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ECONOMIC LOT-SIZE USING MACHINE LEARNING, PARALLELISM, METAHEURISTIC AND SIMULATION

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Abstract
The use of discrete event simulation optimisation methods is a tool commonly used as a decision-making support system in industrial problems, concerning management and resource allocation in order to maximise a set of values regarding costs, revenues and other enterprise interests. The present study has proposed and tested an optimisation algorithm developed on Python, with different wall clock time reduction strategies including parallelism, the Greedy Randomized Adaptive Search Procedure (GRASP) population-based metaheuristic, and ten machine learning methods. With the selected best machine learning method (Decision Trees Regressor) 6 optimisation scenarios were generated and then applied to an economic lot-size problem for a theoretical shop floor. The results showed improvements in the reduction of the processing time of 95.0 % comparing the serial GRASP with the parallel machine learning GRASP, obtaining a solution of 94.0 % of the best local optimum. 33 refs.
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Key Words: *Optimisation, Economic Lot-Size, Machine Learning, Parallelism, Metaheuristic, Discrete Event Simulation*

Pages 217-228

NUMERICAL MODEL OF THREE STAGE SPRAY DRYING FOR ZEOLITE 4A – WATER SUSPENSIONS COUPLED WITH A CFD FLOW FIELD

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Abstract
In the present work, a detailed description of a three-stage spray drying model capable of accurate simulation of drying of zeolite suspensions coupled with a CFD flow solver is presented. The models resolve the temperature field in the interior of the droplet, which consists of zeolite particles with adsorbed water and liquid water in the porous channels between the particles. The diffusion process in the interior of the particle is described by the Stefan diffusion model in the dried outer region, and the temperature field is accounted for by the unsteady state heat conduction model with a phase transition at the interface of the wet core. A new approach to the specification of the effective porosity of the dried crust is proposed, where a linear variation of the effective porosity with respect to radial position is applied. The correctness of the model is tested on the drying conditions, determined by the CFD computation, of droplets of different size in a pilot scale spray dryer. The computational results show, that the developed model presents an important upgrade to the single stage spray drying model, as used in the majority of multiphase CFD codes. 16 refs.
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Key Words: *Heat and Mass Transfer, Spray Drying, Multistage Drying, Particle Transport, Zeolite 4A, Computational Fluid Dynamics*

Pages 229-241

DYNAMIC SIMULATION OF A CRUDE OIL DISTILLATION PLANT USING ASPEN-HYSYS®

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Abstract
Petroleum subproducts are obtained in a crude oil distillation plant. Here, due to the chemical properties of the crude oil, a series of complex reactions occurs, and measurements are not always feasible. This poses a challenge to analyse the outcome of the process under real operating conditions. To overcome these difficulties, this paper presents an unpublished modelling and dynamic simulation of a complete distillation plant using Aspen HYSYS® environment. The process involves four major stages: preflash, atmospheric, stabilizer and vacuum, in which condensers, reboilers, heat exchangers, distillation columns and side strippers are designed based on a deep literature review. Moreover, considering that actual refinery plants work with fixed yields set by plant operators, the present work proposes a control strategy that continuously estimates and obtains stable distillate flows of kerosene, diesel and atmospheric gas oil. The simulation results show the comparison of the modelling parameters with actual data and the performance of the crude oil distillation plant under the implemented control system. 35 refs.
(Received in September 2018, accepted in March 2019. This paper was with the authors 2 months for 1 revision.)

Key Words: *Crude Oil Distillation Plant, Modelling, Simulation, Aspen HYSYS®*

Pages 242-253

ASSESSMENT OF ECONOMIC EFFICIENCY AND RISK OF THE PROJECT USING SIMULATION

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Abstract
The article aimed to present an approach to assessment of economic efficiency and risk of the investment project using Monte Carlo simulation. In this case study, post-audit was presented after 4th year of investment operation. A multilevel post-audit was conducted by combining economic efficiency assessment and the Monte Carlo simulation technique. In the first phase, the most serious factors causing Discounted Economic Value Added (*DEVA*) deviation from the planned value were identified. In the second step, the correction of the selected input variables, and calculation of the corrected indicator *DEVA* were performed. The third step was forecasting the *DEVA* indicator conducted by Monte Carlo simulation. Simulation results were used for assessing the critical factors and their impacts on the *DEVA* indicator. In the end, on the basis of analyses, calculations and simulations, the results were compared, and the relevance of the presented methodology for practice was discussed. 25 refs.
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Key Words: *Project Management, Post-Audit, Risk Analysis, Monte Carlo Simulation*

