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CONSTRAINED RANKING AND SELECTION FOR OPERATIONS OF AN EMERGENCY DEPARTMENT

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Abstract
We consider a problem of finding the optimal number of medical staffs for an emergency department through stochastic simulation. Specifically, the objective is to maximize the expected net profit per period of the emergency department while confining the maximum duration of expected waiting times of critical and noncritical patients. This is formulated as a simulation optimisation problem with two stochastic constraints on waiting times. To find the optimal solution of the problem under statistical guarantees, we introduce a two-step fully sequential ranking and selection framework: we first determine a set of strictly feasible solutions and then select the best solution among them. We implement the proposed framework via Simio and apply it to an emergency department of a university hospital. 24 refs.
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Key Words: *Healthcare Management, Emergency Department, Simulation, Ranking and Selection, Simio*

Pages 576-589

SIMULATION OF BULLWHIP EFFECT IN A SUPPLY CHAIN FOR LEAN LEARNING FACTORY PURPOSES

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Abstract
A mission of the Learning Factory (LF) is a development of practice-based engineering curriculum through the simulation of a real factory by specialized equipment. In this paper, supply chain network simulator is developed, as a replacement for the traditional board Beer Game. The board Beer Game could be misused by participants in order to avoid significant bullwhip effect, which occurrence is the Beer Game main aim. The disadvantage of the board Beer Game, that participants have insight in inventory levels and placed orders and thus strategically act upon their knowledge or even activate a sort of decentralized information sharing policy, is avoided. Further considerations prove the mandatory occurrence of bullwhip effect without decentralized information sharing policy on three case studies. Optimal mathematical model for placing orders within a supply chain was defined according to multi-criteria optimization process using spreadsheet simulation. As even optimal model results with the bullwhip effect, newly developed system will always lead to the tremendous bullwhip effect during the learning process. 26 refs.
(Received in December 2016, accepted in May 2017. This paper was with the authors 1 month for 1 revision.)

Key Words: *Supply Chain Network, Bullwhip Effect, Inventory Level, Beer Game, Learning Factory*

Pages 590-602

NUMERICAL SIMULATION OF EFFECT OF FRICTION DIRECTIONALITY ON FORMING OF ANISOTROPIC SHEETS

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Abstract
The anisotropy of frictional resistances is often omitted in finite element method (FEM) based numerical modelling of industrial processes of sheet metal forming. The aim of this paper is to analyse the effect of anisotropy of frictional phenomena on the formability of drawpieces. As a benchmark experiment, the formability of cylindrical cups is carried out, and as a benchmark material the deep drawing quality (DDQ) steel sheets are used. The effect of friction phenomena on the formability of cylindrical cups is studied using finite element based program ABAQUS/Standard 3DExperience R2016x HF2. The results of predicted location and height of ears allow concluding that material and frictional anisotropy of sheet metals are the main factors that determine high conformity of the finite element based numerical simulation results with the experiments. Comparison of numerical results demonstrates great potential of Hill yield criterion incorporated with the anisotropic friction model in accurate prediction of earing. 30 refs.
(Received in February 2017, accepted in June 2017. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *ABAQUS, Finite Element Method, Friction Anisotropy, Sheet Metal Forming*

Pages 603-616

LAYOUT OPTIMIZATION OF A PRODUCTION CELL

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Abstract
An analysis of a product line of small and medium-sized enterprises (SME) shows that products (component parts or assemblies) are quite similar in terms of design and technology, thus clusters of products are formed. For each cluster a production cell can be organized. According to the product line of a company a certain number of individual production cells is organized, while workshop production is retained for the remaining product line.

The paper shows how clusters of products are designed on the basis of a product line data and how an ideal layout optimization is determined on the basis of the intensity of material flow. Layout optimization of a production cell is based on a combination of Schmigalla modified triangular method and the Schwerdfeger circular process. The method was applied on a cluster of 20 orders similar in design and technology that are processed at 10 workplaces. At the end of the article a transition from a theoretical O-cell to a real U-cell is suggested. 31 refs.
(Received in April 2017, accepted in August 2017. This paper was with the authors 1 week for 1 revision.)

