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SHEAR LAG EFFECT STUDY OF A COMPOSITE GIRDER CABLE-STAYED BRIDGE DURING CONSTRUCTION

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Abstract
To investigate the shear-lag effect in the main girder of a composite twin-box girder cable-stayed bridge during construction, a full-bridge model and a local spatial model were established using the finite element software MIDAS/Civil and ABAQUS, respectively, for the main span of the Chibi Yangtze River Bridge in Hubei Province, China, as an engineering example. On this basis, the shear-lag effect in the composite twin-box girder under multiple typical construction conditions was analysed through numerical simulation, and the accuracy of the model was verified by field measurements at the construction site. Results demonstrate that as the balanced cantilever construction progresses, the stress in the deck slabs near the junction of the anchor plate and the outer web of the side box girder and at the location of small longitudinal beams changes substantially. However, the stress at other girder sections is gradually uniformly distributed, the shear-lag coefficient tends to be stable, and a phenomenon of positive and negative shear-lag effect conversion occurs in the deck slab sections of the main girder. 23 refs.
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Key Words: *Composite Twin-Box Girder, Construction Stage, Shear-Lag Effect, Stress Test, Finite Element Method*

Pages 567-578

ON THE CHOICE OF THE NUMERICAL CONTACT STIFFNESS PARAMETER FOR THE MODAL ANALYSIS

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Abstract
Modal analysis carried out within the Finite-Element-Analysis leads to natural frequencies and mode shapes. Using adjacent solids in linear dynamics generates a computational contact problem with several configuration parameters. Contact stiffness is of importance as it affects the accuracy and convergence behaviour of the results. Thus, an overlarge value leads to a locking phenomenon and causes ill-conditioned system matrices. This paper investigates whether recommendations for appropriate contact stiffnesses in static mechanics are also applicable to modal analysis. In fact, it can be observed that a significantly smaller contact stiffness than stated in the literature is also well suited for modal analysis. Furthermore, choosing the optimum range for the numerical contact stiffness for modal analysis depends on the order of the natural frequency and the corresponding vibration mode. The results of the simulations are validated against experimental modal analysis of a sample with identical elastic properties. The verified contact settings in the present paper permit a more realistic consideration of contact constraints in modal analysis. 27 refs.
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Key Words: *Finite-Element Modal Analysis, Computational Contact Mechanics, Contact Stiffness, Experimental Modal Analysis*

Pages 579-590

ASSESSMENT OF ASYMMETRICAL STRESS PROFILE WITHIN WOOD USING RESTORING FORCE TECHNIQUE

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Abstract
Asymmetrical internal stress profile within the kiln-dried lumber assessed using the restoring force technique on the half-split specimen has been investigated. Unlike the symmetrical internal stress profile in which the measured restoring force is completely described by an elastic beam theory, the asymmetrical internal stress profile also induces a so-called remnant force. By using the released strain and the elastic modulus data across the entire thickness obtained from the McMillen slice test, a numerical result based on the finite element model successfully simulates the restoring force profile for an entire range of both symmetric and asymmetric stress profiles. The finite element model is leveraged to evaluate the effect of asymmetry of stress profile on the remnant force. The value of the remnant force linearly depends on the stress profile deviation which is inferred to the level of asymmetric stress profile. 19 refs.
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Key Words: *Stress Assessment, Finite Element Model, Elastic Beam Theory, Asymmetrical Stress Profile, Wooden Specimen*

Pages 591-602

A NOVEL SIMULATION-BASED TWO-STAGE OPTIMIZATION APPROACH FOR NURSE PLANNING

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Abstract
Maintaining the dynamism of the work scheduling of the nurses without causing them to lose their work motivation provides the sustainability of the effectiveness of health services. Thus, there is a need to develop patient-centred operational research approach applied to health services against new Covid19 waves or new pandemics. In this context, the aim of this study is to develop a novel simulation-based two-stage optimization approach to determine the required number of nurses and schedule the shifts of the nurse working in the Covid19 inpatient service in a Turkish State Hospital. We develop our model in three stages: 1) A simulation model is developed to specify the weekly required number of nurses and run for the scenarios based on demand increases and patient activity, 2) The first mathematical model is used to determine the weekly number of shifts, and 3) The second mathematical model is applied to prepare a fair nurse shift schedule in the pandemic service. This paper suggests a crucial study that will provide managers of healthcare services to plan ahead for personnel needs problems that may take place in the next waves of the Covid19 pandemic in advance. 21 refs.
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Key Words: *Discrete Event Simulation, Mathematical Modelling, Optimization, Covid19, Nurse Scheduling, Capacity Planning*

