International Journal of Simulation Modelling – **Volume 17, Number 4**

Pages 569-582

A STUDY OF FRICTION MODEL PERFORMANCE IN A SKEW ROLLING PROCESS NUMERICAL SIMULATION

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Abstract
This paper studies the influence of diverse friction models on the numerical analysis of an industrial skew rolling mill using FORGE®. The originality of the present contribution is the analysis of the effect of the friction model on important parameters, namely, consumed power, plastic deformation and surface temperature. The aim is to evaluate which of these friction models is appropriate for simulating these industrial processes. The high values of temperature, pressure and sliding velocity at the contacts make the assessment of the friction model incidence on the deformation and temperature evolution fundamental, given its importance on the thermomechanical processing of materials. As a conclusion, IFUM is not valid because of its sliding velocity approach. On the other hand, Neumaier presents the highest deviations in terms of experimental power. It is concluded that Tresca is valid for this sort of processes and Norton model gives the most accurate results for friction power, related to the high sliding conditions at the contact. 27 refs.
(Received in March 2018, accepted in August 2018. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Friction Model, Friction Law, Metal Forming, Skew Rolling Mill, Numerical Analysis*

Pages 583-596

UTILIZATION OF COMPUTER SIMULATION FOR WASTE SEPARATION DESIGN AS A LOGISTICS SYSTEM

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Abstract
The article discusses the problem of total waste separation in the frame of a computer simulation design of these systems. The aim of the article is to employ computer simulation, modelling and logistics for the needs of total separation of waste and its recycling into the form of raw materials and re-usable resources in practice. The results of the computer simulation show that by using total separation and waste recycling in the specifically analysed region, it is possible to produce approximately 7700 tons of recycled paper, 2400 tons of multilevel packages, 8000 tons of glass, 3000 tons of old textiles, 3500 tons of iron, approximately 1500 tons of non-ferrous metals, approximately 2700 tons of wooden pallets, approximately 1200 tons of rubber granulate, to process approximately 800 tons of dangerous waste, 2400 tons of electro waste, 2100 tons of gravel, 840 tons of sand and to liquidate approximately 3200 tons of non-recyclable waste during the whole year. 34 refs.
(Received in March 2018, accepted in June 2018. This paper was with the authors 1 week for 1 revision.)

Key Words: *Computer Simulation, EXTENDSIM, Waste Separation, Logistics, Design*

Pages 597-608

SIMULATION OF RANDOM TAGGED ORE FLOW THROUGH THE BUNKER IN A BELT CONVEYING SYSTEM

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Abstract
Modelling the flow of a non-homogeneous ore is an important element needed to identify ore parameters for the purpose of ore processing control. The simulation model of the underground ore haulage system with the implemented function of estimating ore qualitative and quantitative parameters was built in the dedicated FlexSim simulation environment to address this issue. The transported ore is averaged in transfer and retention points, for instance in ore bunkers. This fact renders the modelling of ore flow inside the bunker a necessary part of the simulation. The movement of the granulated material, restricted by the geometry of the floor and walls, is modelled using Discrete Elements Method (DEM) with regard to the technological cycles of bunker filling and emptying. An experimental task was conducted on the site to identify the transport time of RFID tags that flowed together with the portions of ore they annotated. Empirical model of the transport system in the KGHM Lubin mine was parameterized with mean retention times obtained in DEM simulations in order to be compared with the RFID-tag experiment. The as-parameterized FlexSim simulation for one-chute bunker discharge variant yields tag transport times comparable with the experimental data. The results proved the reliable description of the ore transport time in the FlexSim model. 24 refs.
(Received in March 2018, accepted in August 2018. This paper was with the authors 1 week for 1 revision.)

Key Words: *Discrete Elements Method, FlexSim, Empirical Model, RFID, Ore Transport, Ore Bunker*

Pages 609-622

DETERMINATION OF OPTIMAL PRODUCTION PROCESS USING SCHEDULING AND SIMULATION SOFTWARE

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Abstract
The objective of the article is to present the linking of simulation and planning software. The paper begins with a review of recent literature as well as description of the problem under investigation. Following from practical requirements, five decision-making rules were implemented to the production process. In the final part, the overall results to ensure time and economic efficiency of the production process are presented. The obtained results show that the best option is to apply the rule during which the first part to be machined is the one that first enters the production process to ensure minimum production time, maximum machine load and limit machine costs. By application of this rule, the total production time accounts for 524 seconds at the total cost of 7914.60 €. The overall benefits of the research are being described in details in the final part of the article. 26 refs.
(Received in April 2018, accepted in July 2018. This paper was with the authors 1 week for 1 revision.)

