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Pages 5-16

THE EFFICIENCY INCREASE IN A TWO-STAGE TRANSPORT SYSTEM

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Abstract
In this study, the author investigates a two-stage transport system, which consists of several warehouses and demand points grouped into clusters. The study aims to identify the combination of shipping and delivery strategies, which implementation in two-stage transport system increase efficiency. To achieve this objective, the author models the costs associated with the application of those strategies in different transport solutions, proposes a framework useful for efficiency evaluation and its practical application. During a case study, the author investigates those transport solutions and specifies the most economically attractive ones allowing to achieve costs reduction for products supply to each cluster. According to the case study analysis, approximately 47 % of costs could be minimised in the transport system by applying the transportation solution, which includes the combination of store order shipping and direct store delivery strategies. The scientific novelty of this research is the application of the proposed framework for efficiency examination in the two-stage transport system. 20 refs.
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Key Words: *Transport System, Two-Stage, Shipping Strategy, Delivery Strategy, Costs Metrics*

Pages 17-28

SIMULATION STUDY OF IMPACT OF CAPACITY RESERVATION THRESHOLD ON ORDER FULFILMENT

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Abstract
Given the high prices of machine tools, customers often engage in careful deliberation before placing any orders for machines. The number and size of orders may suddenly change when the demand unexpectedly increases or plummets. This paper proposes the concept of "reservation threshold", which refers to mitigating possible crowding-out by applying advanced capacity for handling potential orders. This threshold also serves as an order entrance control to reduce the number of non-confirmed orders. A simulation model is used to explore the impact of various threshold values on production system profitability. Data abstracted from a representative company are used as a case study. Scenarios for three reservation strategies are examined for negotiation probability distributions. Through numerical experiments, the significance of an appropriate reservation threshold is demonstrated for normal capacity scenarios; the reservation strategy outperforms the no-reservation strategy under conditions of normal and insufficient capacity while the module reservation strategy is the best of the three reservation strategies. 18 refs.
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Key Words: *Capacity Planning, Potential Order, Reservation Threshold, Reservation Strategy, Simulation, Machine Tool Industry, Assembly Plant*

Pages 29-39

MRP SYSTEMS CONSIDERING FUZZY CAPACITY, LEAD TIMES AND INVENTORY AVAILABILITY

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Abstract
This article aims to propose a fuzzy model for closed-loop material requirement planning (MRP) systems considering uncertain parameters like production capacity, on-hand inventory and lead times. For this, a deterministic closed-loop MRP model is proposed, and then fuzzy coefficients in the constraints of the model are used to establish the fuzzy MRP model, which depends on the degrees of satisfaction (λ) of the decision-maker. Data from a production plan of a company dedicated to the manufacture of electrical transformers are employed to verify the proposed fuzzy MRP model, minimizing inventory holding costs, production setup costs, and extra capacity costs. The results show the fuzzy model performs better than the deterministic model, especially for low λ values, providing better performance in terms of the total cost, total inventory, service level, and computational efficiency. 31 refs.
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Key Words: *MRP, Fuzzy Logic, Lead Time, Inventory, Production Capacity*

Pages 40-51

TOOL STIFFNESS CALCULATION IN ROLL FORMING

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Abstract
In roll forming a metal sheet is incrementally bent at room temperature through numerous pairs of opposing forming rolls. The shafts equipped with rolls represent the most compliant assemblies in the whole roll forming mill. The shafts of one forming pass have to be aligned in the right position, relative to each other and the next as well as the prior forming pass, to avoid defects and to ensure profile dimensions which fulfil the geometric requirements. The forming forces vary greatly, depending on the roll set geometry, settings and stiffness of the individual forming passes. These forming forces lead to deflections of the shafts equipped with rolls, which need to be compensated. In this paper, a finite element model with hexahedron elements of the shafts equipped with rolls is developed, in order to determine its load-deflection behaviour. The accuracy of the model is validated with the aid of experimental data. The provided model shows high accuracy compared to the experimental data and no systematic error over the tested load range is observed. Additionally, the nonlinear stiffness behaviour is investigated in detail to understand the occurring nonlinear effects. 20 refs.
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Key Words: *Roll Forming, Tool Deflection, Stiffness, Deflection Behaviour, Finite Element Method (FEM)*

