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DYNAMIC SIMULATION TOOL FOR PLANNING AND OPTIMISATION OF SUPPLY PROCESS

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Abstract
The article deals with the use of dynamic simulation tools for planning and optimising changes in the supply process carried out by an automated guided vehicle (AGV). The integration of new products and the overall increase of the production capacity of the assembly line in the automotive company are foreseen to overexpose some transport node. For problem-solving in practice was applied statistical-experimental research method. The article in its core deals with the designing and creating of a simulation model of AGV-transport processes using dynamic simulation, which is designed to check the patency of routes, the feasibility of processes and detect bottlenecks. Three proposals to reduce logistics downtime were verified. Based on the results of the simulation, one was selected to be applied. After applying the solution, the production line tact increased by 35 %. Based on the results of the experiments conducted on the current situation simulation model, it is important to propose improvements to the AGV's management and transportation systems. The output is a design with virtual verification of a new supply process without bottlenecks. 21 refs.
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Key Words: *Modelling and Simulation, Optimisation of the Supply Process, Automated Guided Vehicle, Automotive Industry*

Pages 453-464

IMPACTS OF CONNECTED AND AUTOMATED VEHICLES ON FREEWAY WITH INCREASED SPEED LIMIT

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Abstract
As a revolutionary technology, Connected and Automated Vehicles (CAVs) have great potential to reduce traffic collisions, increase transportation system performance, and improve environmental sustainability. This research aims to investigate the benefit or trade-off of CAVs on freeway capability, fuel consumption, and emission. To fulfil this goal, the open-source traffic simulation software, SUMO was used to model CAV fleets. This study conducted a sensitivity analysis on three variables, i.e., CAV penetration, CAV time headway, and freeway speed limit. As expected, the simulation results justified that the shorter the time headway is, the higher maximum flow can be achieved. Higher speed limit contributes to a faster free-flow speed and a more substantial road capacity. While at the same time, it weakens the stability of the flow. From the perspective of fuel economy and environment, a recommended optimal time headway must be found. 30 refs.
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Key Words: *CAV Penetration, Time Headway, Speed Limit, Freeway Capacity, Fuel Consumption, Emission*

Pages 465-476

SIMULATION OF MULTI-CRANE SINGLE AND DUAL CYCLING STRATEGIES IN A CONTAINER TERMINAL

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Abstract
Dual cycling is an operational strategy which can improve the efficiency of a quay crane (QC) and the land side operations of container ports by loading and unloading containers in the same cycle. Most of the research on the dual cycling strategy has focused on the modelling of single QC operations. Multi-QC dual cycling reduces the operation time of a vessel involved in an operation. The aim of this study is to show how multi-QC single and dual cycling strategies can be modelled and analysed by simulation. Two simulation models are developed for a port container terminal to analyse the application results of single and dual cycling strategies used for vessel loading and unloading operations. Multi QC single cycling strategy is used in the first model while multi QC dual and single cycling strategy is used in the second model. The method is illustrated by a real-life case study. The findings of the simulation results show that the system performance can be improved by using the multi-QC dual cycling strategy. 15 refs.
(Received in February 2021, accepted in June 2021. This paper was with the authors 6 weeks for 1 revision.)

Key Words: *Terminal Operations, Quay Crane, Dual Cycling, Simulation*

Pages 477-488

A ROBUST METHOD FOR IDENTIFYING THE BEST AND WORST SUBSETS IN STOCHASTIC SIMULATION

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Abstract
Stochastic simulation is a useful tool for evaluating modern discrete-event dynamic systems; however, efficiency issues still exist in simulation experiments because many simulation replications are required to estimate the mean performance of a system configuration accurately. This paper proposes a robust method to identify the m best and n worst candidates from a finite set of configurations according to their mean performance in a high-noise environment. To select the best and worst subsets correctly within a limited simulation budget, the proposed method defines a metric to evaluate the statistical significance of each candidate's current simulation results. Then, it allocates small further replications iteratively based on the calculated metric so the results become significant evidence to verify the correct identification. Experimental results on benchmark problems demonstrate the superior efficiency of the proposed method compared to the existing methods in high-noise situations. The proposed method is beneficial to best-worst scaling problems, multiple-criteria decision-making problems, population-based search algorithms, etc. Furthermore, it allows practitioners to make final decisions by considering qualitative criteria neglected by simulation. 18 refs.
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Key Words: *Stochastic Simulation, Simulation Experiments, Best and Worst Subsets, Simulation Budget Allocation, Robustness*

