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MAINTENANCE SCHEDULING OF HEATING NETWORKS USING SIMULATION IN WITNESS

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Abstract
Vehicle routing has become an important part of the maintenance scheduling mainly in case of the systems consisting of geographically dispersed facilities. In this paper we describe the efficient way to set the schedule of visits for technicians ensuring the preventive maintenance of heating networks. Our model consists of geographic information system, Clarke and Wright savings algorithm to obtain a single route by solving travelling salesman problem and discrete-event simulation to convert the single route to the schedules of visits. Our solution is suitable for applications in large scale systems where the regular preventive maintenance of a facility is required but the frequencies of visits of facilities are hazily specified and randomly distributed over the time. Based on the outputs coming from the simulation of a real heating network consisting of 550 heating facilities located in Prague, Czech Republic and adjacent suburban areas we discuss how the schedule of visits leading to the long-term service of a consolidated territory can positively affect the operational efficiency of the maintenance. 35 refs.
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Key Words: *Preventive Maintenance, Maintenance Scheduling, Vehicle Routing, Discrete-Event Simulation, Witness*

Pages 214-225

SIMULATION OF HOMOGENEOUS PRODUCTION PROCESSES

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Abstract
This paper is focused on streamlining the activity of the homogeneous production processes which form the production logistics of a particular extraction operation. The efficient extraction of millions of tonnes of raw materials presents a requirement for the correct use of the means of transport, machinery and equipment involved in the extraction of raw materials, with an economic, social, technical and ecological impact. The extraction operation studied is performed in a quarry for the extraction of limestone, which is used as input material for the production of various types of building materials. The extracted raw material gradually passes through the chain of extraction – loading – transport – unloading – crushing to the actual processing in the building materials plant. The results of the solution show that the maximum effective use of the operation of the defined system can be achieved with 27 means of transport and 4 loaders, while the utilization of workplaces in extraction operation workplaces is close to 100 % during the defined time of operation. 31 refs.
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Key Words: *Homogeneous Production Processes, Manufacturing Logistics, Streamlining the Mining Industry, Simulation, ExtendSim, System*

Pages 226-236

CAD MODEL OF REAR-VIEW MIRROR AND SIMULATION OF ITS AERODYNAMICS AND NOISE

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Abstract
Very important aspect of the designer's work, which requires going through the process from the initial idea, through the design of the concept, to the desired final state of the selected product, is to understand, what will be impact of designed part on physical properties of product. The paper focuses on the analysis of aerodynamics resistance and noise of proposed design of a selected car component. The car's exterior mirror was chosen as the component for the analysis. In the paper, it is proposed our own design of rear-view mirror. The 3D model was created in the CATIA system and it was then transferred to the environment of SolidWorks system, where were performed Computation Fluid Dynamics (CFD) simulations and analyses. There are described the results of aerodynamics resistance and noise analyses in different speeds. As a default speeds were chosen typical allowed speeds: urban (50 km/h), rural (90 km/h) and motorways (130 km/h). The values obtained by the simulations indicate a further direction of the rear-view mirror design in order to achieve better parameters in terms of aerodynamics and noise. 30 refs.
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Key Words: *Rear-View Mirror, CAD Modelling, Airflow, Simulation, Noise, Aerodynamics*

Pages 237-248

FEA APPROACH FOR PREDICTING THE DYNAMIC BEHAVIOUR OF CORK-RUBBER COMPOSITES

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Abstract
Cork-rubber composites can be applied as isolation blocks for systems under dynamic compressive loading. Under the same loading conditions, different geometries of the same cork-rubber material present distinct static and dynamic compression behaviour. To reduce the number of experimental tests for different geometries, a methodology, employing finite element analysis (FEA), is proposed. Considering static and dynamic experimental results of a 60 Shore A cork-rubber squared cross section specimen, an equivalent single degree of freedom model is derived, and its data is introduced on FEA to determine the dynamic behaviour of samples with different dimensions. Dynamic stiffness and natural frequency results showed a good agreement between experimental and numerical approaches for a standard sample and specimens with different thicknesses and areas, especially when considering static deformation due to preload. The developed study allows the prediction of the dynamic behaviour of different dimension samples through FEA output, based only on experimental testing. 22 refs.
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Key Words: *Cork-Rubber Composites, Dynamic Compression, Dynamic Stiffness, FEA, Natural Frequency, Shape Factor*