Pages 254-266

INTEGRATING PROCESS PLAN AND PART ROUTING USING OPTIMIZATION VIA SIMULATION APPROACH

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Abstract
Determining the best process plan and route for each part is one of the main problems in dynamic stochastic systems. Therefore, multiple process plans are considered for each operation of each part (machine flexibility and/or part routing) and alternative operations (operation flexibility) simultaneously. In this paper, Optimization via Simulation (OvS) is utilized to plan the processes and route the parts in a dynamic stochastic flexible job-shop environment (DSFJS). Genetic algorithm (GA) which is envisaged to be the optimization component of OvS mechanism is integrated with the simulation model of the production system. A four-factor full factorial design is used to analyse the effect of main factors' and factor interactions' effects on the total of average flowtimes of each part performance of the shop. The design includes the flexibility level of the shop, number of parts, number of operations, and number of alternative process plans. Finally, the main findings of cases are summarized in the study. 31 refs.
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Key Words: *Dynamic Stochastic Flexible Job-Shop Scheduling, Process Plan, Part Routing, Optimization via Simulation*

Pages 267-278

1-D SIMULATION MODEL OF A PROGRESSIVE FLOW CONTROLLER FOR HYDROSTATIC BEARINGS

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Abstract
Hydrostatic bearings in machine tools are used for qualitative highest demands. On the one hand, they are used in precision machines, for example, in grinding machines, to get high precision and the highest quality in the production. On the other hand, they are used in machines with high forces during the production process. Generally hydrostatic bearings are characterised by a good damping behaviour and good stiffness of the bearing, as well as wear resistance and nearly no friction in the bearing (fluid friction), thus, no loss of accuracy over the entire lifetime of the machine tool. A progressive flow control is needed in the bearing to get a nearly constant gap in the hydrostatic bearing, which is independent of the load on the bearing. In our case the progressive flow control works with a piston in combination with a control edge and a mechanical spring. The shape of the control edge is essential to get a nearly constant gap in the hydrostatic bearing. Therefore, a 1-D simulation model of the progressive flow control was developed and implemented in an existing 1-D simulation model of hydrostatic bearings to predict the behaviour of the hydrostatic bearing, for example, in machine tools. 13 refs.
(Received in December 2018, accepted in May 2019. This paper was with the authors 1 month for 1 revision.)

Key Words: *Hydraulic, Hydrostatic Bearing, Flow Control, Simulation*

Pages 279-289

EMPIRICAL MODEL OF DISCRETIZED COPPER ORE FLOW WITHIN THE UNDERGROUND MINE TRANSPORT SYSTEM

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Abstract
A model of the transport system in a copper ore mine was prepared using FlexSim software and the simulations were performed for five days. Empirical parameters were applied to each item of the transport system in order for the ore transport times to correspond to the actual conditions. Both the class- and the loading point-specific haul truck courses were based on the five-day schedule. Mean inter-arrival times were modelled for haul trucks according to empirical histograms. The ore portions were discretized and their masses were based on haul truck load capacities. The simulations were performed for twelve variants covering the unavailability of different ore sources. The recorded statistics include ore provenience, lithology, Cu content and tag survival rate for RFID-tagged ore variants. The model represents the new way of solving the problem of ore mixing in a conveyor belt-based transport system. Adoption of the proposed scheme, will allow the enrichment plant managers to adjust the milling and crushing parameters to the lithology of the ore before it will leave the mine. The model allows to pinpoint the areas in the mine that produce certain demanded lithological factions and helps the managers to choose the most desirable pattern of the mining schedule and forecast the economical outcome. 28 refs.
(Received in December 2018, accepted in May 2019. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Ore Flow, Transport System, Quality Management, Ore Lithology, Metal Yield, Empirical Model*

