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Pages 383-394

DESIGN AND SIMULATION OF THE CONTROLLED FAILURE OF CUSTOM-BUILT RIGID SHAFT COUPLING

Rasovic, N.; Cekic, A. & Kaljun, J.
University of Mostar, Faculty of Mechanical Engineering, Computing and Electrical Engineering, Matice Hrvatske bb, 88000 Mostar, Bosnia and Herzegovina
E-Mail: jasmin.kaljun@um.si

Abstract
In this paper, the use of conventional analytical calculating methods for designing the mechanical part with predicted endurance time is investigated. In a case study a design and dimensioning of custom-built shaft coupling with torque limiting function was conducted. Necessary analytical calculations were carried out to determine the possible weak points of the current shaft coupling design. Numerical analyses of the newly designed shaft coupling were performed using predefined material properties and boundary conditions. Using Goodman criteria, the most suitable design was selected. Prototypes of shaft couplings with different designs based on the numerical analysis were tested to validate the numerical results. Analytical approach as well as numerical analysis were compared. The validation of the produced machine part is also performed. Results of the research work showed that conventional analytical methods can be applied to design and dimension a mechanical part with predicted failure following steps (methodology) described in the paper. 16 refs.
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Key Words: *Shaft Coupling, Design, Dimensioning, Fatigue, Simulation, Custom Design*

Pages 395-404

FACILITATED DISCRETE EVENT SIMULATION FOR INDUSTRIAL PROCESSES: A CRITICAL ANALYSIS

Oliveira, M. S.; Leal, F.; Pereira, T. F. & Montevechi, J. A. B.
Federal University of Itajuba (Unifei), Av. BPS, 1303, Itajubá – MG, Brazil, Zip Code: 37500 903
E-Mail: mioliveira@unifei.edu.br

Abstract
Discrete Event Simulation (DES) is one of the most important simulation techniques in decision-making in several areas. Some authors state that small and large companies can benefit significantly through the utilisation of DES. Literature shows that most DES studies carried out are at large companies. Studies carried out at small and medium-sized enterprises (SMEs) have been mostly explored on a one-off, case-by-case basis, given the characteristics and limitations of smaller companies. In order to expand DES studies in a wide range of companies, this article seeks to consider the SME characteristics and limitations prevent them from broadly adopting traditional ("hard") DES. Then an alternative application of DES in "soft" mode was proposed. A review of facilitated DES frameworks was carried out. The frameworks were critically analysed in this review in relation to their adequacy to specific SME requirements and similar contexts. Finally, some issues and characteristics of these frameworks are presented that make directly applying in these contexts difficult. Furthermore, some suggestions are proposed for developing future facilitated DES frameworks. 32 refs.
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Key Words: *Facilitated Modelling, Small and Medium Enterprises, Soft Operational Research, Facilitated Simulation Modelling*

Pages 405-416

SIMULATION BASED PERFORMANCE IMPROVEMENT: A CASE STUDY ON AUTOMOTIVE INDUSTRIES

Thomas, S. K.; Ali, A.; AlArjani, A. & Attia, E.-A.
Leon Linton Department of Mechanical, Robotics and Industrial Engineering, Lawrence Technological University, Southfield, Michigan, MI 48075, USA
E-Mail: a.alarjani@psau.edu.sa

Abstract
In automotive industries, variable customer needs' increase the competition amongst enterprises. However, manufacturers are struggling to complete the customer demand on time. This paper presents a case study taken region in the automotive industry in Michigan, USA. It aims to reduce the production delay by stabilizing manufacturing processes that improve production throughput. Many tools are used including project charter, process flow diagram, Arena simulation, design of experiment (DOE), and layered process audit sheet. The project charter is used to represent the problem, objectives, scope, and methodology. The investigation of the system and the possible improvements are performed using Arena simulation along with DOE. Shop-floor data were collected and statistically analysed to model the different processes. Besides, the Ishikawa diagram was used to identify the root causes of the problems. Results show significant improvements. The number of finished products increased from 726 to 14161 units. The average WIP number increased from 4.9543 to 6.3615 units. The variation amongst the workstations' utilization is reduced. The cycle time decreased from 203.96 to 130.20 sec. 31 refs.
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Key Words: *Automotive Industry, Performance Improvement, Project Charter, Discrete Event Simulation, Arena Simulation, Design of Experiment, Root Cause Analysis, Layered Process Audit Sheet*

Pages 417-428

OPTIMIZATION OF SURFACE ROUGHNESS BASED ON TURNING PARAMETERS AND INSERT GEOMETRY

Vukelic, D.; Prica, M.; Ivanov, V.; Jovicic, G.; Budak, I. & Luzanin, O.
University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia
E-Mail: vukelic@uns.ac.rs