Pages 249-260

CAVITATION EROSION MODELLING – COMPARISON OF TWO SOLID ANGLE PROJECTION APPROACHES

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Abstract
In this paper we compared two different solid angle formulations to determine the amount of cavitation potential energy that is transfer from a source to a surface. The first formulation used an analytical expression for the solid angle of a planar triangle while the second formulation used a fully continuous form of the solid angle projection approach which represents the surface specific impact power at a point location. The comparison was conducted on a NACA 0018-45 hydrofoil. A block-structured computational mesh was created in ICEM CFD. Transient simulations were performed in Ansys CFX where the SST turbulence model with Reboud's correction was used. For the cavitation modelling the Schnerr-Sauer cavitation model with the recommended values was used. Result from Ansys CFX were imported into Matlab where the potential power applied to the surface was calculated for both formulations. The results of the study show that both formulations work well and predict similar locations where erosion occurred, the difference is in the absolute values which are significantly higher in the formulation that used the fully continuous form of the solid angle. 22 refs.
(Received in February 2022, accepted in April 2022. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Cavitation, Erosion, Solid Angle, Numerical Simulation*

Pages 261-272

SIMULATION OF AIRCRAFT CABIN EVACUATION STRATEGY BASED ON EXIT FLOW EQUILIBRIUM

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Abstract
Exit flow equilibrium method based on crowd evacuation dynamics theory was applied in this study to clarify the reasons that hinder the evacuation of aircraft cabin passengers as well as reduce the evacuation time using the A-configuration cabin layout of a B737-800 as an example. Pathfinder simulation software was utilized to simulate and compare the evacuation efficiency of three scenarios: no command scenario, exit equilibrium scenario, and evacuation sequence arrangement; reveal the key reasons causing the evacuation congestion of aircraft cabin; and propose the evacuation strategy with the minimum amount of time. Results show that the evacuation time is 99 s under the condition of no command and 86.8 s under the condition of balanced exit utilization. The evacuation efficiency in the case of balanced use of emergency exits reaches the maximum when passengers near the aisle are evacuated first at an evacuation time of 79.3 seconds. The obtained conclusions provide a significantly reference and method support for efficient emergency evacuation strategies of civil aircrafts. 21 refs.
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Key Words: *Cabin Evacuation, Exit Flow Equalization, Evacuation Sequence, Evacuation Efficiency*

Pages 273-283

LOAD BALANCING IN POLLING SYSTEMS UNDER DIFFERENT POLICIES VIA SIMULATION OPTIMIZATION

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Abstract
A polling system is a type of queueing system in which a single server serves many queues. In contrast to classical queueing systems, the server switches between queues and serves the customers under different routing and service policies. The problem addressed in this study is to define the load balancing problem in polling systems, where the balancing behaviour is dependent on server shifts, not the distribution of customers among queues. Although the load balancing problem in multi-server queuing systems is very common, modelling the load balancing problem in polling systems is the novelty of this study. Furthermore, not only the performance of the system has been analysed as in the previous simulation studies but also the balanced queues with optimal routing probabilities for multi-class queues under different routing and service policies are achieved by using Arena-OptQuest. 25 refs.
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Key Words: *Multi-Class Queues, Polling Systems, Routing, Simulation*

Pages 284-295

DYNAMIC PROPERTIES OF CHAIN DRIVE SYSTEM CONSIDERING MULTIPLE IMPACT FACTORS

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Abstract
Chain drive system is the core subsystem of scraper conveyor. It is affected by the impact load caused by large coal when working, thereby seriously affecting its operation stability. A simulation model of the chain drive system is established by using joint simulation, and simulation scheme are introduced. The dynamic properties of chain drive system under three working conditions of different lumps and different heights of large coal and large coal impacting on different positions in the middle groove are simulated. Results show that when the chain ring is impacted, the vibration amplitude of the impacted chain is positively correlated with the lumpiness of the large coal, and the longitudinal vibration is the main reason for the failure of the chain drive system. With the increase in the impact height of large coal, the longitudinal vibration growth rate of the regional chain in front of the impacted chain is greater than that of the regional chain in rear. Under different position conditions, the stability of the chain drive system is greatly affected when the chain ring in the no load area is impacted. This study provides a reference for the theoretical study of the dynamic properties of chain drive system. 22 refs.
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Key Words: *Scraper Conveyor, Dynamic Property, Impact Load, Joint Simulation*

