *Complexity, iDAV Method, Model Development, Hybrid Simulation*

Pages 199-210

USING SIMULATION TO DETERMINE THE REORDER POINT UNDER UNCERTAINTY OF A RETAIL STORE

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Abstract
This study uses the discrete-event simulation approach to determine the reorder point of a retail store based on an acceptable service level under uncertainty in demand, lead time, and product damage. The proposed model is applied to A1–A12 products in a retail store under study where the owner requires a service level of at least 90 %. The model variables are both deterministic (i.e., order quantities, daily inventory cost per unit, purchase cost, and unit selling price) and probabilistic (i.e., client demand, lead time, and product damage). A simulation technique is used to describe the distribution of the probabilistic parameters and to produce them randomly. The profit and customer service simulation results determine the retail store's inventory policy. Since the retailer decided on the ROP based on the simulation results, it has an impact on 1) reducing the total daily inventory of A1–A10 by 23.0 %, which would increase storage space for the additional products A11 and A12 to their sales, 2) increasing total daily profit of A1–A10 by 2.9 %, and 3) reducing total annual product damage numbers of A1–A10 by 22.2 %. 35 refs.
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Key Words: *Discrete-Event Simulation, Inventory Management, Reorder Point Determination, Uncertain Demand, Uncertain Leadtime*

Pages 211-220

MODELLING AND SIMULATION PROCESS OF EXTENDED PETRI NETS WITH PNML AND MATLAB/SIMULINK

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Abstract
In this work, we introduce a modelling and simulation process based on Matlab/Simulink for Petri nets that considers inhibitor arcs and priorities of transitions, herein named eXtended Petri nets, for modelling deterministic complex systems. The presented process comprises the method for modelling the system, the functions for the import to Matlab of all the data structures that define a Petri net with inhibitory arcs and priorities in transitions, and the functions to perform the simulation of the Petri net behaviour as a Simulink block. We present an exploratory case study about Rate Monotonic Scheduling for tasks with harmonic periods to show the complete modelling and simulation process. First, the scheduling system is modelled with Renew editor and saved as a PNML file. Then, this file is read and transformed into a Matlab data type. The produced data structures are the inputs to the proposed Simulink block, which performs the dynamic of the eXtended Petri net. Finally, the outputs of the simulation help validate the logical and temporal correctness of the scheduler model used as a case study. The concluding remarks section provides a link for downloading and testing the simulation process. 35 refs.
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Key Words: *Discrete Event Systems, Petri Nets, Modelling, Simulation, Matlab, Simulink*

Pages 221-232

SIMULATION OF INTENSIVE CARE BED CAPACITY BASED ON MIXTURE DISTRIBUTION

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Abstract
Intensive care units (ICUs) are one of the most important elements of hospitals. ICUs play a central role in the healthcare system and in providing care for critical patients, so capacity planning in these units is critical. A shortage of ICU beds and staff can have irreparable consequences, including patient death. As a result, hospital managers make efforts to determine the appropriate number of beds. However, the interarrival time (*IAT*) of patients to ICUs and the service time (*ST*) of patients in ICUs are stochastic in nature. Consequently, capacity planning is a dynamic operations management problem. For this research, we used mixture distributions to approximate the interarrival time (*IAT*) and service time (*ST*) of patients in ICUs. We then incorporated these distributions into a simulation model that helps us to determine the number of beds needed to accommodate all incoming patients without any waiting in the queue. The results show that the mixture distributions provide a better estimate than empirical statistical distributions. 35 refs.
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Key Words: *Length of Stay, Interarrival Times, Mixture Distribution, Bed Capacity, Intensive Care Unit*