Pages 52-63

IMPACT OF PROPORTIONAL VALVES' DIFFERENCES TO ENSURE UNIFORM MOTION OF HYDRAULIC MOTORS

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Abstract
Ensuring uniform motion of hydraulic actuators is one of the most demanding tasks in the field of Hydraulic Drive Technology. Various, more or less demanding and precise, mechanical-hydraulic or electro-hydraulic solutions are used depending on the accuracy requirements of uniform motion. In addition to more precise uniform motion, the electro-hydraulic solutions also enable compensation and elimination of many inequalities.

The paper deals with the issue of ensuring quality uniform motion of hydraulic rotary actuators. To ensure high rotation accuracy, proportional valves are used as cost-effective, continuously operating electrohydraulic valves. At the forefront of the discussion is the influence of different valve characteristics on the uniform rotation, with differences arising from faults in valve manufacturing, valve assembly, or due to different valve degradation. Based on a detailed mathematical model of the system and simulations based on real measured different characteristics of the valves used, the effects of these differences are shown and control methods to eliminate them. 26 refs.
(Received in September 2020, accepted in January 2021. This paper was with the authors 1 month for 1 revision.)

Key Words: *Uniform Motion, Hydraulic Motor, Proportional Valve, Simulation*

Pages 64-75

SELECTION OF THE MOST SUITABLE MATERIAL HANDLING SYSTEM IN PRODUCTION

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Abstract
When building a new company or optimising an existing one, material handling (MH) is often forgotten. Therefore, the paper presents a decision tree, on the basis of which it is possible to select the most suitable MH system by simulation depending on the selected production parameters. Such a simulation can greatly facilitate the selection of the most suitable MH system which will ensure minimal time consumption and still acceptable costs.

To perform the simulation, a generalised production system model for 5 different MH systems was created in the FlexSim software, with which 32 different scenarios could be simulated depending on the selected production parameters, tested in a production facility of injection moulded components for the automotive industry. The data obtained from the simulations were then used to analyse the influence of the selected parameters on possible MH systems. For all potential scenarios, the solutions of which are acceptable for MH, a cost-benefit analysis was performed. Based on the analysis, a difference of 75 % between the most and least favourable scenarios was established. 20 refs.
(Received in October 2020, accepted in January 2021. This paper was with the authors 2 weeks for 2 revisions.)

Key Words: *Production, Material Handling Systems, Simulation, Optimisation, Cost-Benefit Analysis*

Pages 76-86

PERFORMANCE DIFFERENCES OF ELECTRICAL SUBMERSIBLE PUMP UNDER VARIABLE SPEED SCHEMES

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Abstract
Frequent shifts of electrical submersible pump (ESP) often lead to system vibration and noise, thereby reducing its operational stability. Three different speed change schemes were investigated to improve the stability of its variable speed process. The operational stability of ESP under different variable speed schemes was analysed. The transient numerical calculations of different variable speed schemes were conducted on ANSYS CFX to obtain the head fluctuation law. The stability of ESP with different head fluctuation laws was analysed, and the accuracy of numerical calculation was verified through tests. Result show that a high similarity is found between the head change curves and speed change curves with all methods. The head stability in uniform acceleration variable speed process and quadratic acceleration process with negative quadratic coefficient is high. The extreme value of head variation rate with the two variable speed processes is small, which is convenient for the stability of the variable speed operation of ESP. The research results serve as guide for improving the stability of the variable speed process of ESP. 32 refs.
(Received in October 2020, accepted in January 2021. This paper was with the authors 2 months for 1 revision.)