Key Words: *Layout Optimization, Manufacturing Cell, Discrete Event Simulation, Clustering, Algorithms*

Pages 617-629

ROBOT AND PLANT SIMULATION FOR AUTOMOTIVE PART PRODUCTION PROCESS DESIGN: A CASE STUDY

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Abstract
Due to the higher competition in automobile industry, automotive part manufacturers who supply parts have also been challenged to improve the quality of their products to meet customers' requirements. Quality of parts or products could be controlled and improved since the stage of production process design. Efficient production process design could reduce work in process (WIP), wastes, reworks, errors, and failures, which could reduce system cost and increase quality of final products. However, production process design for the process which implements automatic systems is sophisticate due to the complication of the equipment itself and the synchronization requirement. This study presents the use of computer simulations to design an automotive part production process. Two objectives are proposed. The first one is to introduce three dimension robot (3D CAD) simulation for robotic work stations designed to meet the desired cycle time with minimum chance of robot collision and minimum number of robots in the system. The second one is to propose plant simulation for production planning design in order to produce product which could meet the desired capacity and customer needs with minimum number of workers. 23 refs.
(Received in April 2017, accepted in August 2017. This paper was with the authors 1 month for 1 revision.)

Key Words: *Robot Simulation, Plant Simulation, Production Process Design, Automotive Part Manufacturing*

Pages 630-643

MODELLING AND PARAMETERIZING PEDESTRIAN BEHAVIOUR IN PUBLIC PLACES: A REVIEW

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Abstract
Literature and practice show a huge interest in modelling pedestrian behaviour, especially in public spaces. The most relevant applications are thereby traffic control, safety, and public security. Understanding the existing frameworks and finding possible measures and parameters for the models are a prerequisite to build a realistic model but very challenging. A literature review was conducted to collect, discuss and compare well-known and frequently cited models in order to derive implications for future models. The models were analysed from multiple points of view, namely the abstraction level, environment space, and behaviour types. Their parameterization was considered on both levels: microscopic and macroscopic. Advantages and disadvantages, difficulties and solution approaches of existing models were studied and discussed. Also, the data foundation is discussed, as a model should not only depend on artificial data and assumptions, which might lightly represent the subjective opinion of the model builder. Some technical approaches are proposed to overcome this difficulty. An analysis of various publications brings a structural and detailed perception about modelling pedestrian behaviour in crowds. 50 refs.
(Received in April 2017, accepted in September 2017. This paper was with the authors 2 months for 2 revisions.)

Key Words: *Pedestrian Behaviour, Modelling Passenger Flow, Crowd Behaviour, Modelling Public Place, Evacuation*

Pages 644-657

AN EFFECTIVE USE OF HYBRID METAHEURISTICS ALGORITHM FOR JOB SHOP SCHEDULING PROBLEM

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Abstract
This paper presents an effective use of hybrid metaheuristics algorithm for solving Job Shop Scheduling Problem (JSSP). Integration of three metaheuristics algorithms: Shuffled Frog Leaping Algorithm (SFLA), Intelligent Water Drops algorithm (IWD) and Path Relinking (PR) algorithm were put together to solve JSSP. First, simulation model was developed and tested on the test data of Traveller Salesman Problem (TSP). Second, the model was tested on real world production line to solve the problem of Minimum Needed Workers (MNW) at the production line. The model enables individual test of three mentioned algorithms and calculation of new proposed Random Multi-Neighbourhood based Shuffled Frog Leaping Algorithm with Path Relinking (RMN-SFLA-PR). Experiments were tested on two software environments MATLAB and Simio, which gives us reliable, robust and tangible results. Results show that the new proposed RMN-SFLA-PR algorithm converged to optimum almost ten times faster than individual algorithms. The most important thing is the successful rate of all independent runs of the proposed RMN-SFLA-PR is 100 % in low-dimensional cases of the 4 benchmarks (dj38) and in JSSP to solve MNW for the real world production line. 24 refs.
(Received in April 2017, accepted in September 2017. This paper was with the authors 2 months for 1 revision.)

Key Words: *Job Shop Scheduling Problem, Metaheuristics Algorithm, Shuffled Frog Leaping Algorithm, Path Relinking, Random Multi-Neighbourhood Structures*