Pages 489-500

A SIMULATION APPROACH FOR TRANSITION TO JIT PRODUCTION SYSTEM

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Abstract
Consumption is increasing day by day due to rapid developments in technology and increasing world population. Companies should review their production processes in order to keep up with the consumption rate and increase their competitiveness as well as profit margins. This research shows a case study of simulation application to improve solar panel manufacturing process. The aim is to achieve goals such as increasing system efficiency, reducing inventory and shortening delivery time. Efficient manufacturing process design may reduce work-in-process (WIP), waste, rework and faults, which may reduce the total number of products and yields an increase in the system cost. Inefficiency points were determined in the process based on the obtained observations of the manufacturing system. Various scenarios have been proposed to design such an efficient production system. According to the proposed scenarios, an increase in the utilization rates of machinery, personnel and the total number of final products has been achieved. 23 refs.
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Key Words: *Discrete Event Simulation (DES), Just-in-Time (JIT), Lean Manufacturing, Production Line Efficiency, Solar Panel Production*

Pages 501-512

IMPROVED EFFICIENCY OF MANUFACTURING LOGISTICS BY USING COMPUTER SIMULATION

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Abstract
The paper deals with the streamlining of production logistics by using the example of a specific construction production company – through design via ExtendSim computer simulation. The issue concerns researching procedures for the company's long-term sustainable competitiveness in the production of building components in a very competitive market. The research aims to use computer simulation as a means for the regular streamlining of production logistics in a specific manufacturing company, focusing on the production of building parts. The company in question produces building material, which takes place in two types of kilns: the first for drying products, the second for product firing. Yet, these operations represent a bottleneck in terms of production logistics. The final packaging of the daily production of construction products is approximately 280-320 pallets in 12 hours. Yet by adjusting the parameters of production logistics in individual parts of material flow, production can be boosted by 14.96 %. The given solution can be practically applied to modernise production, without additional cost, simply by changing work organisation and the production's bottleneck parameters. 23 refs.
(Received in May 2021, accepted in July 2021. This paper was with the authors 1 week for 1 revision.)

Key Words: *Efficiency, Logistics, Simulation, Design, ExtendSim, System*

Pages 513-524

EFFECT OF RADIAL CLEARANCE ON BALL BEARING'S DYNAMICS USING A 2-DOF MODEL

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Abstract
In the present work, a method for the analysis of short time intervals in ball bearings is proposed. We study the effect of the internal clearance on the dynamics of ball bearings using recurrence plots and the recurrence quantification approach. In the proposed method, we focused on the analysis of dynamic states generated from the 2-DOF mathematical model, to which a function changing the damping coefficient in the clearance domain was added. Chosen recurrence methods showed the specific dynamic responses by different values of the radial clearance. The effect of self-consistency concerning the damping effect and vibration development is confirmed. The proposed method can be useful for the prediction of variable radial clearance in time by analysis of the acceleration response of ball bearing during its operation. 35 refs.
(Received in May 2021, accepted in July 2021. This paper was with the authors 1 week for 1 revision.)

Key Words: *Ball Bearings, Radial Internal Clearance, Nonlinear Dynamics, Recurrence Plots, Recurrence Quantification Analysis*

Pages 525-535

INFLUENCE OF THE INCLINED PIPE SECTION ON THE PERFORMANCE OF A WATERJET PROPULSION DEVICE

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Abstract
A waterjet propulsion device is a new type of propulsion system whose inlet passage affects the performance of the entire device. To study the influence of the inlet passage with an inclined pipe section (IPS) on the hydrodynamic characteristics of the device, a numerical method was used to determine the influences of IPS's length L and rotational speed n on hydraulic performance and thrust characteristics. Results show that the head H of the device increases significantly from 3.29 m to 12.64 m as rotational speed n increases (700 r/min < n < 1300 r/min). Moreover, efficiency η increases from 61.37 % to 64.75 % and then decreases to 60.99 %. L exerts minimal effect on η, which reaches its maximum value when $n = 900$ r/min and $L = 1.12\,D$ (D is the outlet diameter of the inlet passage). Device thrust F gradually increases with an increase in n, and the increase rate continues to rise, while L has minimal effect on F. The results provide a reference for optimizing the inlet passage of a waterjet propulsion device. 26 refs.
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Key Words: *Waterjet Propulsion Device, Length of Inlet Passage, Rotational Speed, Hydrodynamic*