Key Words: *Electrical Submersible Pump, Variable Speed Regulation, Transient Calculation, Numerical Simulation*

Pages 87-98

SIMULATION AND EXPERIMENTAL STUDY ON HYBRID BIT WITH DIFFERENT CUTTERS

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Abstract
Rate of penetration (ROP) and wear resistance are important evaluation indexes for the performance of bits. This study proposed a novel bit design method using diamond impregnated block (DIB) and polycrystalline diamond compact (PDC) cutter by simulation experiment analysis to enhance the *ROP* and service life of PDC bits in hard formation. A DIB material suitable for hard formation was determined by the simulation experiment. A DIB-PDC hybrid bit rock-breaking test model was established by analysing the rock breaking mechanism of DIB-PDC elements. Results demonstrate that the *ROP* and wear rate of DIB materials are directly proportional to diamond particle size. The *ROP* of PDC bit is negatively correlated with wear height. The *ROP* of PDC bit is proportional to weight-on-bit (*WOB*). The *ROP* of DIB bits is relatively stable despite the linear correlation with *WOB*. The *ROP* of DIB-PDC bits is 1.99 m/h, which is higher than that of DIB and PDC bits. The result is verified by drilling simulation. The findings provide a good reference for designing personalized PDC bits suitable for special stratum. 24 refs.
(Received in October 2020, accepted in December 2020. This paper was with the authors 1 month for 1 revision.)

Key Words: *PDC, DIB, Rate of Penetration, Experiment, Simulation*

Pages 99-110

COMPREHENSIVE ANALYSIS OF COLD FORMED TUBE IN DRAWING PROCESS USING SIMULATION

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Abstract
Presented paper is focused on comparison of three types of steel for production of tubes with shaped internal surface for applications in energy producing industry. Simulations were performed in Deform-3D software with usage of finite elements method. Steels 20MnCr5, C10 and 34CrNiMo6 were selected for simulations. Obtained results are showing deformation, stress, strain and temperature during cold drawing of tubes with shaped internal surface and also resulting comparison of three tested materials depending on the course of load during the forming process. As a conclusion of the presented research is comparison of presented three steels according to the simulation results. Presented paper has potential to increase knowledge base in the area of forming tubes with shaped internal surface. Obtained results can contribute to a proper selection of tool material, coatings and process set up for forming process of tubes with shaped internal surface. 32 refs.
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Key Words: *Deform-3D, Mandrel, Cold Formed Tube, Drawing Process*

Pages 111-122

INFLUENCE OF DRUM CUTTING HEIGHT ON SHEARER CUTTING UNIT VIBRATION BY CO-SIMULATION METHOD

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Abstract
The shearer consists of the cutting department for coal cutting, the transmission system for power transmission and the hydraulic system for height adjustment. The cutting department determines the service life and work efficiency of the mining machine in application. To study the vibration of the cutting department when the drum works at different heights, the hydromechatronical co-simulation model of the cutting department of the mining machine was established. Using the simulation model and input signal, the vibration of the motor gear, sun gear, and cutting unit arm was simulated when the shearer drum worked at different heights, and the cause of the vibration was analysed in detail in the study. Simulation results demonstrate that a more evident vibration occurs at the measurement positions on the ranging arm when the piston moves by 0.44 m. Moreover, the hydraulic cylinder, sun gear and motor gear also easily suffer vibrations with different levels and more attention should be paid on those components during shearer design process. 25 refs.
(Received in October 2020, accepted in February 2021. This paper was with the authors 2 months for 2 revisions.)

Key Words: *Shearer, Cutting Department, Vibration Analysis, Hydromechatronical Co-Simulation Method, Coal Cutting*

Pages 123-133

INITIAL POPULATION INFLUENCE ON HYPERVOLUME CONVERGENCE OF NSGA-III

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Abstract
A common method for solving multi-objective optimization problems are evolutionary algorithms (EA), which are utilizing an iterative population-based approach and do not need prior information about the problem to be solved. These algorithms require a variety of control parameters, e. g. the three evolutionary operators (selection, crossover and mutation), a termination criterion and the population size, which are subject of many studies. In contrast to these a less considered factor is the initialization of the first population. This paper analyses the influence of different initialization methods besides the classic sampling with a pseudo-random number generator on the convergence behaviour of the algorithm NSGA-III.

