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A COMPARATIVE STUDY OF SIMULATION SOFTWARE FOR MODELLING METAL CASTING PROCESSES

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Abstract
Simulation based casting is used in modern metal casting industries to a great extent. A number of software are available for casting simulations which allow methods engineers to model and verify a casting design to maximize yield and minimize defects. However, selection of casting simulation software is critical and necessitates acquiring the knowledge of commercially available software. A comparison amongst the selected casting simulation software has been done in this study. In total, eight software products are selected with a mix of both high end and low end casting simulation packages. The software tools are compared in terms of casting processes simulated, add-on modules (if any), solution methods used, defects prediction, typical clients/users, and advanced simulation capabilities. The results of this study provide a guide for casting industry personnel to select a casting simulation software based on their requirements. It is concluded that need-based selection of casting simulation software is a must to ensure high benefit-cost ratio of simulation based casting. 26 refs.
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Key Words: *Casting Simulation Software, Comparison, Casting Processes, Solution Methods, Casting Defects*

Pages 210-219

HARDNESS MODELLING OF DEFORMED CW106C ALLOY BY A GENETIC PROGRAMMING

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Abstract
In the paper an evolutionary algorithm method for Brinell hardness modelling of cold deformed copper alloy is presented. Genetic programming method, described in the paper, is very powerful modelling method in the field of evolutionary algorithms. During our investigation, CW106C alloy was cold drawn on drawing bench and the impact of drawing parameters on the change of hardness of deformed alloy was determined. One part of experimental results was used as training data for genetic programming process with the main goal to obtain accurate and suitable models for hardness prediction in deformed alloy. The adequacy of genetically developed models was checked by a testing data. For a comparison a standard linear regression method for modelling is also presented in the paper. These models can be used not only to predict the material hardness but also to search for optimal process parameters for desired hardness of the formed material. 26 refs.
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Key Words: *Cold Forming, Hardness, Alloy, Evolutionary Algorithms, Genetic Programming, Modelling*

Pages 220-230

SIMULATION STUDY OF INDUCTION HEATING OF MULTI-METALLIC INJECTION MOULDS

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Abstract
This paper presents a concept and a simulation study into induction heating of multi-metallic injection moulds. This novel technology involves heating only selected cavity walls which are critical areas in forming thin-walled parts. Such regions are often places, where defects occur. In order eliminate the defects, it requires increasing the temperature of selected critical forming walls within a single cavity. In this work, simplified models of forming inserts of different shapes were created. Walls intended for induction heating were selected and separated. Forming cavities were defined as paramagnetic materials, whereas, heated walls were made of ferromagnetic steel 1.2343. Induction coil was placed 1 - 5 mm away from the wall. As a current source 10 kW induction generator EFD Minac 6 was used. The current frequency was 25 kHz. The obtained results show that it is possible, without a significant cycle time growth, to dynamically increase the temperature of selected walls by applying selective induction heating technology. 27 refs.
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Key Words: *Injection Moulding, Induction Heating, Selective Heating, Multi-metallic Mould*

Pages 231-244

A SIMULATION OF ORDER RESONANCE PHENOMENON IN A SUPPLY CHAIN TRIGGERED BY REINFORCING LOOP

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Abstract
A supply chain as a system has many subsystems. The subsystems include retailers, wholesalers, etc. Croson and Donohue say that the Bullwhip effect (order resonance phenomenon) can be caused by decision makers, not by exogenous variable changes. The purpose of this study is to show the process of collapsing the supply chain by interaction between subsystems, each of which has a balance loop with delay and a reinforcement loop under the oligopolistic competition. For this purpose we made a system dynamics simulation model assuming the supply chain with a wholesaler and two retailers. We give this model a single stimulus, check the activation and the dominance of each loop, and observe how it affects the entire system. The results showed that a single minor stimulus could ignite and therefore distract the whole system. In this process, delay and reinforcing loop has a key role. This study also showed that the oligopolistic competitive supply chain can cause the resonance in order flow. 30 refs.
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Key Words: *Supply Chain, Resonance Phenomenon, Oligopolistic Competition, System Dynamics, Reinforcing Loop, Balancing Loop*

