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SIMULATION-BASED MOULD DESIGN, LIFE PREDICTION AND RELIABILITY ASSESSMENT OF A VALVE BODY

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Abstract
Shrinkage porosities are one of the major casting defects which affects the quality and structural integrity of cast products. Consequently, the service life and reliability of the components are questioned and need to be determined prior to put these parts in service. This study presents a simulation based methodology for mould design, life prediction, and reliability assessment of castings using simulation tools. The methodology is developed and validated for standard test specimens followed by its application on a valve body. The mould design is optimized for porosities using MAGMASoft. Integration of predicted minimum porosity to valve body is done using MAGMAlink. The stress fields with porosity are obtained using ABAQUS which are then used to predict life and estimate reliability. Infinite life i.e. more than 10^6 cycles is predicted with minimum porosity in valve body. The reliability results for valve under normal operating pressure i.e. 1 MPa shows ~100 % reliability for infinite life, however, under the maximum loading conditions i.e. 2.5 MPa, the reliability is significantly compromised. A safe load-induced stress on valve is also determined based on the reliability results. 17 refs.
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Key Words: *Metal Casting, Mould Design, Simulation, Fatigue Life, Reliability, Optimization*

Pages 231-242

RIGOROUS DYNAMIC SIMULATION OF A DEHYDRATION AND DESALTING CRUDE OIL UNIT USING ASPEN HYSYS®

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Abstract
Considering that two-thirds of world oil production receive a treatment after extraction to remove water and salt contents, one of the most important processes to avoid operational problems in refinery plants corresponds to the dehydration and desalting unit. Here, live crude oil at high temperatures and pressures is processed and stabilized. Henceforth, to optimize these petrochemical plants, simulation has become an important tool. Nevertheless, due to its sequential modular nature related with mass/energy recycle steam circuits, the modelling and simulation of this process is commonly simplified. Thus, to reproduce the process behaviour of the unit under operating conditions and identify its effect on the final product, this work presents an unpublished rigorous dynamic simulation-based procedure of a complete real dehydration and desalting process using Aspen HYSYS®. Different pieces of equipment are carefully designed based on literature review, and a specially tailored procedure is proposed to estimate the water and salt contents at any stage of the plant. Finally, to validate the simulation, the accuracy of the main flows and chemical contents along the process are compared with actual data. 35 refs.
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Key Words: *Dehydration Unit, Desalting Unit, Modelling, Simulation, Aspen HYSYS®*

Pages 243-254

KINEMATIC MODEL OF A LOGISTIC TRAIN WITH A DOUBLE ACKERMANN STEERING SYSTEM

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Abstract
The demand for fast, economic and high load capacity intralogistics transport is a growing trend. One of the recent solution is a logistic train, which consists of a tractor and a certain number of towed trailers. It is essential that the trailer follows the track of the preceding unit as it allows reduction of shopfloor area dedicated for transport. A perfectly suited steering system for this application is the double Ackermann system. In this study, the kinematic model of the tractor with *n* trailers was developed based on the Jacobian matrix. The tractor model was adapted to drive along a given trajectory using a PD controller. The simulation studies confirmed that the PD controller is sufficient to control the trajectory for developed kinematic model. The obtained results showed that the trailers with the double Ackermann steering system follow a similar path, which is the most convenient for narrow turn ride. The developed kinematic model can be used for the fast path planning and the design of transportation routes in manufacturing areas. The expanded model with an advanced control system can be used to control a real logistic train. 28 refs.
(Received in November 2020, accepted in February 2021. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Logistic Train, Milk-Run, Kinematic Model, Double Ackermann, Tractor-Trailer System, Trajectory Control*

Pages 255-266

BUSINESS PROCESS MANAGEMENT MODEL AS AN APPROACH TO PROCESS ORIENTATION

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Abstract
Business process management (BPM) and process orientation is the focus of many researchers in the operational management. Various models have been developed that demonstrate the maturity, importance and role of BPM in setting a business strategy, as well as in design, implementation and control of business processes. Accepting the idea of the need for further research in this area, a research was conducted, and the results are presented in this article. The presented model is a result of numerous examples from various literary sources, experimentally obtained information, as well as knowledge from competent respondents. The model includes five dimensions of key factors for successful design, implementation and control of business processes, in accordance with the set of business strategies. Respondents in this research were middle and upper-level managers (315 respondents) from 45 organisations set in industrial, financial and telecommunications sectors. Research results show that organisations that have accepted the proposed model have a chance to take advantage of the process orientation positive effects and successfully manage business processes. 35 refs.
(Received in December 2020, accepted in April 2021. This paper was with the authors 1 month for 1 revision.)