Pages 290-301

LOAD DISTRIBUTION AND CONTACT OF AXLE BOX BEARINGS IN ELECTRIC MULTIPLE UNITS

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Abstract
The rolling bearing, as the key part of the moving component of an electric multiple unit (EMU), its mechanical behaviour has become an active area of research in the development of high-speed EMUs. To provide a reliable basis for evaluating service life span and operational reliability of double-row tapered roller bearings, the load distribution of axle box bearings and the contact stress of bearings were investigated in this study. The methods of numerical analysis and actual load measurement were performed to calculate the internal load distribution. After obtaining the internal roller load distribution relation, a model of a single roller contacting the inner and outer raceways was established to calculate the contact stress state using Abaqus software and the Hertz theory. Results show that the contact load of each roller in the bearing decreases with the increase of the azimuth angle until the roller is outside the load-bearing area. The contact half width and the contact stress distribution of the simulation and the theoretical computation results are consistent. This study can provide a basis for the design and service life evaluation of this type of bearing. 18 refs.
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Key Words: *Axle Box of EMU, Double-Row Tapered Roller Bearing, Load Distribution, Contact Stress*

Pages 302-313

DEVELOPMENT OF A NUMERICAL TOOL FOR DYNAMIC SIMULATIONS OF TWO-PHASE COOLING SYSTEMS

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Abstract
In this article, the development of a simulation tool for two-phase cooling systems is discussed. The targeted application is modelling of the two-phase pumped loop systems used for Silicon tracking detector cooling at CERN. These systems are similar to vapour compression systems in that the thermal dynamics of such systems are dictated by the two-phase fluid present inside the heat exchangers. To properly account for such dynamics, non-homogenous void fraction based two-phase flow models (used for accurate modelling of vapour compression systems) have been incorporated. The tool has been validated against measurements taken for an R-410A-based residential heat pump unit. Both the heating and cooling mode have been simulated and the results have been compared against measured data. The simulated transients are found to compare well against measured trends. The simulations proceed faster than real-time. The tool shows readiness for use in the design of future detector cooling systems. 23 refs.
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Key Words: *EcosimPro, High Energy Physics, Dynamic Simulations, Two-Phase Flow, Cooling System, Heat Pump*

Pages 314-324

NUMERICAL SIMULATION FOR ENERGY HARVESTING OF PIEZOELECTRIC FLAG IN UNIFORM FLOW

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Abstract
Piezoelectric energy harvesters (PEHs) have been investigated for decade years for powering low energy consumed electric devices. However, research of PEH more focuses on the structure and energy capture performance, ignoring the interaction between the PEHs and environmental vibration. In order to investigate energy harvesting performance of PEHs in uniform flow, this study presented a two-dimensional (2D) simulation method. The fluid kinematics was simulated by the discrete lattice Boltzmann equation. Fluid effecting on the piezoelectric flag were handled by immersed boundary method (IBM). Coupled with Euler-Bernoulli beam and piezoelectric theory, the full-coupled fluid-structure-electric (FSE) was established by using the immersed boundary-lattice Boltzmann method. Results indicate that due to the simple boundary treatment and time saving calculation of the lattice Boltzmann method (LBM) and IBM, the numerical method is superior efficiency for the FSE problems. The identified peak energy conversion efficiencies for various velocities are significant to explore the optimum structure of piezoelectric flags in various fluid situations. 34 refs.
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Key Words: *Numerical Simulation, Piezoelectric Flag, Energy Harvesting, Flow*

Pages 325-334

A PETRI NET-BASED HYBRID HEURISTIC SCHEDULING ALGORITHM FOR FLEXIBLE MANUFACTURING SYSTEM

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Abstract
Considering the importance and complexity of scheduling to modern manufacturing systems, this paper puts forward a hybrid heuristic scheduling algorithm for flexible manufacturing system (FMS) based on Petri net (PN). Specifically, the PN modelling and scheduling algorithm of the FMS were discussed in details, and the hybrid heuristic scheduling algorithm was proposed based on the reachability graph of PN model. On this basis, a PN-based strategy for discrete event system (DES) modelling was developed, and applied to simulate the scheduling of a production line of shock absorbers. The results show that the FMS scheduling can be simulated effectively through the combination between extended PN and FlexSim. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Flexible Manufacturing Systems (FMS), Petri Net (PN), Heuristic Scheduling, Discrete Event System (DES)*