Pages 603-614

SHAPE CHANGE SIMULATION ANALYSIS OF WHEEL STEEL IN A FOUR-HIGH HOT ROLLING MILL

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Abstract
To reveal the shape change characteristics during the rolling process of the four-high hot continuous rolling mill, a three-dimensional finite element model was built with the wheel steel 380CL as the sample. The equivalent stress field, strain field, and displacement change of thickness of the wheel steel in each rolling process were analysed, and the field measurement and verification analysis were carried out. Results show that the equivalent stress, strain and thickness displacement of the strip edge gradually increases with the rolling, respectively. Reasonable tension before and after loading can effectively reduce the equivalent stress in the deformation zone and the rolling pressure required during rolling. The difference between the simulated rolling outlet thickness of 7.61 mm and the field measured thickness of 7.69 mm is small, which verifies that the calculation accuracy of the finite element is high. The conclusions obtained in this study provide a basis and reference for the development of similar wheel steel rolling calculation model. 29 refs.
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Key Words: *Hot Rolling, Continuous Rolling, Plate Shape, Finite Element*

Pages 615-626

PARAMETRIC OPTIMIZATION OF TWO POINT INCREMENTAL FORMING USING GRA AND TOPSIS

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Abstract
Different innovative forming methods have been developed in order to make custom made goods at a reasonable cost. Due to stress induced between the tool and die, the procedure facilitates the ability of metal sheets to be formed. The dimensional accuracy of formed items can be improved by selecting the best Two Point Incremental Forming (TPIF) process parameters. In this work, TPIF of SS316L sheets of 0.8 mm was performed by varying the process variables such as die angle, step of forming, rate of feed and tool rotational speed to form a double wall angle circular cone with a forming height of 40 mm. The output responses such as surface roughness and thickness of the formed components were measured. An ANOVA was performed with a confidence level of 95 % to identify the most influential process parameter on the output response. The accuracy of the proposed methods, Grey Relational Analysis (GRA) and TOPSIS, were validated by choosing the optimal process parameter combination resulted from several experimental trial runs. 18 refs.
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Key Words: *Two Point Incremental Forming, Surface Roughness, Thickness, Taguchi, Grey Relational Analysis, TOPSIS, ANOVA*

Pages 627-638

IMPORTANCE OF SUSTAINABLE COLLABORATIVE WORKPLACES – SIMULATION MODELLING APPROACH

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Abstract
The paper presents the use of simulation modelling methods to evaluate the impact of the collaborative workplaces (human-robot collaboration) importance in correlation to the sustainable manufacturing. Based on an example, numerical simulation results of an existing manual assembly workplace and a newly proposed collaborative workplace are presented using production parameters that describe all three key aspects of sustainable manufacturing: economic, social and environmental aspect. A data-driven simulation model was used, mainly using the input parameters of the real-world production system and numerical assumptions obtained from the literature, with the main objective of detailing the impact on the sustainable orientation of the production process. The results presented in the paper demonstrate the high suitability of simulation modelling methods in the evaluation of existing and newly proposed technologies from the sustainable manufacturing point of view. The results demonstrate that collaborative workplaces, if implemented appropriately and using correct input data, are a possible solution that can cope with limited human resources and ensure high production efficiency. 28 refs.
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Key Words: *Sustainable Manufacturing, Manufacturing Efficiency, Collaborative Workplace, Collaborative Robot, Cobot, Simulation Modelling*