Pages 233-244

CAVITATION EROSION MODELLING – COMPARISON OF DIFFERENT DRIVING PRESSURE APPROACHES

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Abstract
In this paper we compared different driving pressure approaches to calculate the cavitation potential energy from a source, which is transferred to a surface. The first approach used the reference pressure, the second approach used the pressure calculated at each timestep with no averaging, the third approach used the averaged pressure values from all timesteps included in one shedding cycle, and the last approach used pressure values from the steady state simulations results. The results show that for all formulations the averaged pressure values and steady state pressure values give similar results in terms of mean potential power distribution on the hydrofoil surface as in absolute values. The reference pressure approach gave similar results for the derivative and divergence formulation while for the source term the mean potential power distribution on the hydrofoil surface differs and the maximums were near the leading edge. The approach where we used no pressure averaging gave adequate results in terms of mean potential power distribution but differs from other approaches in absolute values which were considerably lower for all potential power formulations. 35 refs.
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Key Words: *Cavitation, Erosion Potential, Driving Pressure, Numerical Simulation*

Pages 245-254

BALANCING SUPPLIER CHANNELS: AN INCENTIVE MODEL FOR ONLINE AND OFFLINE SALES CHANNELS

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Abstract
In this paper, we first propose online and offline channel incentive models (CIM) with consideration of the consumers' rational choices to solve and simulate the channel incentive problem (CIP) for supplier. We investigate whether the increase in demand along with channel incentive activities is enough to compensate for the decrease in the supplier's marginal revenue and retailers could benefit from the increase in market demand when retail channel information reference factor satisfies a certain threshold value. Our results show that decision preference of channel members is influenced by the reference factor and marginal revenue. Furthermore, the numerical achievements indicate that there is a unique optimal channel incentive coefficient related to the rational choices in benchmark channel incentive model (BCIM) for omnichannel. Both suppliers and retailers would benefit from the increased orders. Channel efficiency is improved from 72 % to 79 %. And the supplier profit function is a concave function of supplier's input in the offline channel incentive in the offline CIM. 32 refs.
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Key Words: *Channel Incentive, Channel Conflict Level, Bounded Rationality, Reference Prices*

Pages 255-266

IMPROVING ELECTRIC MOTOR ASSEMBLY USING ONE PIECE FLOW, ERGONOMICS, AND CELLULAR LAYOUT

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Abstract
Manufacturing organizations continuously strive to improve their performance to survive in the competitive market. This study aims to improve the performance of a production line by utilizing a discrete event simulation model for manufacturing the rotor part of an electric motor. While previous studies have focused primarily on technical factors, this paper addresses the shortage of research on the impact of physical ergonomics on production line performance. By integrating human movements into other improvement methods, this study proposes four strategies: one-piece flow, elimination of unnecessary human motions, their integration, and switching to a Cellular Manufacturing System (CMS). The results demonstrate that the adoption of the one-piece flow among some workstations increases productivity and utilization of resources by about 21 % and 9 %, respectively. However, the elimination of the unnecessary motions resulted in insignificant improvement due machine's automatic nature. Lastly, the study found that converting the production line into a CMS resulted in a significant increase in productivity (32 %), maximum resource utilization (17 %), and a decrease in work in process (40 %). 34 refs.
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Key Words: *Assembly Lines, Simulation, Single-Piece Flow, Human Factors, Cellular Manufacturing System, Work in Process*

Pages 267-278

MODELLING ANALYSIS OF COUPLING DEFORMATION BETWEEN STRIP STEEL AND ROLLER SYSTEM

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Abstract
To reveal the characteristics of strip shape and roll change during the rolling process of six-high cold rolling mill (SHCRM), a three-dimensional finite element model of SHCRM was established by computer-aided design. The coupling deformation under various working conditions such as friction coefficient and bending roller force was analysed. Results show that the width of the plate, the amount of pressure, the friction coefficient, the rolling force, and the bending force are the key affecting factors of the deformation of the roller system, the shape of the load roll seam and the contact stress and strain. The deformation of the roll system, the shape change of the load roller seam and the stress and strain of the contact region are revealed. The obtained conclusions provide a reference for the development of rolling model of high cold rolling mill. 22 refs.
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Key Words: *Six-High Cold Rolling Mill, Bending Roller, Roll Shifting, Loaded Roller Gap, Flatness*

