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MULTI-RESPONSE OPTIMISATION OF TURNING PROCESS PARAMETERS WITH GRA AND TOPSIS METHODS

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Abstract
The research deals with the optimisation of CNC turning process parameters to determine the optimal parametric combination that provides the minimal surface roughness (R_a) and maximal material removal rate. The experiment was conducted by the CNC turning process of S355J2 carbon steel. Data from the Taguchi design of experiments were the subject of analysis with Grey Relational Analysis (GRA) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In the present study, three process parameters, such as cutting speed, feed rate and depth of cut, were chosen for the experimentation. It was found that 250 m/min cutting speed, 0.10 mm/rev feed rate and 1.8 mm depth of cut presented the optimal parametric combination by both used multi-objective optimisation methods. Analysis of variance (ANOVA) at a 95 % confidence level was used to determine the most significant parameters. Finally, the accuracy of GRA and TOPSIS results were validated by confirmation experiments. 23 refs.
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Key Words: *Turning, Cutting Parameters, Optimisation, Grey Relational Analysis, TOPSIS*

Pages 559-570

MINIMIZING TOTAL PRODUCTION COST IN A HYBRID FLOW SHOP: A SIMULATION-OPTIMIZATION APPROACH

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Abstract
To ensure the competitiveness of manufacturing companies in the market, batching and batch scheduling are among the most important tasks. This paper presents a simulation-optimization approach that combines the discrete event simulation (DES) and the genetic algorithm (GA) to solve the batching and batch scheduling problem in a hybrid flow shop (HFS). HFS is widely used for the production of medium and large quantities of different technologically complex products. Based on a real-world manufacturing company, the HFS simulation model was developed using the Tecnomatix Plant Simulation software package. By analysing the influencing factors that represent production costs, a new formulation of the total cost of production was proposed. The purpose of this case study was to ensure timely delivery and minimize production costs by integrating simulation and optimization tools. This research considers sequence-dependent setup times, and availability of manufacturing and transportation equipment. The results of this research showed that the proposed simulation-optimization approach can be applied to solve the problem in many industrial case studies. 29 refs.
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Key Words: *Hybrid Flow Shop, Batching, Batch Scheduling, Production Cost, Discrete Event Simulation, Genetic Algorithm*

Pages 571-582

SIMULATION PROJECT FOR LOGISTICS OF BRAZILIAN SOYBEAN EXPORTATION

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Abstract
Decision-making in complex logistics systems involves high risks and associated impacts. A way to forecast the impacts of these decisions is through the use of systems simulation projects, where the systematic impacts of the parameters can be visualized. This study presents a project based on Discrete-Event Simulation (DES) that analyses Brazilian soybean export logistics from producing regions to main international customers. The strategic analysis of a global logistics system using DES is a particularity of this study. At the conception stage, the conceptual modelling was made using IDEF-SIM (Integrated Definition Methods – Simulation) method, which allowed a better abstraction of reality and more accurate model implementation. The experimental analysis took place through the construction of 39 scenarios with specific characteristics that verified system behaviours through proposed changes. The analyses and decisions are based on costs. The simulations indicated the necessity for: a) an integrated management between the systems agents; b) the development of internal transportation infrastructure, especially railways and waterways, to increase competitiveness of Brazilian soybeans in the international market. 21 refs.
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Key Words: *Simulation Project, Discrete-Event Simulation, Conceptual Modelling, Logistics, Soybean*

Pages 583-594

SIMULATION OF TEMPERATURE EVOLUTION OF CORK COMPOSITES DURING MOULDING PROCESS

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Abstract
Cork-based composites result from a combination of cork granules with different materials – like thermosets or thermoplastics – and its manufacture involves a thermal process. In order to simulate the manufacturing process, of these types of composites, a new methodology was applied. A material composed of cork and a thermoplastic served as a case study. A model for the prediction of a cork composite mixture properties and a simulation methodology were developed for studying the variation of temperature during the moulding process of cork composites. Density, thermal conductivity, and specific heat were determined based on the formulation of the composite and the properties of cork and the agglutinant agent. Numerical analyses were carried out and compared to experimental results obtained from a moulding process. Three types of simulations, according to the model of the chosen properties were developed using finite volume and finite element methods. In general, the results from the simulations were in good agreement with experimental results. 17 refs.
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Key Words: *Temperature, Cork Composites, Thermal Conductivity, Specific Heat, Density*