Key Words: *Simulation Software, Scheduling Software, Time Efficiency, Economic Efficiency*

Pages 623-632

DEVELOPMENT OF A FRAMEWORK FOR BALLISTIC SIMULATION

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Abstract
The ability to predict the trajectory of ballistics under the effect of environment is a crucial factor to guarantee the fidelity of ballistic simulator systems. Therefore, this research focuses on developing a framework for modelling and simulating the trajectory of ballistics under the complex effect of environment in reality. From the beginning, the overview of framework is given which includes the process to generate the aerodynamic databases and the models for flight dynamics such as gravitational force, Coriolis force, propulsion model and environmental model especially. A data treatment method is proposed to optimize the calculation of aero databases in which the low-fidelity and high-fidelity data are fused to obtain the most accurate data as possible while minimizing the computational resources. In addition, details of non-linear flight dynamics model are analysed and make a clarification in the dynamic model section. The environmental model is also mentioned and presented in this section. Finally, several simulation results are shown to validate and verify the mathematical models of framework for ballistic simulation and then demonstrate the efficiency in calculating the trajectory with and without effect of the environmental model. 18 refs.
(Received in May 2018, accepted in September 2018. This paper was with the authors 1 week for 1 revision.)

Key Words: *Trajectory, Non-linear Dynamics, Ballistic Simulation, Environment Effect, Multi-Fidelity Analysis, Flight Simulation*

Pages 633-642

LEARNING THE PROCEDURE ON TAKT PRODUCTION OF TPS BY METHODS ENGINEERING AND SIMULATION

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Abstract
A systematic procedure of experiments, performing simulation in conjunction with work measurement techniques, is introduced and aimed at undergraduate students in Industrial Engineering (IE) to learn a basic procedure for designing and implementing takt production in terms of the Toyota Production Systems (TPS). Students are split into small groups in a class. A series of experiments is designed and performed for an assembly line of magnetic contactors. Using the concept of the TPS, students perform work measurement studies including time study, process design, such as line balancing, and execute simulation experiments. At the end of the course, the teaching staff evaluates each group based on the performance of the simulation results. 16 refs.
(Received in May 2018, accepted in August 2018. This paper was with the authors 1 month for 1 revision.)

Key Words: *Simulation Education, Takt Production, Toyota Production System (TPS), Work Measurement Technique*

Pages 643-656

ANALYSIS OF SPIRAL AGGREGATE DEVICE ON THE SUMP CLEANING MACHINE BY DISCRETE ELEMENT METHOD

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Abstract
Sump cleaning machine is important coal mine equipment designed to reduce the labour intensity of underground workers, and its front end usually uses a spiral aggregate device. However, the traditional empirical design methods cannot accurately obtain the optimal parameters and defects in design of the spiral aggregate device due to the complex structure. To improve the design approach, the discrete element numerical model of the working process of the spiral aggregate device was constructed to conduct simulation research and design three key parameters, namely, screw shaft speed, roof inclination angle of the feeding port, and number of throwing plates. Results demonstrate that the aggregate rate increases first and then decreases with the increase in the rotating speed of screw shaft. In addition, the increase in the number of throwing plates is beneficial to improve the stability of the axial movement of slime water. The roof inclination angle of the feeding port has no significant influence on the aggregate effect. The results provide guidance for improving the structure of the spiral aggregate device and a reference for optimizing the design of complex screw mechanisms. 24 refs.
(Received in June 2018, accepted in September 2018. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Discrete Element Method, Sump Cleaning Machine, Spiral Aggregate, Conveyor*

Pages 657-666

AUTOMATED TOPOLOGICAL CLUSTERING OF DESIGN PROPOSALS IN STRUCTURAL OPTIMISATION

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Abstract
Topology optimisation provides support in designing new components. However, the inbuilt multitude of optimisation parameters (penalty factor, etc.) as well as the finite element parameters (mesh, etc.) influences the simulation results and leads to a multitude of design proposals, which have to be evaluated manually by the product developer. Therefore, an evaluation algorithm was developed, which is able to quantitate the structural resemblance of two design proposals. By enabling a computer to generate and process both the visual compare and its result, it is possible to cluster design proposals that share the same major topology. So systematic parameter studies are simplified and this provides a deeper simulation and product understanding. 23 refs.
(Received in June 2018, accepted in August 2018. This paper was with the authors 1 week for 1 revision.)