Pages 639-650

AN ANFIS-MECHANISTIC SIMULATOR OF TOOL LOADS IN BALL-END MILLING OF LAYERED METAL MATERIALS

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Abstract
This article presents a universal simulator of instantaneous loads on the cutting edges of ball-end mills for the processing of layered metal materials. The ANFIS-mechanistic simulator of cutting edge loads is designed for all typical geometries of ball-end mills and for layered materials with different machinability of individual layers. Two ANFIS (Adaptive Neuro Fuzzy Inference System) models are included in the simulator, which, based on the instantaneous radial thickness of the chip and the geometry of the spherical part of the ball-end mill, predict the material coefficients for the material layers. Comparison of the predicted tool loads with experimental data shows that the simulator accurately predicts the direction and magnitude of the instantaneous loads of the ball-end mill cutting edges when milling 3-layer metal material with different machinability of individual layers. The largest observed deviation of simulated load magnitudes for all verification machining tests is 21.7 %. 35 refs.
(Received in August 2022, accepted in October 2022. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Ball-End Milling, Layered Metal Material, Cutting Edge Loads, Coefficients of Material, ANFIS-Mechanistic Simulator*

Pages 651-662

ANALYSIS OF DIFFERENT POSITIONAL RELATIONSHIPS OF ADJACENT DOUBLE PICKS ON CUTTING FORCE

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Abstract
To optimize the design of the pick arrangement and improve the force state of picks, a finite element model of double pick cutting rock is established by defining the mechanical properties of rock with Holmquist-Johnson-Cook model. The ANSYS/LS-DYNA software is used to analyse the changes in the pick force and rock stress distribution under different cutting depths and spacing between picks when adjacent double picks are used to cut the rock. The results show that the mean cutting force is proportional to the cutting depth when cutting the rock with a single pick. With the increase in the spacing between picks, the mean cutting force of pick 2 increases first and then remains unchanged, and the rate of increase gradually becomes larger with the increase in the cutting depth of pick 2. The mean lateral force of pick 2 increases first and then decreases. Selecting suitable spacing between the picks and cutting depth plays an important role in improving the force state of the picks. This research provides a reference for the optimal design of pick arrangement on the cutting head of roadheaders. 21 refs.
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Key Words: *Numerical Simulation, Adjacent Picks, Spacing between Picks, Cutting Depth, Cutting Force*

Pages 663-674

OPTIMIZATION OF THE SUBASSEMBLY PRODUCTION PROCESS USING SIMULATION

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Abstract
Using simulation as a tool for production process optimization represents a useful approach to exploring many optimization options which lie ahead on the process improvement path. Previously published research papers report on combining the simulation with another optimization method or a set of manufacturing practices or digital technology. To avoid the complexity of the developed optimization approach in practical application, this paper presents an approach that focuses on grouping the parts first and then simulating the parts group schedule, batch size, and parts interarrival time options to minimize production process cycle time and maximise the output quantity. The developed algorithm was tested with the data from a real case, for the production of the subassembly for the metal frame used in automotive parts logistics. The experimental results show improvements in defined performance parameters for set optimization goal. 31 refs.
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Key Words: *Simulation Optimization, Manufacturing, Parts Group Schedule, Batch Size, Interarrival Time, Subassembly Process*

Pages 675-683

SIMULATION OF FINANCING DECISIONS WITH BEHAVIOURAL PREFERENCES AND YIELD UNCERTAINTY

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Abstract
We consider a two-level supply chain comprising a retailer and capital-constrained farmer, with three cases of behavioural preferences: stockout aversion (SA), waste aversion (WA), and stockout and waste aversion (SW); the farmer can solve financial constraints through bank loans and internal financing. We analyse the financing decision simulation of the farmer in a yield uncertain environment. The results show that – regardless of the preferences of the farmer – the largest expected utility and production input of the farmer and the expected profit and order quantity of the retailer are those under internal financing, followed by bank loans and non-financing. Finally, we analyse the influence of the farmer's SA and WA on the expected utility (profit) and decision-making of supply chain members by numerical simulation. Most supply chain studies do not factor in the high risk faced by farmers. Our study provides data on various option outcomes for those advising farmers facing difficult financing decisions. 24 refs.
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Key Words: *Financing Decisions, Stockout Aversion, Waste Aversion, Yield Uncertainty, Supply Chain*