Pages 595-606

EFFECT OF VIBRATION ON SURFACE ROUGHNESS IN FINISH TURNING: SIMULATION STUDY

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Abstract
This paper presents the results of simulation analyses carried out to investigate the effect of adding controlled vibration of varying amplitudes and frequencies onto simulated workpiece profiles on surface roughness. The surface profiles were generated using the nose edge image of a real cutting tool insert at various stages of wear. The invariant moment sub-pixel edge detection method was used to extract the precise tool nose profile. The extracted nose profile was duplicated 20 times to generate the simulated workpiece profile. Vibration signals in the form of sine waves of amplitudes 0 to 50 % of the peak-to-valley height of the original workpiece profile and various frequencies were added to the simulated profile. Noise signals emanating from real machining were also added to the original profile to investigate their effect on roughness. The simulation study has shown that average roughness may increase continuously or fluctuate randomly depending on the magnitude of vibration added to the vibration-free workpiece profile. In the absence of vibration, the surface roughness of the workpiece decreases due to flattening effect of the tool nose during early stages of tool wear. 26 refs.
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Key Words: *Surface Roughness, Vibration, Simulation, Tool Wear*

Pages 607-618

ANALYSIS OF ROCK DYNAMIC STRESSES DURING THE DRILLING BY POLYCRYSTALLINE DIAMOND COMPACT BITS

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Abstract
In view of shortening the development period of polycrystalline diamond compact (PDC) bits, the finite element method was adopted to simulate the dynamic stress of rocks. By employing drilling related theories, the three dynamic principal stresses of rock were analysed and the dynamic rock-breaking criterion was established. Second, the drilling model of PDC core bit was constructed, and the stress was simulated and calculated. Finally, laboratory tests were carried out to verify the simulation results. The analytical results demonstrate that the two obvious stages in the rock-breaking process are the initial rock-breaking stage and the normal one. The dynamic rock-breaking stress in the normal drilling stage varies from 66.3 to 99.6 MPa, which is lower than 278.4 MPa in the initial rock-breaking stage. During spud drilling, the axial force and the tangential force are 1.85 and 1.60 kN, respectively. During normal drilling, the axial force ranges from 0.2 to 0.9 kN, and the tangential force from 0.15 to 0.6 kN. The load of normal drilling is lower than the spudding load, and the bit is more likely to be damaged during spudding. The bit is normally worn during normal drilling. 23 refs.
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Key Words: *PDC Bit, Rock Breaking, Dynamic Stress, Simulation Calculation, ANSYS/LS-DYNA, Wear Resistance*

Pages 619-630

SIMULATOR WITH EMBEDDED INTELLIGENCE FOCUSED ON THE DESIGN PROCESS

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Abstract
Mechatronic design practice was conceived as various successive steps involving expertise. However, employers expect recently graduated engineers to start working with the shortest training period. This paper reports a research that developed a simulation tool that introduces modifications and additions to the regular methods of dynamic simulation, integrating in it several of the steps of the systematic mechanic design. The design tool encompasses for each element or object of the simulator seven new features that in an intelligent way gives the student a little design practical expertise. The connection between elements follows the method by wires and the window of assembly includes a workspace where the 3D depiction of all elements is seen and animated according to the values of the variables. The concept was prototyped and now all technological components are available to start the development of a product. This concept, due to the volume of information that it uses, instead of being attractive to cover all fields of knowledge is valuable to adapt to specific fields as academic courses. Potential users evaluated the attractiveness of the concept through a work section, giving good indicators. 27 refs.
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Key Words: *Mechatronic Simulation, Engineering Training, Dynamic Systems, Conceptual Design, 3D Animation, Methodical Design*