Key Words: *Business Process Management, Process Orientation, Operational Management, Model*

Pages 267-278

GO-KART CHASSIS DESIGN USING FINITE ELEMENT ANALYSIS AND MULTIBODY DYNAMIC SIMULATION

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Abstract
For the accurate design of some types of mechanisms, it is necessary to combine multibody dynamics computer simulations with finite element structural analysis. These types of mechanisms are the multibody mechanisms in which the body (frame) stiffness of some of the bodies have the same magnitude as some of their elastic elements. With this in mind, the traditional go-kart chassis design process is reviewed. The traditional approach to evaluate the structural properties of its frame consists of an iterative process in which FEM techniques are applied considering constant load cases. These load cases are defined according to the maximum stresses to which it will be subjected during its operation (circulation in a race circuit). However, as it will be proven in this work, the load case will depend on the design of the frame itself. Due to the stiffness of the frame, for the same driving conditions (vehicle trajectory and speed) the structural load condition varies significantly. A design methodology is proposed for this type of system that combines multibody simulation and finite elements. 32 refs.
(Received in December 2020, accepted in April 2021. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Go-Kart, Finite Element Analysis, Multibody Dynamics*

Pages 279-290

SELECTION OF OPTIMAL INVESTMENT VARIANT BASED ON MONTE CARLO SIMULATIONS

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Abstract
This paper presents a methodology for the selection of an optimal investment variant using Monte Carlo simulation and OptQuest optimization. The decision-making process also includes risk analysis. Investment variants involve renewal and development of production equipment. Two approaches to investment decision making are introduced. The first approach is based on the analysis of the distribution function of Net Present Value (*NPV*), and the rule of mean value and coefficient of variation is used as the decision criterion for determining the profitability of investment variants. The second approach, based on the cumulative probability distribution of *NPV*, provides a comparative assessment of the investment variants using stochastic dominance rules. Both approaches lead to the choice of the same investment variant. In order to increase the profitability of the selected investment variant and reduce its risk, OptQuest optimization is subsequently implemented. The introduced approaches can be a useful support tool in investment decision-making. 28 refs.
(Received in January 2021, accepted in April 2021. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Investment, Decision-Making, Monte Carlo Simulation, Risk Assessment*

Pages 291-302

MESO-SCALE SIMULATIONS OF LIGHTWEIGHT AGGREGATE CONCRETE UNDER IMPACT LOADING

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Abstract
To reveal the damage evolution and energy dissipation characteristics of lightweight aggregate concrete (LWAC) under impact loading, some simulations of lightweight shale ceramsite concrete under high strain rate impact with a 3D meso-scale model were carried out. After the meso-scale model considering the randomness of the shape and distribution of lightweight aggregates being established and the material parameters of each component being determined by test results, the damage evolution and energy dissipation characteristics of the model under different strain rates were analysed. Results show that the damage evolution of LWAC can be divided into four stages from the perspective of energy. The large deformation and stress concentration firstly occur on the lightweight aggregates, which leads to the generation of micro-cracks. There is an upper limit of the strain energy density of the lightweight aggregate component. The energy absorption efficiency of the specimen first increases and then decreases with the increase of strain rates. The obtained conclusions can provide a reference for understanding the dynamic performances and damage mechanism of LWAC. 29 refs.
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Key Words: *Lightweight Aggregate Concrete, Strain Rate, Energy Dissipation, Simulation, Damage*