Pages 684-695

A COMBINED SERVICE OPTIMIZATION AND PRODUCTION CONTROL SIMULATION SYSTEM

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Abstract
Manufacturing resources are the core resources for intelligent manufacturing enterprises. It is of great practical significance to improve the reliability and stability of production control in a dynamic production environment with long-term frequent disturbances. This paper explores the simulation system design and development for combined service optimization and production control of intelligent manufacturing. After specifying the system architecture, modelling and matching were carried out according to the specific requirements of intelligent manufacturing combined service objects in the production process. Next, a six-tuple was introduced into the service provided by the production control system combined with the Internet of things (IoT), the formal definition was given to the IoT service and intelligent manufacturing combined service, and the key parts were described in detail with the overall service description and combined service description of the six-tuple as examples. Through experiments, the results of the simulation system were outputted. 28 refs.
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Key Words: *Intelligent Manufacturing, Combined Service Optimization, Production Control, Simulation System Design and Development*

Pages 696-707

IOT-BASED DISTRIBUTED SIMULATION OF INDUSTRIAL AUTOMATION PRODUCTION LINE MANAGEMENT

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Abstract
The IoT maximizes the information and intelligence of large-scale producers, and greatly improves the supervision quality and efficiency of production lines. Existing research fails to use modern logistics simulation for distributed simulation, verification and analysis of industrial automated production line management (IAPLM). Thus, this paper studies the distributed simulation of IoT-based IAPLM. The time domain, component information and other elements are introduced into the distributed Petri network model to realize the optimization of the logic model of the industrial automation production line. The key points of distributed simulation design of IAPLM are introduced in detail, and the timing design of the production process, the mapping of logical model to distributed simulation platform, the structured processing of models, and the construction of simulation strategies for production equipment control are completed. Experimental results verify the effectiveness of the proposed model. 27 refs.
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Key Words: *IoT, Industrial Automated Production, Production Line Management (PLM), Distributed Emulation*

Pages 708-719

SIMULATION OF IMPACT OF RESOURCE COMPETITION ON SHARED RESOURCE UTILISATION

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Abstract
This study aims to address the problem that the uncontrolled business response process of resource-matching platforms (RMPs), which leads to resource competition. The system dynamics (SD) is applied to obtain optimisation policy of the platform's resource utilisation from a production system. The business transaction system of RMPs is considered as a complex social and economic system. Then the SD simulation model of the business response process of RMPs is established, for which the success rate of demander response and resource utilisation are used as observation indices. Simulations of influencing factors were conducted from the perspective of platform controllability. It is indicated that the decision attributes especially the expected profit and the resource distribution have impacts on the user response, transaction success rate and the resource utilisation; and the influence of decision distribution is more obvious than that of decision attributes. An improvement in each of these factors can promote the response success rate and resource utilisation. These conclusions provide guidance for the coordination of resource competition and resource scheduling of the platforms. 20 refs.
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Key Words: *System Dynamics, Resource Matching Platform, Resource Utilisation, Demander Response Success Rate, Business Response*

Pages 720-731

DEMAND PREDICTION OF PRODUCTION MATERIALS AND SIMULATION OF PRODUCTION MANAGEMENT

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Abstract
In modern times, production management must quickly respond to the fluctuations in the demand for production materials by production equipment oriented to different orders. This calls for a reasonable plan for production management. Based on Markov model, this paper explores the demand prediction of production materials, and investigates the simulation of production management. Firstly, the grey system model and the Markov chain model were combined into a hybrid prediction model for the dynamic and time-varying demand for production materials in the production process. Through dynamic scenario analysis, the authors explored the formulation of production management and control strategies under multiple uncertain demands for production materials, and gave the specific analysis process. Multiple performance indices were considered synthetically, the optimization objectives of production control simulation were given under the multiple uncertain demands for production materials, and a solution was put forward for the production control problem. The simulation results verify the effectiveness of the proposed model. 25 refs.
(Received in August 2022, accepted in November 2022. This paper was with the author 1 month for 1 revision.)

Key Words: *Markov Model, Demand Prediction of Production Materials, Simulation of Production Management*