Pages 335-343

A SOLUTION TO SINGLE-MACHINE INVERSE JOB-SHOP SCHEDULING PROBLEM

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Abstract
Concerning the inverse job-shop scheduling problem (JSP), this paper proposes a hybrid solution based on genetic algorithm (GA) and improved particle swarm optimization (PSO), with the aim to minimize the parameter adjustment. The solution was presented as a block coding plan with decimal mechanism, under which both processes and parameters can be optimized simultaneously. To enhance the local search ability of the proposed algorithm, four neighbourhood structures were designed, and an adaptive selection mechanism was created to select the most suitable neighbourhood. Finally, the proposed algorithm was proved valid through discrete event simulation (DES) and comparison with other algorithms. 21 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Inverse Scheduling, Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Job-Shop Scheduling Problem (JSP), Discrete Event Simulation (DES)*

Pages 344-354

OPTIMIZATION OF REMANUFACTURING PRODUCTION SCHEDULING CONSIDERING UNCERTAIN FACTORS

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Abstract
This paper attempts to optimize the remanufacturing production scheduling under randomness and fuzziness. Firstly, the rough set theory and multi-objective approximation ranking algorithm were combined into a quality evaluation method of remanufacturing recycling resources, which eliminates the redundant information in quality evaluation. Then, a remanufacturing production scheduling model was constructed under uncertain conditions, and a hybrid algorithm coupling double fuzzy algorithm, backpropagation (BP) neural network and genetic algorithm was developed to solve the model. The simulation results show that the algorithm achieved good convergence and the obtained solution can minimize the total cost of production scheduling and the processing time. This means the model algorithm can effectively optimize the scheduling of remanufacturing production. The research findings shed new light on the fast quality evaluation of recycled resources and the optimization scheduling of remanufacturing production. 27 refs.
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Key Words: *Uncertain Factors, Remanufacturing, Production Scheduling, Optimization, Simulation*

Pages 355-365

BI-OBJECTIVE COLLABORATIVE SCHEDULING OPTIMIZATION OF AIRPORT FERRY VEHICLE AND TRACTOR

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Abstract
With the continuous growth of aviation business, the flight ground support capability of airport is facing great challenges. The resources of ferry vehicle and tractor are important factors that restrict the flight service level of the airport. This paper analyses the collaborative scheduling of airport ferry vehicle and tractor through innovatively constructing a bi-objective mixed integer programming model, one objective is to minimize the number of ferry vehicles and tractors, and the other is to balance the vehicle usage. To deal with this problem, two methods based on standard particle swarm optimization are adopted: the lexicographic method and Pareto method, and virtual flights are introduced for the convenience of particle coding. The effectiveness and comparison of two methods are illustrated by employing the real flight data of Beijing Capital International Airport. The results of this study may provide reference for the evaluation and optimization of the airport ground support vehicles. 16 refs.
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Key Words: *Flight Ground Support, Vehicle Scheduling, Bi-Objective Programming, Particle Swarm Optimization*

Pages 366-377

MODELLING AND PRODUCTION CONFIGURATION OPTIMIZATION FOR AN ASSEMBLY SHOP

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Abstract
Flexible production is able to respond to a changing production system. To efficiently optimize a changed production layout and configuration, a modelling and optimization method based on discrete event simulation (DES) was proposed. A mathematical optimization model of the workshop layout was formulated and solved using a genetic algorithm (GA). In addition, a general modelling method for workshop logistics processes using DES was proposed to efficiently develop a simulation model of the complex production processes. Moreover, the simulation model of the entire production process was constructed using the Plant Simulation software package, and more production factors were considered and optimized. After the optimization process, the logistics volume decreased by 63.5 %, and the throughput increased by 42.0 %. Additionally, the production process was optimized, and the optimal equipment allocation, worker allocation, buffer allocation, and logistics vehicle allocation were determined. Our work can provide decision guidance and simulation validation for workshop planning. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Production Performance, Logistics Simulation Modelling, Production Configuration, Plant Simulation, Layout Optimization, Production Process Optimization*