Abstract
This study is focused on dry longitudinal turning of AISI steel using CVD coated cutting inserts. The machining was conducted at different levels of cutting speed, feed, depth of cut, corner radius, rake, inclination and approach angles. Surface roughness was measured after each experiment, and statistical analysis was used to derive an empirical, regression model for arithmetical mean surface roughness. The regression model was used to theoretically minimize surface roughness, followed by additional verification experiments. The 95 % confidence interval constructed using ten additional batteries of experiments, contained the theoretically predicted minimum roughness of $Ra = 0.238$ μm. The mean absolute prediction error of the optimal roughness equals 0.006 μm. The results reveal practical applicability of the developed model. 35 refs.
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Key Words: *Surface Roughness, Turning Parameters, Insert Geometry, Modelling, Optimization*

Pages 429-440

EMERGENCY ROUTE PLANNING WITH THE SHORTEST PATH METHODS: STATIC AND DYNAMIC OBSTACLES

Ibrahim, N.; Hassan, F. H.; Ab Wahab, M. N. & Letchmunan, S.
School of Computer Sciences, Universiti Sains Malaysia (USM), 11800 Minden, Pulau Pinang, Malaysia
E-Mail: fadratul@usm.my

Abstract
In extreme cases, evacuation difficulties could cause casualties in a closed layout during an emergency. The existing emergency routes are designed based on the shortest path to the nearest egress in a vacant layout. This research aims to design an emergency route plan in a realistic closed layout with interior arrangements and crowds as static and dynamic impediments that cause movement divergence and misdirection that affect evacuation time. This research proposes an automated emergency route design using Cellular Automata (CA) based pedestrian simulation in a realistic layout. The simulation was integrated with the Pythagorean Theorem (PT) and Dijkstra's Algorithm (DA) to imitate human exit-finding behaviour during evacuation. The results showed that PT is viable in layouts with static obstacles, requiring 20 % less travel distances and evacuation time than DA with similar experiment sets. However, the DA approach results have become on par with the PT in a layout with dynamic and static obstacles. DA outperforms PT in densely populated regions, while PT outperforms DA in less populated regions. 34 refs.
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Key Words: *Emergency Route Plan, Shortest Path, Pedestrian Simulation, Pedestrian Evacuation, Pythagorean Theorem, Dijkstra's Algorithm*

Pages 441-452

A SIMULATION-BASED DECISION-MAKING APPROACH TO EVALUATE THE RETURNS ON INVESTMENTS

Ordu, M.
Osmaniye Korkut Ata University, Faculty of Engineering, Department of Industrial Engineering, 80010, Osmaniye, Turkey
E-Mail: muhammedordu@osmaniye.edu.tr

Abstract
The feasibility of Turkish Individual Pension System (IPS) for participants is empirically investigated under different scenarios determined based on its special conditions. Firstly, a system behaviour of the Turkish IPS is modelled by using system dynamics simulation method by taking into account the historical data of a pension company operating in Turkey. After that, all pension plans are evaluated under five "what-if" scenarios depending on the participant's age and the investment period that the deductions and the investment returns are directly related to these conditions. Secondly, the key performance metrics (i.e., net present value and profitability index) are measured to better understand which pension plans are suitable or not for participants. In conclusion, the IPS investment is not suitable for short-term investments, however, all pension plans are profitable in the medium-long term. In the long term, the IPS, particularly dynamic and aggressive funds, is determined as a very profitable investment tool for participants. 34 refs.
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Key Words: *Simulation, System Dynamics, Engineering Economy, Decision Support System, Individual Pension System, Pension Plans*

Pages 453-464

ANALYSIS OF PUMPING STATION INLET CHARACTERISTICS BASED ON VORTICITY

Xi, W.; Lu, W. G.; Wang, C. & Liu, J. F.
College of Hydraulic Science and Engineering, Yangzhou University, Yangzhou, 225009, China
E-Mail: wglu@yzu.edu.cn

Abstract
This study aims to solve this problem and understand the formation mechanism of the vortex attached to the side pump sump. Thus, numerical simulations were conducted using the calculation software, and the flow characteristics of the side pump sump were studied based on the vorticity field. The flow field data of the physical model of the pumping station forebay and pump sump were obtained by particle image velocimetry. The distribution of vorticity in the different flow layers and vertical axes at the study location was obtained using Tecplot postprocessing software and corroborated with the results of the numerical simulations. This basis was used to analyse the mechanism of the formation of the adherent vortex. Results show that the inflow distribution is uneven and the water flow resistance and vortex strength are imbalanced due to the asymmetry of the vorticity of the inflow of the side pump sump. This causes the attachment of the vortex to the wall, which causes the generation of the suction vortex, vibration of the unit, and instability of the overcurrent, endangering the safety of the project. 27 refs.
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Key Words: *Pump Station Engineering, Side-Pump Sump, Vorticity, Adherent Vortex*