Pages 303-314

FUSED DEPOSITION MODELLING FOR 3D PRINTING OF SOFT ANTHROPOMORPHIC ACTUATORS

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Abstract
Soft actuators are increasingly gaining attention in the robotics community due to several favourable properties rooted mainly in their inherent compliance. They are safe, can easily grasp different objects, and cheap to manufacture. However, particularly in the case of FDM (Fused Deposition Modelling) printed actuators, their design is usually an iterative process that relies on intuition due to complex material models, nonlinearities, large deformations, and residual stresses caused by imperfect interlayer structure. This makes such actuators difficult to model and control and limits their implementation despite some comparative advantages over the other 3D printing technologies. In this study, to characterize the properties of FDM printed soft actuators, we compare a simple but computationally effective linear model with a realistic experimentally generated hyperelastic material model of a soft actuator. Based on these insights, we 3D print a fully operational soft anthropomorphic hand and use it in a set of experiments to evaluate the limitations of the models and suggest design and printing parameters to improve soft actuators' performance. 30 refs.
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Key Words: *Soft Robots, Modelling, Analysis, Fused Deposition Modelling, Anthropomorphic Actuator*

Pages 315-326

VIBRATION REDUCTION ON OVERHEAD CONTACT RAILS: A SIMULATION-OPTIMIZATION APPROACH

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Abstract
The use of overhead contact rail systems in rail transport has been favoured by the need of having an electrification system that allows its installation where space is limited.

The displacement of a train pantograph running through a railway line causes an oscillating movement on the contact line. The overhead contact rail systems or rigid catenary, due to its characteristics, describes a movement with greater inertial forces than the equivalent flexible overhead contact lines. The main consequence is that at higher speeds larger variations in the contact force between pantograph and catenary wires occur, leading to contact loses and producing electrical arcs.

Results obtained in the study developed on the implementation of stiffness compensation systems are described on this paper. Simulations demonstrate that it is feasible to reduce the effects of the movement described by the overhead contact rail's beam. This opens a new investigation field focused on develop the most efficient configuration for alternative overhead contact rail solutions. 18 refs.
(Received in February 2021, accepted in April 2021. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Pantograph-Catenary Interaction, Overhead Contact Rail, Vibration*

Pages 327-338

FORMATION MECHANISM OF AN ADHERENT VORTEX IN THE SIDE PUMP SUMP OF A PUMPING STATION

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Abstract
The inflow of the side pump sump is not smooth enough during the operation of a pumping station, resulting in an asymmetric adherent vortex that endangers the station's normal operation and safety. To solve this problem, flow field and vorticity distribution charts of different flow layers were created through the establishment of a numerical model of the pumping station inflow by means of the fluid simulation software. The formation mechanism of the asymmetric adherent vortex in the side pump sump was analysed by combining Reynolds shear stress distribution, the simplified Navier–Stokes equation, and the transport equation of turbulent kinetic energy. Furthermore, the accuracy of the numerical simulation results was verified using flow field data collected via particle image velocimetry at the junction of the forebay and pump sumps of the station. Results show that the distribution of inflow velocity is uneven due to the asymmetric friction of the inflow in the side pump sump. The transverse velocity formed from it generates the asymmetric vortex in the side pump sump and creates an inspiratory vortex. 23 refs.
(Received in February 2021, accepted in April 2021. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Pump Station Engineering, Side Pump Sump, Adherent Vortex*

Pages 339-350

ANALYSIS OF LASER INTERFEROMETER MEASUREMENT UNCERTAINTY BY SIMULATING ERROR SOURCES

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Abstract
The article presents measurement uncertainty analysis of accurate one-dimensional measurements with laser interferometers in precise industrial production and in calibration laboratories. To enable high measurement accuracy, environmental conditions shall be well controlled and laser interferometers, including air sensors, shall be calibrated periodically. Additionally, for calibration of measurement instruments and coordinate measuring machines, a positioning system, such as a video probe, shall be evaluated. In the presented research, the influencing parameters were observed on specific cases in laboratory measurement conditions, as examples of calibration systems that are applied in the accredited metrology laboratory (Laboratory for Production Measurement, Faculty of Mechanical Engineering). Through the review of possible error sources, which can be categorized into three groups - instrumental, environmental, and geometrical errors of the measuring system, the uncertainty budget was summarized with the aim to recognize and reduce the most influencing components and reach a proper measurement accuracy in real production environment. 21 refs.
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Key Words: *Laser Interferometry, Measurement Uncertainty, Simulation, Calibration*