It can be shown that different sampling methods affect the convergence behaviour significantly, whereby some methods increase while others decrease the convergence speed. The results also show a strong dependency and interaction between the initialization method and the optimization problem. 36 refs.
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Key Words: *Evolutionary Algorithm, Multi-Objective Optimization, NSGA-III, Sampling, Initial Population*

Pages 134-145

SIMULATION TESTING OF THE E-KANBAN TO INCREASE THE EFFICIENCY OF LOGISTICS PROCESSES

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Abstract
Combining lean techniques with software and digital tools currently creates a high potential to be more efficient, faster, and better. The reason is that the Lean tools are more standardized, more transparent than others and are limited to the necessary work. The case study aimed to create a model of the current state, testing the productivity and efficiency of production and logistics flows and then design optimization options using software support. The analysis resulted in the design and testing of e-Kanban in terms of business practice to increase the efficiency of logistics processes using selected elements of modeling and simulation. The design consisted in the implementation of a selected Lean tool e-Kanban, its testing and optimal setup using the simulation software Tecnomatix Plant Simulation. The created simulation model can be used in connection with the solution of process digitization in the researched company. 18 refs.
(Received in November 2020, accepted in February 2021. This paper was with the authors 1 week for 1 revision.)

Key Words: *Logistics, Lean Tools, Simulation, E-Kanban*

Pages 146-157

MODELLING OF MICRO-TURNING PROCESS BASED ON CONSTANT CUTTING FORCE

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Abstract
In this research, an evaluation of the external transverse micro-turning with conventional cutting inserts was performed with a constant cutting force in a dry environment. During machining, the number of revolutions, machining time and cutting forces was varied. Before and after machining, the diameter of the workpiece, circularity and the roughness of the machined surface was measured. The obtained results indicate that with increasing number of revolutions, time and cutting force, the cutting depth increases. The results show that this type of machining can achieve very small cutting depths and reduce circularity deviation and roughness of the machined surface. Based on the experimental results, the modelling of the artificial neural network (ANN) was performed which reliably predicted the change in diameter, cylindricity, and roughness after micro-turning operation, with a mean percentage error smaller than 3 %. It can be concluded that the application of ANN is adequate during the machining process with the constant cutting force, since the output parameters can be predicted with small error, while also reducing effort and costs. 26 refs.
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Key Words: *Micro-Turning, Constant Cutting Force, Artificial Neural Network, Cutting Quality*

Pages 158-169

PRODUCTION MANAGEMENT AND CONTROL BASED ON ANT COLONY OPTIMIZATION AND NEURAL NETWORK

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Abstract
The neural network (NN) has an advantage in handling the massive real-time monitoring data on discrete manufacturing. Therefore, this paper proposes a production management and control method for discrete manufacturing job-shops based on ant colony optimization (ACO). Firstly, the production management and control problem for discrete manufacturing job-shops was described through the functional analysis on the management and control system, followed by establishing the corresponding mathematical model. After that, the ACO was improved to solve the static multi-objective production management and control problem. Then, the authors set up an NN-based production management and control model for dynamic discrete manufacturing job-shop, and detailed the way to select and transform the judgement result on production state and to set up the training set. Finally, the effectiveness of our algorithm was verified through experiments. 23 refs.
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Key Words: *Ant Colony Optimization (ACO), Neural Network (NN), Discrete Manufacturing, Job-Shop Production Management and Control*