Pages 245-256

ANALYSIS OF ASPHALT PAVEMENT MECHANICAL BEHAVIOUR BY USING A TIRE-PAVEMENT COUPLING MODEL

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Abstract
The tire operation condition in highway transportation exerts a significant influence on pavement mechanical behaviour. However, in-depth analysis of pavement mechanical behaviour under complicated tire operation conditions is limited. This study employed the finite element method to analyse the influence of truck tires on pavements in expressway freight transportation. A tire-pavement coupling model was established, and a simulation analysis was conducted for pavement stress under different parameters. Results indicate that the σ_1 of the upper layer is significantly affected by the horizontal contact stress between the tire and pavement. The horizontal contact stress should therefore be fully considered when conducting a refined mechanical analysis of pavement surface layers. Tresca stress is mainly concentrated in the pavement surface layer and the upper base, and the high Tresca stress in the two layers is related to unstable rutting and top-down cracking. Moderate tire load and pneumatic tire pressure effectively improve the operation status of the pavement. On the contrary, excessive tire load or pneumatic tire pressure increases the road deterioration, and should be forbidden in expressway transportation. With the established tire-pavement coupling model, this study revealed the influence of tire operation condition on pavement mechanical behaviour. The conclusions obtained in this study provide a reference for pavement design and highway transportation management. 22 refs.
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Key Words: *Tire-Pavement Coupling Model, Tire Force, Pavement Mechanical Response*

Pages 257-270

A SIMULATION OPTIMISATION TOOL AND ITS PRODUCTION/INVENTORY CONTROL APPLICATION

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Abstract
JaamSim is a prominent, discrete-event simulator with an established and fast growing community of users. To the authors' knowledge, no simulation optimisation package was available for JaamSim up to now. For the purposes of this research, we developed the open-source software JSOptimizer that can be used to optimise simulation models of complex engineering systems built with JaamSim. The proposed tool utilises the jMetal framework, a well-known and validated library of meta-heuristic optimisation algorithms. The contribution of this article is twofold. First, we present the most important aspects of the proposed software JSOptimizer. Secondly, we examine a novel, multi-objective problem pertaining to a stochastic manufacturing system which involves production control and job routing decisions. Several instances of the optimisation problem are solved and the resulting local non-dominated sets are compared under various performance metrics by utilizing the functionalities of JSOptimizer. This investigation also serves as a proof of concept for the proposed software's applicability. 21 refs.
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Key Words: *JaamSim Discrete-Event Simulator, Simulation Optimisation Tool, Open Source Software, Multi-Objective Optimisation Algorithms, Just-In-Time Manufacturing, Pull-Type Production Control*

Pages 271-283

OPTIMIZATION OF CAVITATING FLOW CHARACTERISTICS ON RBSS OF WATERJET PUMPS

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Abstract
Cavitation, as a key factor that influences safe and stable system operations, has been a scientific research challenge in the field of hydraulic machineries. Waterjet pumps are typical hydraulic machineries in which cavitation is generated near rotor blades suction surface (RBSS), and their geometric structures are the main factors that influence cavitation flow. To optimize the cavitation flow of the pumps, the flow laws near the RBSS and generation mechanisms of cavitation should be defined. This study used the shear stress transport (SST k-ω) turbulence model based on the Zwart-Gerber-Belamri cavitation model combining with the experimental method to implement a comparative analysis of the unsteady flow fields near the RBSS under different operating states, in which two blades optimization schemes were proposed. Numerical simulation results demonstrate that the calculation errors are within permissible engineering error range. In the original blade scheme, the unsteady phenomena occur with axial turbulence intensity, shearing stress, and pressure fluctuation near the RBSS at blade inlet-edge. The changes of the unsteady phenomena are acute under different operating states, and the cavitation is enlarged in the unsteady regions. After optimization, the two blades structures effectively optimize the unsteady flow near the RBSS and improve the hydraulic performance and cavitation performance of the pumps. Conclusions obtained in the study have important implications to optimize the cavitation of axial-flow hydraulic machineries. 20 refs.
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Key Words: *Waterjet Pump, Cavitation, Unsteady Flow, Performance Optimization*