Pages 351-362

VEHICLE ROUTING PROBLEM WITH SOFT TIME WINDOWS OF CARGO TRANSPORT O2O PLATFORMS

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Abstract
To attain the goal of cost minimization, a vehicle routing model for cargo transport O2O platforms were established in this study. In consideration of differences in vehicle origin in the traditional vehicle routing problem as well as the one-to-one corresponding relationship between cargo owners' pickup and delivery points, constraint conditions such as half-open, multiple depot, multiple vehicle type, origin–destination pair, loading limit, and soft time window constraints were introduced into the proposed model. Given the model characteristics, an improved genetic algorithm, which is commonly used in vehicle routing problem, was used as the solving tool. The nearest matching method currently used by cargo transport O2O platforms was simulated using the simulation software AnyLogic. Moreover, vehicle–cargo orders on a platform within a certain time period were selected and allocated, and a matching scheme was obtained. Then, the optimized matching scheme for the same order was calculated using the improved genetic algorithm. Results show the comprehensive cost obtained by the improved genetic algorithm is 21.14 % lower than that of obtained by the nearest matching method. 18 refs.
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Key Words: *Cargo Transport O2O, Vehicle Routing Problem, Soft Time Window, Improved Genetic Algorithm*

Pages 363-374

FLOW CHARACTERISTICS OF OIL-GUIDING SPLASH LUBRICATION: SIMULATION AND EXPERIMENT STUDIES

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Abstract
Based on the computational fluid dynamics (CFD) method, the performance of the oil-guiding cylinder, a key component in a novel splash lubrication system of the helicopter main reducer, was investigated in terms of three different kinds of structures. The pressure and velocity distribution characteristics were firstly simulated and analysed. The numerical simulations indicated that the oil free surface formed in the rotating cylinder was a paraboloid, meanwhile the structure without a bottom flange can achieve the splash effect constantly. Furthermore, the experimental findings agreed well with the numerical results, it was verified that the cylinder with a cylindrical-shaped lower wall surface gave a better lubrication performance than the conical-shaped. Besides, it was found that the oil volume increased with the rotating speed and oil level increasing, and the geometry parameters of the oil-guiding cylinder and the operating conditions have a great effect on the oil-guiding splash lubrication performance. 21 refs.
(Received in December 2020, accepted in March 2021. This paper was with the authors 3 weeks for 1 revision.)

Key Words: *Splash Lubrication, Computational Fluid Dynamics, Forced Vortex, Main Reducer, Oil-Guiding Cylinder*

Pages 375-386

A DEEP REINFORCEMENT LEARNING BASED SOLUTION FOR FLEXIBLE JOB SHOP SCHEDULING PROBLEM

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Abstract
Flexible job shop Scheduling problem (FJSP) is a classic problem in combinatorial optimization and a very common form of organization in a real production environment. Traditional approaches for FJSP are ill-suited to deal with complex and changeable production environments. Based on 3D disjunctive graph dispatching, this work proposes an end-to-end deep reinforcement learning (DRL) framework. In this framework, a modified pointer network, which consists of an encoder and a decoder, is adopted to encode the operations to be scheduled according to the selected scheduling features. Then with the attention mechanism, an input is pointed as an action in each decoding step, and a recurrent neural network (RNN) is used to model the decoder network. To train the network to minimize the makespan, a policy gradient algorithm is applied to optimize its parameters. The trained model generates the scheduling solution as a sequence of consecutive actions in real-time without retraining for every new problem instance. Experimental results show that this method can obtain better performance than the classic heuristic rules when only one model is trained on all the test instances. 19 refs.
(Received in December 2020, accepted in March 2021. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Flexible Job Shop Scheduling Problem (FJSP), Deep Reinforcement Learning (DRL), End-to-End, Pointer Network, Attention Mechanism, 3D Disjunctive Graph*