Pages 296-307

EFFECTS OF FITTING ERROR ON THE HYDRAULIC PERFORMANCE OF BIONIC HYDROFOILS

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Abstract
To improve the hydromechanical performance, sturgeon was chosen as the research object in this study, and a body surface structural model was built using 3D reverse engineering technology. An inhomogeneous B-spline curve fitting technique based on local refining was proposed. Meanwhile, three different bionic hydrofoils were designed and compared with three bionic hydrofoils gained from the least square method and NACA0015. Research results demonstrated that the new curve fitting technology can fit a high-accuracy hydrofoil (error $< 7\times10^{-4}$) by using only 15 control points, and the gained bionic hydrofoil has a good lift-drag ratio. With the bionic hydrofoils gained from the new curve fitting technology, the separation point of the laminar boundary layer moves toward the trailing edge of the hydrofoils, and the structure of the reflux eddy is refined. When two bionic hydrofoils were applied to the pump impeller structure, compared with NACA0015, the propulsive water-jet pump designed using the bionic hydrofoil gained from the new cutting fitting technology is in the scope of $0.8\,q_{th}$–$1.2q_{th}$, the head and efficiency are increased by about 7.05 % and 2.22 %, respectively. 28 refs.
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Key Words: *Bionic Hydrofoil, B-Spline, Local Refinement, Transient Cavitation Flow*

Pages 308-319

SIMULATION MODEL OF ADVANCED SYSTEM FOR APPLICATION OF SUSTAINABLE FUELS

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Abstract
On the present, a considerable reduction of the greenhouse gas emissions is one of the most important challenges in construction of the motorcars and their driving units. Application of the biofuels essentially contributes to reduction of air pollution caused by the exhaust gases. However, application of the bioethanol as a fuel in the spark ignition engines requires to perform some important constructional adjustments of these engines in order to ensure their proper functioning and to eliminate the potential operational risks. The scientific publication is focused on creation of a simulation model describing the advanced system, which is developed for application of the sustainable fuels. The scientific contribution of this work consists in original system of the cooling channel, which is applicable in all the high-performance sport applications. There were obtained very good results during testing of this system in real operation, especially in the case of the E85 fuel. Combustion of this fuel, using the above-mentioned system, significantly eliminated thermal loading of the whole drive unit. The authors of this scientific publication also obtained a patent for this system. 15 refs.
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Key Words: *Simulation Model, Advanced System, Sustainability, Biofuel, Combustion*

Pages 320-331

FATIGUE-LIFE EVALUATION METHOD FOR RING-WELDED JOINTS

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Abstract
The *Fa–N* curves of ring-welded specimens were obtained by performing tensile-shear fatigue tests to develop a method for accurate prediction of the fatigue lives of ring-welded joints. The correlation, affecting factors, and survival rate of the *Fa–N* curve were analysed. It was observed that unified *S–N* curve was required to improve the poor correlation and non-universality deficiencies of the *Fa–N* curve. Eight types of finite-element models of a ring-welded joint were established and the C_BAR umbrella finite-element model was used as a simplified model of the ring-welded joint. Subsequently, the Δ*S–N* and *P*–Δ*S–N* curves of the ring-welded specimens were obtained. A comparison with the *Fa–N* curve indicated that the Δ*S–N* and *P*–Δ*S–N* curves were comparatively relevant and universal. Finally, three extrapolation fatigue-assessment methods were proposed to predict the fatigue life of ring-welded joints with unknown plate thicknesses. A comparative analysis was conducted and it was concluded that the prediction using the interpolation extrapolation method had the highest accuracy. The research provides guidance for fatigue-life prediction of ring-welded joints in engineering application. 21 refs.
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Key Words: *Ring-Welded Joints, ΔS–N Curve, Fa–N Curve, Finite Element Simulation, Fatigue Evaluation*