Pages 465-476

QUICK WORKPLACE ANALYSIS USING SIMULATION

Grznar, P.; Gregor, M.; Gola, A.; Nielsen, I.; Mozol, S. & Seliga, V.
Department of Industrial Engineering, Faculty of Mechanical Engineering, University of Žilina, Slovakia
E-Mail: patrik.grznar@fstroj.uniza.sk

Abstract
Modelling and simulation is a highly progressive area that can create significant financial savings for companies that use it. Simulations can be used in the production area to analyse or verify certain decisions and conditions, on the basis of which correct measures can be taken. However, modelling is a highly time-consuming and therefore costly process, which narrows its use for decisions in high-priority processes. The content of the article is a description and results of the created tool designed for quick analysis of the workplace using simulation. The entire process of functioning was described through Unified Modeling Language (UML) diagrams. Siemens's Tecnomatix Plant Simulation software was used to create the tool. The tool itself was compared both to the length of creation of the mid-size simulation model and the time variance of model creation in a standard way. The tool can be used to reduce the time needed to create a model that is used to analyse the selected workplace, which ultimately increases the productivity of the simulation expert. 25 refs.
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Key Words: *Workplace Analysis, Computer Simulation, Object-Oriented Modelling, TX Plant Simulation*

Pages 477-488

OPTIMIZATION OF UNMANNED VEHICLE SCHEDULING AND ORDER ALLOCATION

Liu, M. L.; Yao, X. Z.; Huang, J. Y. & Zhang, C.
School of Transportation Engineering, East China Jiaotong University, Nanchang, 330013, China
E-Mail: HJY@ecjtu.edu.cn

Abstract
With the development of unmanned vehicles from laboratories to commercial logistics distribution, unmanned vehicles are facing prominent problems, such as order allocation, reasonable setting of appointment time windows, and vehicle route optimization. With the campus distribution of Cainiao unmanned vehicles as an example, an appointment order allocation and route planning problem model of unmanned vehicles was constructed to realize efficient order picking and optimize the operating cost. The operation and distribution efficiency of unmanned vehicles before and after planning was compared using the improved genetic algorithm with limits of load and soft time windows as model constraint conditions. Results of the calculation example reflect that the parcel distribution amount under the planned 1 h appointment mode more than doubled that under the current unplanned 1 h appointment mode. Moreover, the operating cost and parcel picking scheme of Cainiao unmanned vehicles under the planned 1 h and 30 min appointment modes are given, providing decision-making reference for enterprises to balance customer satisfaction and unmanned vehicle scheduling. 17 refs.
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Key Words: *Unmanned Vehicle, Vehicle Scheduling, Order Allocation, Improved Genetic Algorithm*

Pages 498-500

A SIMULATION STUDY ON THE IDENTIFICATION OF ECO-DRIVING BEHAVIOUR

Yan, L. X.; Jia, L.; Guo, J. H. & Lu, S.
School of Transportation Engineering, East China Jiaotong University, Nanchang 330013, China
E-Mail: yanlixinits@163.com

Abstract
Eco-driving is considered as one of the effective ways to reduce energy consumption. The objective of this study is to establish an eco-driving behaviour identification model and analyse the eco-driving behaviour characteristics. First, this study built a driving simulation platform and conduct an experiment for research. Then, based on significant driving behaviours related to fuel consumption, Piecewise Linear Representation (PLR) method was used to fit multivariate time series consisting of Significant driving behaviour variables. At last, the features of each time series segment were extracted as the input of a Random Forest (RF) model to recognize the eco-driving behaviour. The results indicated that the depth of the acceleration pedal, the depth of the clutch pedal, the depth of the brake pedal, steering wheel angle, and gear position had significant effects on fuel consumption. The eco-driving behaviour identification model demonstrated a high predictive power with a prediction accuracy of 0.718. The graph of eco-driving behaviours during lane change was established. The conclusions provide theoretical support for developing eco-driving intervenes. 31 refs.
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Key Words: *Eco-Driving, Driving Behaviour, Time Series Segmentation, Piecewise Linear Representation, Random Forest*

Pages 501-512

CONTROL OF WELDING RESIDUAL STRESS AND DEFORMATION FOR THE ROD SUPPORT OF A CRANE

Zhou, Q. H.; Zhu, X. Y.; Sun, J. M. & Li, J.
School of Mechanical-Electrical and Vehicle Engineering, Beijing University of Civil Engineering and Architecture, Beijing, 100044, China
E-Mail: zhouqinghui@bucea.edu.cn