Key Words: *Evaluation Tool, Topological Clustering, Design Automation, Simulation Based Design*

Pages 667-676

REDUCTION OF SURFACE DEFECTS AND OPTIMIZATION OF CONTINUOUS CASTING OF 70MnVS4 STEEL

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Abstract
High-strength steel 70MnVS4 is often used for forging connecting rods in the automotive industry. Connecting rod performance depends also on surface quality. Several defects, including surface defects, originate from the continuous casting process. The paper presents the monitoring of the most influential parameters (casting temperature, type of mould steel jacket, casting speed, water flux in the mould and the difference between input and output water temperature in the mould) during continuous casting of 70MnVS4 steel. Also the results of surface control of the rolled material (automatic control line) were collected. Using the gathered data, the model for predicting the ratio between material with surface defects and the examined material was developed using linear regression and genetic programming. Based on modelling results, only one type of mould steel jacket was used, while casting speed and mould water flow were increased from 1.13 m/min to 1.18 m/min and from 1300 l/min to 1500 l/min, respectively. In the period from January 2015 to October 2018 the scrap rate of 70MnVS4 and overall scrap rate was reduced by 22.29 % and 18.04 %, respectively. 33 refs.
(Received in July 2018, accepted in September 2018. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Steel, Continuous Casting, Surface Defects, Casting Parameters, Modelling and Optimization, Genetic Programming*

Pages 677-689

SIMULATION FOR TRAJECTORY TRACKING OF MULTI-FLEXIBLE-LINK SPACE ROBOT WITH DEADZONE

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Abstract
Trajectory tracking is a key step for a free-floating space robot (FFSR) system to complete a space operation. However, the flexibility of links and deadzone in joint input torque decrease the system's trajectory tracking accuracy. The angle tracking for the multi-flexible-link FFSR was discussed to suppress the vibrations of the flexible links and prevent the influence of the deadzone. First, the dynamic equation of the FFSR system was derived. Second, the FFSR system was decomposed into the slow and fast subsystems. Then, for the slow subsystem, a robust control method based on a nominal model and a deadzone estimation compensator were proposed. For the fast subsystem, a linear quadratic regulator optimal method was used to actively suppress vibrations. Finally, experiments were carried out to verify that the FFSR is capable of effectively tracking the desired trajectory. The simulation results show the robustness of the control scheme. It effectively suppressed the vibrations as the vibration modes of the links convergent to zero. This study provides a control scheme for improving the trajectory tracking accuracy of FFSR, which is of practical importance. 21 refs.
(Received in July 2018, accepted in September 2018. This paper was with the authors 2 weeks for 2 revisions.)

Key Words: *Multi-Flexible-Link Space Robot, Deadzone, Trajectory Tracking, Flexible Vibration Suppression*

Pages 690-701

OPTIMIZATION OF THE INTELLIGENT WORKSHOP CONTROL BASED ON THE IMPROVED GROUP LEADERSHIP OPTIMIZATION ALGORITHM

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Abstract
This paper takes the existing optimized single product production scheduling scheme as the cloud service resource, and the production planning scheme for the product to be processed as the request task, and then subjects the two to semantic search and matching to generate a set of optimal production planning schemes. Then this paper innovatively takes the minimum production and processing cost, processing time, equipment state and minimum transport distance in product processing as the objective functions, and uses the penalty function to establish the fitness function to constrain the group leader optimization algorithm. After that, the proposed improved group leader optimization algorithm (GLOA) is used to screen the generated scheme set, and finally the optimal intelligent workshop control and scheduling scheme is obtained. The simulation results show that the proposed GLOA algorithm achieves a good convergence and is well adaptable. The research conclusions can provide theoretical reference for the intelligent workshop control and scheduling in single product manufacturing. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Intelligent Workshop, Optimization of Scheduling Control, Group Leadership Optimization Algorithm, Penalty Function*