Pages 332-340

PROCESS PARAMETERS OPTIMISATION FOR SPRING SEAT BASED ON RESPONSE SURFACE METHODOLOGY

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Abstract
Due to the complex structure of spring-seat, six steps were adopted from initial blank to finished product. In this paper, simulation of the stamping process of spring-seat with Dynaform platform was presented and the resulting defects of rupture, wrinkling and spring back were the same as those in a certain factory. Aiming at the wrinkling defects of the helical surface in the forming process, die clearance, blank hold force, and friction coefficient were selected as input variables, wrinkling and thickness uniformity were used as evaluation indexes of stamping quality, and the function relation between the evaluation indices of the stamping quality and variables was obtained through response surface methodology (RSM). After optimisation, the wrinkle index decreased by 31.72 %, and thickness uniformity index decreased by 2.85 %. Stamping validation test was conducted using the optimized stamping parameters. The stamping quality of product was evaluated by gauges. Results showed that spring-seat achieved the quality requirements. The numerical simulation results can provide parameters for manufacturing and reduce the cost in development work. 18 refs.
(Received in January 2022, accepted in April 2022. This paper was with the authors 3 weeks for 1 revision.)

Key Words: *Spring Seat, Multistep Stamping Process, Simulation Modelling, Response Surface Methodology (RSM), Stamping Test*

Pages 341-351

NUMERICAL ANALYSIS ON MULTIPHASE FLOW IN NEAR-WALL AND NEAR-BOTTOM AREAS

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Abstract
To mix a solid-liquid multiphase flow more uniformly before filling, this paper numerically analyses the multiphase flow field distribution in the near-wall and near-bottom areas in the agitator tank under the effect of spiral ribbon-frame combined paddle, with the aid of the Eulerian multiphase flow model. The results show that, compared to the spiral ribbon paddle, the combined paddle structure with an additional frame paddle could weaken the high-density aggregation in near-wall and near-bottom areas, and reduce the low-density area on the top, making the flow more uniform. As far as the near-wall area is concerned (200-220 mm from the centre), compared to the combined paddle with oblique outer frame, the combined paddle with straight outer frame improves the uniformity of density distribution for the mixed multiphase flow, stabilizes the volume fraction of each single phase, and reduces the deviation from the set value (4 % - 17 %). The numerical analysis may guide the flow mechanism research of the mixing process of complex solid-liquid multiphase flow, and promote the optimal design of mixing structures. 15 refs.
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Key Words: *Multiphase Flow, Spiral Ribbon-Frame Combined Paddle, Near-Wall Area, Near-Bottom Area, Flow Mechanism*

Pages 352-363

LOW-CARBON PRODUCTION CONTROL AND RESOURCE ALLOCATION OPTIMIZATION

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Abstract
The existing simulation platforms cannot effectively simulate large-scale low-carbon production control systems. To solve the problem, this paper explores the low-carbon production control and resource allocation optimization based on dynamic integrated simulation. Firstly, a multi-level integrated simulation architecture was provided for low-carbon production control, and the core functional modules were introduced in detail. Next, a resource allocation optimization model was constructed under carbon emissions policies. Drawing on the business flows on different levels in different production phases, the authors investigated how to build a simulation model for the process information of low-carbon production, and the multi-resolution basic information of production resources. In addition, the integrated simulation flow was explained fully for the proposed model. The effectiveness of our model was verified through experiments. 28 refs.
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Key Words: *Integrated Simulation, Low-Carbon Production, Production Control, Resource Allocation*

Pages 364-374

BLOCKCHAIN-BASED COLLABORATIVE MANAGEMENT OF JOB SHOP SUPPLY CHAIN

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Abstract
Blockchain supports free and reliable transactions of the production material supply chain (PMSC). However, few scholars have combined the blockchain with supply chain management. Based on blockchain, this paper explores the collaborative management of material supply chain for production and manufacturing job-shops (PMJs). Specifically, a collaborative management model was constructed, and the execution of the smart contract between PMJ and production material supplier (PMS) was explained. Then, the Stackelberg game between PMJ and PMS in the model was analysed, and the calculation method of the total benefit of PMS and PMJ was derived, under the information sharing mode of the blockchain-based PMSC model. Through trust evaluation, the dishonest companies were identified in the PMSC. To ensure the safe and reliable data sharing between the companies in our model, the probability for the dishonest companies to participate in smart contract was reduced, making it less likely for false shared data to appear in the chain. The effectiveness of the proposed blockchain-based model for the collaborative management of PMSC was proved through simulations. 28 refs.
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Key Words: *Blockchain, Production Materials, Supply Chain, Collaborative Management*