Pages 658-669

DYNAMIC CHARACTERISTICS OF COUPLED VEHICLE–TRACK–TUNNEL INTERACTION SYSTEM

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Abstract
Traditional studies simplify vehicle–track–tunnel system into vehicle–track or vehicle–tunnel models and neglect dynamics influences of vehicle on tunnel through track or track–tunnel on vehicle. This study established the mathematical model of vehicle and finite element model of track–tunnel to disclose vibration characteristics of vehicle–track–tunnel coupled dynamic system. Next, a vehicle–track–tunnel dynamic coupled model was established based on the wheel–rail displacement coordinated relation. Finally, variation laws of vehicle and stress and displacement fields of tunnel surrounding rock when the train travelled at speed of 200 km/h were studied under different track slab stiffness and track structures. Numerical simulation results demonstrate that vehicle vibration indexes change in the linear law with the increase in track slab stiffness. Sleeper embedded ballastless slab track has better damping reduction performance than sleeper buried ballastless slab track. The best damping reduction performance is achieved when the track slab stiffness is 3.5 kPa. The maximum vertical displacement and stress of the tunnel surrounding rock due to vibration at low levels and the tunnel surrounding rock slightly influence vibration indexes of vehicles. 20 refs.
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Key Words: *Vehicle–Track–Tunnel Coupled System, Equilibrium Equation, Vehicle Motion Quality, Dynamic Characteristics, Track Irregularity*

Pages 670-681

MODELLING OF SPECIAL EQUIPMENT SUPERVISION GAME CONSIDERING RISK EXPECTATION

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Abstract
To reveal the causes of unlawful behaviours between special equipment quality supervision institutions and third-party special equipment inspection institutions, an evolutionary game model was developed. Since the expected payoff matrix frequently used in general game model cannot accurately describe the influence of the risk expectations, the prospect value function was proposed to build the revenue perception matrix of the model. Then, the evolutionary characteristics were analysed through replicator dynamics equations. Accordingly, the evolutionary stable strategies were obtained based on the Jacobian matrix. Moreover, the dynamic evolution phase diagrams were formulated to describe the behaviours. Finally, numerical simulation examples were conducted to investigate the evolutionary path and the evolutionarily stable strategies. Results show that the probability of the third-party special equipment inspection institution choosing the passive performance strategy is negatively correlated with the expected risk value. The supervision probability of the quality supervision institution is directly proportional to the social benefits. In addition, the supervision probability is dependent on the penalty risks, and the initial population scale. 21 refs.
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Key Words: *Prospect Theory, Third-Party Special Equipment Inspection Institution, Supervision Strategies, Evolutionary Game*

Pages 682-693

IMPROVEMENT OF PRODUCTION EFFICIENCY OF TAPERED ROLLER BEARING BY USING PLANT SIMULATION

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Abstract
The aim of this article is to create a simulation model of specific production system in Plant Simulation environment. The main production program that we monitor in this article is focused on the production of tapered roller bearings. Types of produced products are wide; therefore we focus attention on a material flow of one particular dimensional type of bearing. This article is divided into five parts. In the first part there is a theoretical overview of utilization of the system module Plant Simulation. The second part is focused on product that will be used for simulation process, concretely tapered roller bearing 32303A. Third part deals with analysis of simulated system model in Plant Simulation. Fourth section is oriented on proposal of monitored production system optimization in Plant Simulation and final fifth part is about benefits evaluation of the proposed solution. 29 refs.
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Key Words: *Tapered Roller Bearing, Simulation Process, Plant Simulation, Production System, Optimization*

Pages 694-706

SIMULATION ANALYSIS OF A NEW CHIPS RECYCLING PROCESS TERMED FORMING EXTRUSION CUTTING

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Abstract
Every year an enormous amount of metal scraps are produced from machining, causing waste and pollution. The existing recycling methods, such as melting and solid state recycling could not solve the problem of cumbersome processes and high costs, while in this study, a novel chips recycling process, namely the Forming Extrusion Cutting (FEC) was provided. It could turn irregular chips into grooved strips with industrial value during cutting, resulting in advantages such as high efficiency, low costs and high flexibility.

In this study, the FEC deformation was studied through finite element model analysis, while various structures of pure copper grooved strips were prepared with forming conservation rates beyond 80 %, confirming that the FEC could be adjustable in the production of strips with various groove structures. Furthermore, the grooved strips surfaces had abundant substructures, which meant that the grooved strips prepared by FEC had a wide range of applications and high potential for development in the heat transfer field. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Chips Recycling, Forming Extrusion Cutting (FEC), Metal Cutting, FEM, Grooved Strips*