Pages 279-290

SIMULATION OF CORROSION IN THE RIVETED ZONE OF ALUMINIUM-BASED SKIN

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Abstract
In order to explore the local corrosion mechanism of the riveted zone of aluminium-based skins under coating pre-damage, COMSOL Multiphysics was utilized to simulate a physico-chemical model with the laboratory test results of electrochemical parameters as boundary conditions. The time-domain variation of electrochemical behaviour parameters was analysed, and the dynamic corrosion characteristics in the riveted zone were revealed. Results show that after coating damage, with the simulation time going on from 0 day to 30 days, erosive ions continuously invade, and the corrosion reaction is gradually aggravated in the riveted zone, leading to a growth trend of the electrolytic electrode potential. At 30 days, the thickness of electrode deposits increases by 0.16 μm, and the electrolytic potential distribution ranges from 0.025 V to 0.028 V. By setting the electrolytic ion concentration in the coating pre-damage zone reasonably, the corrosion mechanism and morphology of the riveted zone of aluminium-based skins under different electrolyte concentrations can be explored, which can save laboratory check and verification time as well as improve work efficiency. 21 refs.
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Key Words: *Aluminium-Based Skin, Corrosion, Coating Pre-Damage*

Pages 291-302

ANALYSIS OF THE DYNAMIC LOAD CHARACTERISTICS OF DOUBLE-TOP-BEAM SUPPORTS WITH GAPS

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Abstract
Double-top-beam support (DTBS) is an important protective device for backfilling mining. Frequent roof movements cause the DTBS to bear dynamic loads, making it prone to instability and damage. The gaps between the supporting parts exacerbate this condition. To solve this problem, we studied the dynamic characteristics of the DTBS with gaps under various impact loads. Firstly, the numerical model of the support was built. The connecting joints of the DTBS were defined with a gap clearance. Then, the attitude and load characteristics of the DTBS were analysed by applying biased, symmetrical, and torsional load to both top beams. The results indicate that the connecting joints at the top beam are more sensitive to the impact loads. When the impact loads appear at the front part, the load of the connecting bar joints increased. The gap size has a minimal effect on the lateral inclination of the DTBS. The biased loading condition plays a crucial role in the deviation of the top beam supporting attitude. Under the same loading condition, the inclination of the rear top beam is much higher than that of the front top beam, with a degree difference of approximately 130 minutes. 24 refs.
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Key Words: *Double-Top-Beam Support, Joint Gap Clearance, Attitude Variation, Dynamic Load*

Pages 303-314

OPTIMIZATION AND SIMULATION OF GARMENT PRODUCTION LINE BALANCE BASED ON IMPROVED GA

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Abstract
In order to solve the problem of low balance rate of garment production line and unbalanced work intensity of employees, an improved genetic algorithm was proposed to optimize the balance problem of blouse production line. The computer simulation technology was used to verify the effect of the optimization scheme. According to the optimal solution and simulation results, the balance rate of the blouse production line was increased from 70.5 % to 97.05 %, and the production cycle was shortened by 32.80 %. On the one hand, this study can provide research ideas for the balance of garment production lines and even other industry production lines. On the other hand, this research can be applied in actual production. First, the improved genetic algorithm can be used to generate the optimal layout plan. Secondly, through the simulation of the production line, the efficiency and cycle can be predicted. The production line will run stably and efficiently. This research shows the application potential of intelligent algorithm and computer simulation technology in solving the production line balance problem. 19 refs.
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Key Words: *Garment Production Line, Improved GA, Balance Optimization of Blouse Assembly Line, AnyLogic Simulation*