Pages 702-711

GENETIC ALGORITHM-BASED DESIGN AND SIMULATION OF MANUFACTURING FLOW SHOP SCHEDULING

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Abstract
This paper applies the non-dominated sorting genetic algorithm (NSGA) to the design of non-compact flow shop scheduling plan, and successfully solves the multi-objective optimization problem considering process connection. Specifically, an NSGA-based scheduling strategy was developed after analysing the features of the non-compact flow shop in manufacturing enterprises, and an improved algorithm was created for the multi-objective optimization of non-compact flow shop scheduling considering process connection. The research results show that: the improved NSGA is a desirable way to solve the multi-objective optimization of non-compact flow shop scheduling, as it ensures the population diversity and guarantees the evolution effect; this algorithm is more realistic than traditional algorithms, which overlooks the process connection; the case simulation and analysis reveal that the established multi-objective scheduling model for non-compact flow shop enjoys good adaptability. The research finding carries profound theoretical and practical significance for enterprises, e.g. improving the scheduling of non-compact flow shop, production efficiency and response to market situations. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Non-Dominated Sorting Genetic Algorithm (NSGA), Manufacturing Enterprises, Non-Compact Flow Shop, Multi-Objective Job Shop Scheduling*

Pages 712-723

LOW-CARBON FLEXIBLE JOB-SHOP SCHEDULING BASED ON IMPROVED NONDOMINATED SORTING GENETIC ALGORITHM-II

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Abstract
Considering the impacts of multiple production objectives, makespan and low carbon factor on job-shop scheduling optimization, this paper puts forward a novel low carbon scheduling method for flexible job-shop based on the improved nondominated sorting genetic algorithm-II (NSGA-II). Firstly, a low-carbon scheduling optimization model was established for multi-objective, multi-speed job-shop. Then, the flow of the NSGA-II-based core algorithm was explained, and the new population selection was optimized through the calculation of congestion and nondominated level. Finally, multiple simulation examples were adopted to validate the proposed algorithm. The results show that the proposed NSGA-II low carbon optimization algorithm can converge to the global best Pareto solution rapidly, and lower the no-load and total energy consumption of the production line through automatic management while ensuring production efficiency. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Flexible Job-Shop Scheduling Problem (FJSP), Nondominated Sorting Genetic Algorithm-II (NSGA-II), Low-Carbon Scheduling*

Pages 724-733

OPTIMIZATION OF DYNAMIC AND MULTI-OBJECTIVE FLEXIBLE JOB-SHOP SCHEDULING BASED ON PARALLEL HYBRID ALGORITHM

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Abstract
This paper aims to develop a dynamic, real-time scheduling strategy under interference that can minimize the negative impact of interference on production scheduling without sacrificing the production efficiency. Taking the minimal cost and makespan as the objectives of the optimization function, the author put forward a parallel hybrid optimization algorithm for production rescheduling under interference, aiming to strike a balance between processing cost and scheduling disturbance. The benchmark test results show that the proposed algorithm achieved better accuracy than the NSGA-II and the AMOSA, and its accuracy has nothing to do with the distribution shape of the objective function or the continuity of the interference. In other words, the proposed algorithm enjoys strong computing stability. In the simulation tests, the proposed algorithm reached the global convergence state before reaching the maximum runtime, and consumed less time than the contrastive algorithms under the same problem scale. The research findings shed new light on the optimal scheduling of multi-objective FJSP under disturbance. 26 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Production Scheduling, Multi-Objective Scheduling, Parallel Hybrid Algorithm, Multiple Disturbances, Optimization, Simulation*

Pages 734-743

OPTIMIZATION AND SIMULATION OF REMANUFACTURING PRODUCTION SCHEDULING UNDER UNCERTAINTIES

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Abstract
This paper aims to develop a desirable optimization method for the remanufacturing production scheduling under uncertainties. For this purpose, a quality evaluation standard was proposed in light of the two uncertainties, i.e. randomness and ambiguity, of remanufacturing job scheduling. Inspired by the rough set theory and multi-objective approximation sorting algorithm, this evaluation standard can eliminate the redundant information in quality evaluation. On this basis, a remanufacturing production scheduling model was constructed under uncertainties, and solved by a hybrid algorithm developed from the double algorithm, backpropagation (BP) neural network and the genetic algorithm (GA). Simulation results show that the proposed algorithm excels in convergence, and its solution can lead to the minimal scheduling cost and makespan. This algorithm can effectively optimize the scheduling problem of remanufacturing production and processing. The research findings shed new light on the rapid evaluation of recycled resource quality and the optimal scheduling of remanufacturing production. 28 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Uncertainties, Remanufacturing, Production Scheduling, Optimization, Simulation*