Pages 707-719

DYNAMICS ANALYSIS AND PLANNING FOR A SPECIFIC LEG MODEL WITH A VARIABLE STIFFNESS ELEMENT

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Abstract
Variable compliant elements in the leg play an important role in quadruped mammals' locomotion. This paper mainly investigates the dynamics characteristics of a specific leg model with a variable stiffness element during the stance phase. By choosing appropriate initial states and planning joint motion under specific constraint conditions, the model is able to move normally and pivot about the contact point. Particularly, the passive motion of the variable stiffness element is planned based on forced vibration characteristics and is set to experience a compression and extension process. In a detailed study, the optimal combination of the system parameters, meeting constraint conditions, were evaluated. We investigated the effects of the initial states on the leg's motion, and obtained the necessary variable stiffness characteristics under different conditions. The ground reaction features of the leg model present similar characteristics to those of a canine. A variable stiffness device with a good adjustability feature and a large adjustable range is discussed. 18 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Leg Model, Variable Stiffness, Quadruped Robots, Dynamics Analysis, Motion Creation*

Pages 720-730

AN OPTIMIZATION MODEL FOR AUTOMOBILE MIXED ASSEMBLY LINE UNDER MULTIPLE CONSTRAINS

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Abstract
To solve the problems in planning and design of automobile mixed-model assembly line, this paper puts forward the improved genetic algorithm-based equilibrium optimization algorithm for the automobile mixed assembly line and establishes corresponding theoretical model. The convergence and feasibility of the model are analysed, and the optimization model presented in this paper is verified by the assembling situation of the actual assembly line of an automobile door. The research conclusions are as follows. The optimized scheduling mathematical model under multiple constrains of the automobile assembly line was established and improvements were made to the traditional genetic algorithm. Self-adaptive genetic operator was added to the original model. The performance verification indicated that the time consumption of CPU in the proposed improved algorithm is much less, and its maximum load is larger, so it has better convergence compared with traditional genetic algorithm. The improved optimal algorithm of automobile mixed ASSEMBLY LINE was verified taking into consideration such constraint conditions as the proportion of a single product put into assembly line, staffing, and balance of the left door and right door. It is found that the overall balance efficiency is about 92 %, reaching the standard for leaving factory. When the proportion of a single product that was put into production gradually rises, the overall time-consumption of the whole assembly line becomes shorter and shorter and the balance efficiency of the mixed assembly line presents a "U-shape" variation trend, first decreasing and then increasing. The growth of workers doesn't have an obvious impact on the assembling time consumption. 23 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Automobile, Mixed Assembly Line, Constraint Conditions, Optimization, Improved Genetic Algorithm*

Pages 731-741

A MULTI-OBJECTIVE LOT-STREAMING OPTIMIZATION SCHEDULING MODEL CONSIDERING THE BLOCKING EFFECT

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Abstract
In view of such difficulties as multi-objective, multiple constraints and the uncertainty of calculating parameters in product line scheduling, the multi-objective batch scheduling model considering the blocking effect was constructed. The feasibility and superiority of the algorithm in this paper are verified through carrying out a comparison between the model in this paper and the traditional assembly line scheduling. The research conclusions are as follows. The probability distribution model is established using discrete product coding way to enhance the quality of initial population. The application of restarting mechanism can improve the diversity of population. The blocking constraints occurring in the processing of adjacent machines are considered, and multiple lot-streaming flowshop scheduling model considering the blocking effect is taken into consideration. The solutions to the problem of obstruction are sought by using hybrid artificial swarm method. The global convergence of the model is enhanced utilizing the Pareto local search method. The original cross operator is improved with the information of non-dominated solutions and new generations are generated. The established model is compared with the traditional flow shop model. It is verified that the algorithm in this paper has fairly high global convergence and can generate high quality solution. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Production Line, Optimal Scheduling, Multiple Target, Improved NSGA-II Algorithm, Blocking Effect*

Pages 742-753

DYNAMIC CONTACT ANALYSIS AND TOOTH MODIFICATION DESIGN FOR EMU TRACTION GEAR

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Abstract
Taking traction helical gear of EMU CRH380A as an example, the meshing characteristics was analysed. Based on Pro/E, three-dimensional helical gears were modelled. Combined with ANSYS, the gears' contacts were analysed under multi-condition, such as start-up, continuous and high speed. Through transient dynamics, the distribution cloud of the equivalent stress and contact pressure in a meshing period are solved, which at different meshing position under different condition. And the contact state, the stress changes and distribution regularity in the meshing process were analysed. Then on the basis of the results, gear modification parameters were designed, and the modification gears finite element model were constructed. To compare gear contact stress distribution before and after being modified, it shows that the modification scheme can effectively reduce the gear meshing impact and the transmission noise. 19 refs.
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Key Words: *EMU (Electric Multiple Units) Traction Helical Gear, Traction under Multi-Condition, Finite Element Model, Dynamic Contact Analysis, Modification Design*