Pages 631-642

AERODYNAMIC CHARACTERISTICS OF THE X-TAIL STABILIZER IN A HYBRID UNMANNED AIRCRAFT

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Abstract
The paper presents the results of the numerical calculation of the flow around hybrid unmanned aircraft with X-tail stabilizers. This aircraft design is an innovative combination of a gyroplane and a multi-rotor. The aerodynamic properties of the two-part X-tail stabilizer were analysed. The aerodynamic forces and moments on this element of the aircraft were specified from the CFD simulation calculations for the defined values of the angle of attack and the slip angle, and particular attention was paid to the differences between the upper and lower parts of the stabilizer. In addition, the turbulence kinetic energy on the surface of the vortex core region were analysed to conduct a qualitative and quantitative analysis of energy losses in flow, resulting from local separation and vortices. The obtained results allow for conducting further aerodynamic comparative analyses on other types of stabilizers. 36 refs.
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Key Words: *Aerodynamic Characteristics, Autogyro, Hybrid Aircraft, Multicopter, Stabilizer*

Pages 643-654

COUPLING PROPERTIES OF CHAIN DRIVE SYSTEM UNDER VARIOUS AND ECCENTRIC LOADS

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Abstract
The chain drive system is a core subsystem of heavy scraper conveyors. During operation, violent oscillations of fluctuating loads on the chain and uneven loads at the two chain sides are observed, thus intensifying chain wear and even causing chain breakage. The dynamic properties of a chain drive system under various load and eccentric load were discussed thoroughly by combining dynamic and discrete element coupling analyses to improve the reliability of the scraper conveyor. Based on the discrete element method and multibody dynamic theory, a coupling analysis model of a scraper conveyor was constructed, and a simulation analysis on coal conveying process under various load and eccentric load was carried out. Simulation results demonstrate that the transverse vibration of the chain is positively related to coal conveying quantity, whereas longitudinal vibration is negatively correlated to coal conveying quantity. The transverse vibration rate under full loads is 513.62 % higher than that under idle condition, while the longitudinal vibration rate is 53.44 % lower. The effects of coals on transverse vibration and longitudinal vibration of a chain ring are opposite. 23 refs.
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Key Words: *Scraper Conveyor, Dynamic Properties, Various Load, Eccentric Load, Coupling Analysis*

Pages 655-666

SIMULATION OF PNEUMATIC SYSTEMS USING AUTOMATION STUDIO™ SOFTWARE PLATFORM

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Abstract
Nowadays, more and more industrial applications use pneumatic systems instead of hydraulic, electrical or mixed systems. This article presents the applicability of pneumatic engines for compressed air vehicles (CAV) from the perspective of their simulation on the Automation Studio software platform. It is desired to use the mechanical work produced by only pneumatic cylinders taken over by a mechanical system that transforms the linear motion into a rotational one, this helping to propel the CAV. A feature of this engine is the limited quantity of compressed air at disposal (a reservoir). Also, the most efficient operation of the pneumatic cylinders is studied to achieve the operation with low consumption of compressed air, thus leading to increased performances. The current simulation was run without the use of specific electric/electronic equipment (PLC /PACs). Therefore, the pneumatic devices had assured the command and control of the system. 22 refs.
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Key Words: *Pneumatics, Simulation, Pneumatic Engine, Mechatronics, Automation Studio*

Pages 667-677

IDENTIFICATION OF CUTTING CHATTER THROUGH DEEP LEARNING AND CLASSIFICATION

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Abstract
The traditional analytical method has difficulty in accurately modelling cutting chatter. This paper constructs the vibration datasets of different chatter states and establishes a machine learning (ML) model for chatter identification, treating physical vibration signal as the input. Specifically, the cutting vibration signal was converted into the time-frequency spectrum, which was then classified by a self-designed deep residual convolutional neural network (DR-CNN). After that, the cutting vibration signal was broken down into chatter bands through variational mode decomposition (VMD). The information entropies of the chatter bands were calculated as cutting chatter features. Next, support vector machine (SVM) was introduced to classify the extracted features and used to create an online cutting chatter identification algorithm. The proposed method achieved a much higher mean identification accuracy (92.57 %) than the traditional identification method. 26 refs.
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Key Words: *Cutting Chatter, Chatter Identification, Deep Residual Convolutional Neural Network (DR-CNN), Support Vector Machine (SVM), Variational Mode Decomposition (VMD)*