Pages 387-397

MULTI-SCENARIO SIMULATION OF SUBWAY EMERGENCY EVACUATION BASED ON MULTI-AGENT

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Abstract
This study introduces the mainstream theory of crowd evacuation based on multi-agent. Then a simulation model is developed based on Agent and Pathfinder to simulate the evacuation of three subway space types, including platform, station hall and stair. In addition, simulation is also carried out on the situation of the reverse running of the firefighters walking ladder and the different distribution of the crowd density. Finally, the simulation parameters are adjusted respectively to observe and compare the simulation results under different circumstances. Through the simulation of the situation of crowd evacuation under different conditions and parameters, key data such as crowd speed, number of people passing through space and remaining number, number of people passing through exit and evacuation path are recorded. These key data and the above simulation test results are vital for constructive suggestions that can be put forward for subway space design and fire control scheme. 18 refs.
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Key Words: *Multi-Agent, Subway Emergency Evacuation, Simulation*

Pages 398-409

GAME-BASED HYBRID PARTICLE SWARM OPTIMIZATION OF JOB-SHOP PRODUCTION CONTROL

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Abstract
The traditional multi-objective particle swarm optimization (PSO) cannot effectively handle the production control problem involving multiple types of production lines or production objectives. Therefore, this paper designs a game-based hybrid PSO (GBHPSO) for job-shop production control. Firstly, a job-shop model was established with parts processing line, parts assembly line, and product assembly line, and the production control ideas were designed to combine real-time monitoring of events and operation sequence adjustment. Then, the production control objectives were determined for the three production lines. After that, the GBHPSO was applied to solve the job-shop production control problem, the product utility function was constructed, and the execution low was detailed for the solving algorithm. Experiments demonstrate the effectiveness of our algorithm. The research provides a reference for applying our algorithm in resource allocation of other production fields. 25 refs.
(Received in January 2021, accepted in April 2021. This paper was with the author 1 month for 2 revisions.)

Key Words: *Game-Based Hybrid Particle Swarm Optimization (GBHPSO), Production Control, Product Utility*

Pages 410-421

APPLICATION OF MACHINE LEARNING AND RULE SCHEDULING IN A JOB-SHOP PRODUCTION CONTROL SYSTEM

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Abstract
As intelligent and precision manufacturing becomes the trend of industrial production, it is of practical significance to study the job-shop production control. However, the existing studies have not provided an evaluation mechanism to reasonably measure the control efficiencies of different plans. The desired control objectives are not easily achieved for job-shop production control problems with dynamic changes. Therefore, this paper probes into the dynamic job-shop production control problem based on deep reinforcement learning and rule scheduling. Firstly, a multi-objective optimization model was established for the production control system of dynamic job-shop. Then, deep reinforcement learning was introduced to job-shop production control system to transform the dynamic job-shop production control problem. After that, the authors proposed a dynamic job-shop production control method based on deep reinforcement learning, and explained the collaboration strategy for multiple subsystems. The proposed method was proved effective through experiments. 26 refs.
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Key Words: *Deep Reinforcement Learning, Rule Scheduling, Job-Shop, Production Control*

Pages 422-433

PRODUCTION MANAGEMENT OF MULTI-OBJECTIVE FLEXIBLE JOB-SHOP BASED ON IMPROVED PSO

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Abstract
It is of great practical significance to improve the traditional particle swarm optimization (PSO) for the production management of multi-objective flexible job-shop. However, the current studies have not solved the problem that the traditional PSO cannot apply to the production and processing environment with numerous uncertain changes. Therefore, this paper improves the PSO for the production management of multi-objective flexible job-shop under different conditions. Firstly, the author modelled the production management of high-dimensional dynamic multi-objective flexible job-shop, and explained the pre-reaction dynamic rescheduling method for production management. Then, the PSO was improved in terms of inertial weight, learning factors, global search ability, and local search ability, and the dynamic response mechanism was presented for the improved algorithm. The feasibility of the improved PSO was demonstrated through experiments. The research provides a reference for applying the improved PSO to the optimization in other fields. 27 refs.
(Received in February 2021, accepted in May 2021. This paper was with the author 1 month for 2 revisions.)

Key Words: *Multi-Objective Flexible Job-Shop Production Management, Improved Particle Swarm Optimization (PSO), Dynamic Response*