Pages 315-326

OPTIMIZATION OF A SIMULATED RECONFIGURABLE HYBRID FLOW ASSEMBLY SYSTEM

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Abstract
The existing research on hybrid flowshop scheduling (HFS) has typically neglected important factors such as workload balance and storage costs. Therefore, in this study, we simulate a reconfigurable hybrid flow assembly (RHFA) system, and propose five significant objective functions that consider the above factors, designed to attain a joint optimization of equipment composition and assembly sequence. To solve this multi-objective optimization problem, the multi-objective Harris hawks optimization (MOHHO) method is adopted to generate optimization solutions. Results demonstrate that MOHHO outperforms other alternatives in terms of generating more dominant solutions and achieving better evaluation results on several representative indicators, including mean ideal distance, maximum spread, and spacing metric. Given empirical evidence of a hybrid flow assembly workshop, the research outcomes hold significant implications for the optimization of assembly sequences and equipment layout. The findings presented herein can assist decision-makers in devising more informed and rational production plans, thereby enhancing production efficiency and reducing associated costs. 19 refs.
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Key Words: *Simulated RHFA System, Assembly Sequence, Equipment Composition, Multi-Objective Harris Hawks Optimization*

Pages 327-337

A SIMULATION STUDY ON SUPPLY CHAIN FINANCING STRATEGY OF MANUFACTURING FIRMS

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Abstract
This study considers a manufacturing supply chain comprising a single risk-neutral manufacturer and a single risk-averse retailer. Among them, the manufacturer can produce traditional or green products and has sufficient funds to produce traditional products but lacks green processing costs. When the manufacturer produces green products, it can solve its financial difficulties through bank loans or internal financing from the retailer. This study examines the manufacturing supply chain financing strategy under capital constraints and risk aversion and draws the following conclusions: the manufacturer's wholesale price is the largest and smallest under the bank loan financing and internal financing modes, respectively; the retailer's retail price is the largest and smallest under the bank loan financing and traditional product production modes, respectively. The green input levels between the two financing modes directly depend on the bank loan interest rate and risk aversion. The optimal decisions of the manufacturer and retailer are to sell green products and choose internal financing, while selling traditional products is the worst decision. 29 refs.
(Received in March 2023, accepted in April 2023. This paper was with the authors 1 week for 1 revision.)

Key Words: *Green Manufacturing, Manufacturing Supply Chain, Financing Strategy, Capital Constraints, Risk Aversion*

Pages 338-349

COLLABORATIVE MODELLING AND SIMULATION FOR MANUFACTURING COST ANALYSIS

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Abstract
Research on collaborative manufacturing process modelling and simulation is of great significance in improving production efficiency and product quality, reducing costs, promoting collaborative work, and supporting decision-making. However, current studies have not offered the optimal costs of node enterprises participating in collaborative manufacturing, and ignored the impact of demand uncertainty of suppliers, manufacturers and customers on costs and economic benefits. Therefore, this paper aimed to study the collaborative manufacturing process modelling and simulation of production cost and economic benefit accounting analysis. First, this paper summarized three cost types, conducted cost accounting for the collaborative manufacturing process, and analysed its economic benefits. Second, based on the basic timed automata (TA) model, this paper used a timed input/output automata with port labels (Lp-TIOA) for modelling test cases of the simulation system. Finally, the experimental results verified the effectiveness of the constructed simulation model. 26 refs.
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Key Words: *Production Cost, Economic Benefit, Accounting Analysis, Collaborative Manufacturing, Modelling and Simulation*

Pages 350-361

BLOCKCHAIN-DRIVEN OPTIMIZATION IN INTELLIGENT MANUFACTURING

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Abstract
Intelligent manufacturing automation is a future trend, and optimizing production resource control using blockchain technology is a meaningful research topic. Existing studies have limitations, such as varying PSCO-PC models and insufficient flexibility in simulation models. This paper proposes a novel blockchain-based PSCO-PC strategy for intelligent manufacturing. It details the PSCO-PC model, improving the matching rationality and applicability of simulation system functions. The adaptive difficulty concept is introduced to address data throughput and consensus mechanism issues. Calculation steps for solving the optimal package revenue of PSCO matching records are provided. Experimental results confirm the effectiveness of the proposed simulation model and PSCO-PC strategy. 32 refs.
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Key Words: *Blockchain Technology, Intelligent Manufacturing, Production-Service Combinatorial Optimization and Production Control (PSCO-PC), Simulation*