Pages 536-546

SUPPORT OF SCHEDULING OF MULTIPRODUCT PIPELINE SYSTEMS USING SIMULATION IN WITNESS

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Abstract
In this paper, we describe the efficient discrete modelling of multiproduct pipeline systems in Witness simulation software environment. Our simulation model consists of 6 blocks called System structure, Pumping modes, Pumping schedule, Pumping execution, Collecting of outputs and Simulation run control and is supported by MS Excel. Algorithm for the assignment of a scheduled pumping requirement to execution is proposed too. Our model is innovative in that pipelines for the transport of products, tanks for storing products in warehouses as well as the products themselves and their material flow are represented neither by the continuous physical elements (Pipes, Tanks, Fluids) nor their discrete equivalent (Conveyors, Buffers, Parts) but by the logical elements called Variables. Avoiding physical elements enables efficient modelling of bidirectional flow of products in a pipeline and furthermore leads to the high speed of a simulation run. Based on the outputs of simulation of a simple pipeline system we show how our model can be used to support scheduling in complex multiple sources, multiple destinations pipeline networks. 32 refs.
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Key Words: *Logistics, Scheduling, Pipeline System, Discrete-Event Simulation, Witness*

Pages 547-558

STABILITY OF A FACE GUARD IN A LARGE MINING HEIGHT WORKING FACE

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Abstract
Hydraulic support is an important piece of equipment in a fully mechanized mining face, and it is used to prevent the roof from falling out of control and protect the workers underground. The stability of hydraulic support under different conditions is related to security and must be taken seriously. To analyse the mechanical response of hydraulic support, a rigid–flexible coupling numerical analysis model of the face guard mechanism, which is part of hydraulic support, is established based on the multi-body dynamics software ADAMS. The equivalent spring is used to replace the face sprag ram to analyse the influence of the structural types of face guards on the stability of a coal wall under various coupling conditions with a coal wall. The support characteristics of the face guard mechanism are also explored. Results show that the errors of the contact characteristics of the face guard mechanism between the theoretical and numerical calculations are less than 3 %. Compared with the split face guard, the integral face guard exhibits greater flexibility and more favourable stability under different coupling states. The study provides a reference for optimizing face guards with hydraulic support. 21 refs.
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Key Words: *Coal Wall Spalling, Hydraulic Support, Face Guard Mechanism, Coupling Relationship*

Pages 559-570

DESIGN AND KEY PROCESS SIMULATION OF A NEW TYPE OF PIPE BENDING UNIT

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Abstract
The pipe bending mechanism was analysed and a new unit was designed to solve problems of low efficiency and high incidence of defects in large-diameter products. Subsequently, the workflow of the unit was formed, and the finite element model of elbow formation was established. A pipe with D = 60.3 mm and t = 3.05 mm was used as an example to simulate the effects of key parameters on the forming quality and determine the optimization parameters. Results show that as clearance increases within in a small range, the flowability of the pipe and the forming quality of the elbow improve. As the surface friction and push-bending speed increase, the quality gradually deteriorates and more defects appear. The mandrel helps enhance the forming quality of the elbow. The wall is thinner in the extrados near the push head but thicker in the intrados near the push head. The obtained conclusions provide a basis for establishing a quantitative relationship between the process parameters of bending machines and forming quality and the comprehensive optimization of the bending machine process. 24 refs.
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Key Words: *New-Type Pipe Bending Unit, Finite Element Model, Clearance, Surface Friction, Push-Bending Speed*