Pages 678-688

MULTI-OBJECTIVE MASTER PRODUCTION SCHEDULE FOR BALANCED PRODUCTION OF MANUFACTURERS

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Abstract
Focusing on the balanced use of production capacity in the formulation of master production schedule (MPS), this paper sets up a single-product, multi-stage, multi-objective MPS model based on balanced production. Whereas the model aims to achieve multiple objectives through nonlinear integer programming, a genetic algorithm based on automatic transformation (AT-GA) was designed to solve the model. Specifically, the chromosomes were encoded as integers to satisfy the model constraints; the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was adopted to handle the four nonlinear objectives of the model, thereby obtaining the fitness function; the fuzzy logic control (FLC) was introduced to automatically adjust the crossover and mutation parameters, and balance the global and local search abilities of the GA, enhancing the computing power of the algorithm. The experimental results show that the AT-GA can effectively solve the multi-objective MPS optimization problem under balanced production. 25 refs.
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Key Words: *Manufacturer, Master Production Schedule (MPS), Balanced Production, Multiple Objectives*

Pages 689-700

STRUCTURAL PARAMETERS OPTIMIZATION FOR A PROPORTIONAL SOLENOID

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Abstract
This paper presents an optimization method for the structural parameters of a proportional solenoid. The 3D finite element method simulation model for performance analyse of proportional solenoid was validated by force-displacement characteristic experiment. Parameter sensitivity analysis results showed that the displacement of the armature, the length of the armature, the radius of the armature, the width of the first half of the sleeve and the angle of the magnetic-isolated ring have significant effects on the electromagnetic force. Key structural parameters were optimized according to the simulation results. Experiments results showed the average electromagnetic force was increased by 20.1 % and the effective stroke was extended to 2.1 mm. 18 refs.
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Key Words: *Optimization, Proportional Solenoid, Force-Displacement Characteristic, Parameter Sensitivity Analysis*

Pages 701-712

SOLVING MULTI-ROBOT PICKING PROBLEM IN WAREHOUSES: A SIMULATION APPROACH

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Abstract
This paper focuses on the order batching problem, aiming at this order batching problem of an e-commerce unmanned warehouse multi-robot picking system, considering the complexity and uncertainty of the system. In this paper establishes a two-stage model with the objective function of maximizing the sum of the average similarity of each picking station and balancing the picking station picking times, and uses a dynamic clustering algorithm to solve the model. The simulation results show that a two-stage order batching model that considers the order similarity and the picking time balance can be established, which can reduce the number of shelves effectively and improve the picking efficiency of warehouse multi-robot system. 22 refs.
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Key Words: *Multi-Robot, Picking System, Warehouses, Two-Stage Order Batch Model; Dynamic Clustering Algorithm*

Pages 713-724

COOPERATIVE AUTOMATIC CONTROL FOR THE CANOPY POSTURE OF A FOUR-LEG HYDRAULIC SUPPORT

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Abstract
The contact state between the canopy and roof of a hydraulic support considerably influences the bearing capacity and stability of the support. To ensure a secure contact between the canopy and roof in the setting stage, this paper proposes a cooperative double closed-loop automatic control technique for the canopy posture, with MATLAB used to simulate the canopy posture under different roof conditions. First, a cooperative double closed-loop automatic control model was established. Second, the method to determine the target value of the canopy posture and constraint conditions of the rising process were formulated. Finally, by simulating the canopy posture under three roof conditions, the response curve of the canopy posture and the leg length were obtained. The results show that the front and rear legs can rise through either synchronous or asynchronous coordination, and the canopy posture can approach the target value. The presented findings can guide the realization of the automatic control of the canopy posture of hydraulic support. 22 refs.
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Key Words: *Four-Leg Hydraulic Support, Canopy Posture, Cooperative Control, Double Closed-Loop*