Pages 170-180

INFLUENCE OF FIT CLEARANCE ON THE STABILITY OF "THREE OIL FILM-ROTOR" STRUCTURE

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Abstract
During the rotation, the stability of the shaft changes with the fit clearance between the bearing and the journal. Taking the "three oil film-rotor" structure as the object, this paper systematically explores the variation in oil film pressure, oil film thickness, and shaft axis orbit, when the shaft is subject to transient impact load and oil film cavitation, based on the Reynolds equation under three-dimensional (3D) conditions. The results show that: The intermediate oil film of the "three oil film-rotor" structure had the greatest impact on the carrying capacity of the system; the most significant variation in oil film thickness was observed, when the pressure on the intermediate oil film reached the peak; the fit clearance between the bearing and the journal suppressed the surface pressure on oil film, and intensified the deformation of oil film. The research findings lay the theoretical basis for how the fit clearance of the lubrication system affects system stability. 17 refs.
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Key Words: *"Three Oil Film-Rotor" Structure, Fit Clearance, Oil Film Pressure, Oil Film Thickness, Axis Orbit*

Pages 181-191

AMOS-BASED RISK FORECAST OF MANUFACTURING SUPPLY CHAIN

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Abstract
Manufacturing supply chain is vulnerable to various risks, because of its complex network structure, as well as the strong sensitivity of manufacturing to the dynamic market changes. Therefore, the management of supply chain risks has become the focus of manufacturers. To help Chinese enterprises reduce or eliminate supply chain risks, this paper puts forward several hypotheses and a risk forecast model for manufacturing through theoretical analysis. By the Amos method, the hypotheses were tested through path analysis with empirical data. Finally, an artificial neural network (ANN) was adopted to verify the effectiveness of the proposed Amos model. The study provides the reference for preventing supply chain risks and promoting the healthy development of manufacturing enterprises. 33 refs.
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Key Words: *Manufacturing Supply Chain, Risk Forecast, Modelling, Amos, Artificial Neural Network (ANN)*

Pages 192-200

E-COMMERCE WORKSHOP SCHEDULING BASED ON DEEP LEARNING AND GENETIC ALGORITHM

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Abstract
With the gradual rise of customized manufacturing, the connection between e-commerce and intelligence manufacturing system have been deepened, highlighting the importance of intelligent scheduling to both intelligent manufacturing and e-commerce. The key to intelligence manufacturing lies in workshop scheduling. This paper optimizes the genetic algorithm (GA) with deep learning neural network (DLNN) and applies the optimized GA to realize intelligent workshop scheduling. Firstly, the production methods of e-commerce products were analysed, as well as the features of workshop scheduling problem (WSP). On this basis, the authors established a mathematical model of the WSP. Considering the actual needs of the workshop, an integrated scheduling algorithm was designed combining DLNN and GA. The algorithm improves the GA with a DLNN called long short-term memory network (LSTM) and constructs the fitness function in a novel manner. Simulation results show that our algorithm can avoid the local optimal trap that plagues the original GA, and better the global search performance. 22 refs.
(Received in December 2020, accepted in January 2021. This paper was with the authors 1 month for 1 revision.)

Key Words: *Workshop Scheduling, Genetic Algorithm (GA), Deep Learning Neural Network (DLNN), E-Commerce, Long Short-Term Memory Network (LSTM)*

Pages 201-211

AN IMPROVED GENETIC ALGORITHM FOR RESOURCE-CONSTRAINED FLEXIBLE JOB-SHOP SCHEDULING

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Abstract
Flexible job-shop scheduling could effectively lower the costs of manpower and materials. However, there is little report on the scheduling algorithm or optimization model for the optimization of production resources. This paper proposes a resource-constrained flexible job-shop scheduling algorithm based on an improved genetic algorithm. Firstly, an optimization model was established for resource-constrained FJSP, together with the objective functions about resources and time, as well as constraints. Next, the multi-objective genetic algorithm (MOGA) was combined with the whale optimization algorithm (WOA) into a combinatory method to solve the proposed model for resource-constrained FJSP. Experimental results show that the combination enhances the adaptivity of crossover and mutation probabilities, and improves the local search ability, presenting an effective solution to the FJSP. 27 refs.
(Received in December 2020, accepted in February 2021. This paper was with the authors 1 month for 1 revision.)

Key Words: *Multi-Objective Genetic Algorithm (MOGA), Resource Constraints, Flexible Job-Shop*