Pages 284-294

TWO-MACHINE ROBOTIC CELL SEQUENCING UNDER DIFFERENT UNCERTAINTIES

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Abstract
Currently, robotic manufacturing cells entail complex decisions concerning sequencing issues due to uncertainty which arises in different parameters such as time to failure, time to repair and cycle times that can be effectively supported by computer simulation models. The paper is focused on part sequencing of a two-machine robotic cell in a flow shop which produces different parts. The process is supported by a single gripper robot to load/unload products and also in displacement within the system. This study considers machine failures and repair such that S_2 cycle time and total production cost should be minimized. In this study, simulation facilitated input part sequence and also data envelopment analysis method is applied to trace the optimum sequence for satisfying the objective functions. Results through some numerical examples showed some simulation advantages specially to model many uncertainties and what if analysis. 35 refs.
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Key Words: *Robotic Manufacturing Cell, Sequencing, Breakdowns, Multiple Part Type Production, Simulation, Data Envelopment Analysis*

Pages 295-307

PRODUCT MIX OPTIMIZATION BASED ON MONTE CARLO SIMULATION: A CASE STUDY

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Abstract
Simulations are widely used in manufacturing system design, production planning and decision making. The aim of this paper is to present the possibility of using Monte Carlo simulations in the production plan optimizing and in the project risk management. Optimization is accomplished through two different approaches which principles and results are mutually compared. According to the first approach, production optimization is performed via a deterministic model using the Generalized Reduced Gradient algorithm. The second approach is based on the stochastic model. The optimized production plan is submitted to risk analysis. Two approaches are demonstrated in order to reduce the rate of risk. The first way is modifying the production plan to increase the forecast reliability; the second approach is limiting the uncertainty of key variables. The detailed methodology enables implementing presented approaches in solving various optimization tasks. 26 refs.
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Key Words: *Investment Efficiency, Production Planning, Computer Simulation, Optimisation*

Pages 308-317

A TWO-STEP SMOOTHING ALGORITHM FOR AN AUTOMATED PRODUCT DEVELOPMENT PROCESS

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Abstract
In this paper, we develop a smoothing algorithm that allows a subsequent production of components directly after topology optimisation. This is achieved by keeping features that are important for production, such as flat surfaces or straight edges.

The algorithm works in two steps. The first step is based on the marching cubes algorithm and is necessary to prepare the optimisation result for the second step. The optimisation result consists of a density distribution and needs to be transformed to a surface representation without further material or density information. The second step makes use of an implicit method for smoothing surfaces, the so-called implicit fairing.

The proposed two-step algorithm is exemplarily shown on two models. The results are compared to those received from a commercial solution to evaluate the quality of the algorithm. We show that the proposed algorithm allows a subsequent production directly after the optimisation and leads to results that are similarly good compared to those obtained by the commercial solution. 21 refs.
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Key Words: *Smoothing, Structural Optimisation, Automated Product Development, Marching Cubes, Implicit Fairing*

Pages 318-326

NUMERICAL SIMULATION AND OPTIMIZATION OF OIL JET LUBRICATION FOR ROTORCRAFT MESHING GEARS

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Abstract
Oil jet lubrication performance directly influences the operation, reliability and fatigue life of meshing gears working under high-speed and heavy-load conditions in the main reducer of rotorcraft. An oil-air two-phase mixture flow numerical simulation model for jet lubrication on the surface of a pair of meshing gears was established by the computational fluid dynamics (CFD) simulation code ANSYS/FLUENT. The effects of the spin flow caused by a high-speed rotating gear pair on the jet flow trajectory deviation were considered in the numerical simulation. The oil volume and oil pressure distribution characteristics of the meshing area were obtained and compared according to different nozzle position layouts, and the optimal nozzle position layout was determined to obtain a maximum oil volume and oil pressure. A gear-jet-lubrication experimental system was built in which the meshing surface temperatures were measured by an infrared thermometer; meanwhile, the jet flow trajectories were photographed by a high-speed camera. The experimental and numerical simulation results were mutually validated and proved the proposed optimal design scheme for the nozzle position layout. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Rotorcraft High-Speed Meshing Gear, Oil Jet Lubrication, Two-Phase Flow Numerical Simulation, Spin-Flow Effect, Optimal Nozzle Position Layout*