Pages 571-582

PRODUCTION MANAGEMENT OF HYBRID FLOW SHOP BASED ON GENETIC ALGORITHM

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Abstract
The production management of hybrid flow shop (HFS) has a great practical significance. Proper production management can improve the machine utilization and shorten the makespan in a complex production control environment. However, the relevant research has not paid enough attention to realistic constraints like multi-period control, and job transport time. To solve the problem, this paper explores the production management of HFS based on improved genetic algorithm (GA). Specifically, several assumptions were proposed for the multi-objective optimization problem of HFS production management, and new constraints like multi-period control, and job transport time were introduced to the problem. Then, the authors established a multi-objective optimization model for HFS production management, and improved the traditional GA to solve the model more rapidly and accurately. The proposed model and algorithm were proved effective through experiments. 14 refs.
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Key Words: *Genetic Algorithm (GA), Hybrid Flow Shop (HFS), Production Management*

Pages 583-594

SIMULATION ANALYSIS OF ROBOTIC MOBILE FULFILMENT SYSTEM BASED ON CELLULAR AUTOMATA

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Abstract
This paper analyses the picking performance of a robotic mobile fulfilment system (RMFS) and proposes a Simulation Framework of RMFS based on cellular automata (SFRMFSCA). Many previous RMFS simulation platforms stipulate all aisles to be set up in a fixed directional road network for one-way lines. The warehouse robot had to travel an unnecessarily long distance to perform tasks. We relax the one-way constraint on aisles and cross aisles in the warehouse and allocate the right of way among the warehouse aisles and cross-aisles intersection by referring the idea of traffic light and traffic flow control to the RMFS warehouse scenario. To improve the efficiency of RMFS order picking, this paper designs a comprehensive strategy combining adaptive traffic light update rule, deadlock detection and recovery algorithm, and traffic control to improve the traffic flow of the system. A series of numerical experiments show that the comprehensive strategy designed in this paper can effectively improve the order picking efficiency of RMFS and reduce the probability of scale deadlock. These results and strategies provide a useful reference for designers who initially set up the RMFS warehouse. 26 refs.
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Key Words: *Robotic Mobile Fulfilment System (RMFS), Warehouse Performance, Cellular Automaton Model, Simulation*

Pages 595-605

CFD SIMULATION ON HYDRODYNAMICS OF UNDERWATER VEHICLE WITH DUCTED PROPELLERS

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Abstract
Underwater vehicles are currently the most effective equipment for exploring ocean mineral resources, whose movement performance been paid more attention by many scholars. According to the underwater vehicle integrating with 19A/Ka4-55 type ducted propellers, this paper researches the hydrodynamic characteristics of the overall vehicle in water under different movement states by leveraging CFD method. Combining structural grids and non-structural grids, an underwater vehicle model with 19A/Ka4-55 ducted propellers is constructed according to the designed propeller arrangement. A specific test rig is set up to verify the accuracy and effectiveness of the CFD method. Finally, the hydrodynamic performance of the integral underwater vehicle carrying the ducted propeller under different working conditions is further analysed. The result suggests that the vehicle still has sufficient propulsion at the inflow velocity of 1 m/s in the forward direction. Under ascending condition, the maximum running speed of the operating vehicle is around 0.5 m/s. It also has shown the feasibility and necessity of hydrodynamic performance analysis. 24 refs.
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Key Words: *Underwater Vehicle, Ducted Propeller, Hydrodynamics Characteristics, CFD Simulation, Test Verification*

Pages 606-617

DIGITAL PRODUCTION CONTROL OF MANUFACTURING WORKSHOP BASED ON INTERNET OF THINGS

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Abstract
The penetration of Internet of things (IoT) in the production control of modern manufacturing workshop has prompted advanced intelligent and information-based manufacturing techniques. However, the relevant studies fail to collect and process the various manufacturing parameters in real time, and rarely consider the coordination between manufacturing workshop and machines. This paper explores the digital production control of manufacturing workshop based on the IoT. Firstly, block diagrams were drawn for IoT-based digital workshop production control and software design of digital production control system, and a multi-objective optimization model was established for IoT-based digital workshop production control, aiming to optimize delivery time, machine load, and machine utilization rate. Next, the order sequencing method was detailed for digital workshop production control. Finally, machine competency and collaborative efficiency were introduced as optimization objectives, and an IoT-based strategy was designed for collaborative allocation of sub-tasks for workshop production. Our method was proved effective through experiments. 22 refs.
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Key Words: *Internet of Things (IoT), Digital Production, Production Control, Manufacturing Workshop*