Pages 327-336

MECHANISM DESIGN AND MOTION PLANNING OF PARALLEL-CHAIN NONHOLONOMIC MANIPULATOR

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Abstract
Inspired by the nonholonomic theory, this paper proposes a parallel-chain nonholonomic manipulator with a chainable kinetics model. To build the manipulator, the friction disc motion synthesis and decomposition mechanism was taken as the joint transmission component. Based on Chow's theorem, the kinetics model of the manipulator was proved as nonholonomic and controllable. Then, the system's configuration coordinates were mapped from the joint space to the chain space via coordinate transformation, and the manipulator motion was planned in the chain space. Through two simulation experiments, it is proved that all joints of the proposed manipulator can move to the target configuration within the specified time. To sum up, the author successfully built an underactuated manipulator that can drive the motion of four joints with two motors. The research findings lay the basis for the development of small lightweight manipulators. 17 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Nonholonomic, Parallel-Chain, Chain Transformation, Motion Planning*

Pages 337-346

JOB-SHOP SCHEDULING PROBLEM BASED ON IMPROVED CUCKOO SEARCH ALGORITHM

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Abstract
This paper makes an in-depth exploration into the job-shop scheduling problem (JSP). After reviewing the related literature, the local search mechanism of the particle swarm algorithm (PSA) and the large-span search principle of standard cuckoo search algorithm (CSA) were combined into an improved cuckoo search algorithm (ICSA), which is capable of both local search and global search. Later, several simulation experiments were carried out on the LA type typical library proposed by Lawrence, and the stability and accuracy of the ICSA was contrasted with those of the PSA and the genetic algorithm (GA) based on the means and variances in multiple iterations. After the comparison, a convergence analysis of the ICSA was specially designed for our model. The results demonstrate that the ICSA provides a better tool for solving the JSP than other algorithms. The research findings lay a solid theoretical basis for the JSP in the actual production process. 21 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Job-Shop Scheduling Problem (JSP), Improved Cuckoo Search Algorithm (ICSA), Numerical Simulation*

Pages 347-358

SIMULATION OF MULTIVARIATE SCHEDULING OPTIMIZATION FOR OPEN PRODUCTION LINE BASED ON IMPROVED GENETIC ALGORITHM

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Abstract
This paper attempts to overcome the defects of bottleneck recognition and scheduling optimization in open production line. For this purpose, the author analysed the impact mechanism of external disturbances and system configuration changes on the production line, and put forward a multi-bottleneck identification model for production line through computer simulation. Then, the proposed model was applied to optimize the scheduling of open production line. Specifically, the bottlenecks of production line were identified based on hierarchical clustering and multi-attribute decision-making, aiming to overcome the small candidate set and low accuracy of traditional bottleneck identification algorithms. The measured results show that the proposed algorithm has clear primary and secondary logics; the number of main bottleneck clusters decreased with the increase in the order; the number of machines in the main bottleneck cluster changed nonlinearly. The traditional genetic algorithm (GA) was improved in three aspects: the local optimum trap was avoided by enhancing population diversity; the iteration speed was accelerated with the introduction of adaptive crossover operator and genetic operator; without sacrificing the computing speed, the convergence quality was guaranteed through the addition of multivariate competition algorithm. The research findings provide new insights into the efficient operation of production line. 34 refs.
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Key Words: *Production Line, Scheduling Optimization, Bottleneck Identification, Improved Genetic Algorithm, Computer Simulation, Multivariate, Hierarchical Clustering*

Pages 359-368

THREE-MACHINE JOB SHOP SCHEDULING WITH INTERMEDIATE TRANSFER

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Abstract
With the purpose of minimizing the makespan of three-machine job shop scheduling problem with intermediate transfer, in this study, a new model was built to perform the makespan minimization, which was proved to be strongly NP-hard. From this model a heuristic algorithm was subsequently derived with a worst-case error bound. The proposed model and derived algorithm were verified through computational experiments carried out on a couple of small size random instances. The results show that the heuristic algorithm possesses a tight worst-case bound of 2. This research presents an approach for obtaining the optimal solutions of the NP-hard problem within a reasonable time. 33 refs.
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Key Words: *Job Shop Scheduling, Heuristic Algorithm, Worst-Case Performance, Coordinated Scheduling*