Abstract
The counter jib and rod support are the main stress-bearing parts of crane due to large load. But the long weld seams of their joints produce great residual stress and deformation affecting the welding strength. In order to reduce the residual stress and the deformation simultaneously, an optimal welding procedure was proposed considering the effective length of welding seam. Firstly, a theoretic model of welding seam was built as T-joint of Q355 steel. The accuracy of model was verified by the welding experiments. By numerical simulation, the appropriate welding process parameters were obtained. Four welding procedures were designed to investigate the influence of the welding sequence. Results show that the welding sequence has a great influence on residual stress and deformation of the long welding seam. The welding quality can be improved by segmented welding and simultaneous welding. The optimized welding procedure of long welding seam can reduce the residual stress by 8.04 % and the maximum deformation by 74.1 % considering welding sequence. Therefore, it is recommended in the actual welding process of crane. 28 refs.
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Key Words: *Tower Crane, Welding, Residual Stress, Numerical Simulation, Deformation*

Pages 513-524

STATIC CONTACT MODELLING AND ANALYSIS FOR RAIL GRINDING WITH ABRASIVE BELT

Liu, Y.; Fan, W. G.; Zhang, X. L.; Wu, Z. W. & Wu, C. X.
School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing 100044, P. R. China
E-Mail: wgfan@bjtu.edu.cn

Abstract
Rail grinding with abrasive belt is increasingly applied in daily rail maintenance due to its high efficiency and high quality. The contact between rail and abrasive belt largely determines grinding efficiency and grinding quality, but the influences of grinding process and contact wheel's parameters on the contact behaviour are obscure. To explore the influences, a finite element model of the wheel-rail contact was established. The simulation results showed that the grinding angle significantly affected the shape of contact spot. The contact spot gradually became narrower as the grinding angle increased. Similarly, the reduction of the contact wheel radius significantly increased the contact stress. But when the ratio of the thickness of rubber layer to wheel radius increased above 60 %, it had little effect on the size of contact spot and maximum contact stress. This study provides the basis for the selection of grinding process and contact wheel's parameters. In the actual grinding process, grinding process and contact wheel should be selected according to grinding requirements. 24 refs.
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Key Words: *Rail Grinding, Abrasive Belt, Contact, Stress Distribution*

Pages 525-536

FLEXIBLE JOB SHOP SCHEDULING BASED ON DIGITAL TWIN AND IMPROVED BACTERIAL FORAGING

Huo, L. & Wang, J. Y.
School of Computer and Communication Engineering, Dalian Jiaotong University, Dalian 116045, China
E-Mail: huoli@djtu.edu.cn

Abstract
To realize the dynamic scheduling of complex workpiece processing in complex workpiece job shop, a hybrid dynamic scheduling method with Digital Twin and improved bacterial foraging algorithm (IBFOA) is proposed to minimize the maximum completion time and machine load. During the actual workshop processing, the flexible job shop scheduling problem (FJSP) is divided into two sub-problems: machine assignment and process sequencing. The initial scheduling scheme is completed using an IBFOA to construct a Digital Twin flexible job shop scheduling model. Digital Twin model is used to solve the impact of workshop emergencies. Based on typical benchmark cases and real data from a machine company's mould shop, the machining shop production scheduling experiments are conducted. The results show that the scheduling scheme using the IBFOA combined with the Digital Twin can optimize the system performance as a whole and effectively deal with the problem of extended production time caused by disruption. The algorithm can obtain the most satisfactory scheduling solution and the effectiveness of solving the multi-objective FJSP are verified. 22 refs.
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Key Words: *Flexible Job Shop Scheduling, Improved Bacteria Foraging Optimization Algorithm, Digital Twin, Complex Product, Dynamic Scheduling*

Pages 537-547

MANAGEMENT DECISIONS IN MULTI-VARIETY SMALL-BATCH PRODUCT MANUFACTURING PROCESS

Li, Z. P.
School of Economics, The University of Queensland, Brisbane 4072, Australia
E-Mail: zepeili828@163.com

Abstract
The existing mathematical analysis approaches for the management of product manufacturing process cannot satisfy the global optimization and high feasibility required for product manufacturing. Neither do they reflect the actual production situation accurately and comprehensively. Therefore, this paper explores the simulation and modelling of management decisions in multi-variety small-batch product manufacturing process in discrete production environment. Firstly, the management knowledge in product manufacturing process was expressed mathematically, and the product manufacturing system was modelled in discrete production environment. Then, the flow of the interactive simulation model was explained, along with the realization steps of the model. Taking a real multi-variety small-batch production unit as the engineering background, an empirical analysis was carried out to detail the interactive simulation of the line change management for the production lines in the management system of the product manufacturing process, and to build a simulation model for the product manufacturing system. The simulation model was proved effective through simulations. 23 refs.
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Key Words: *Discrete Production Environment, Multi-Variety Small-Batch, Product Manufacturing Process, Management Decisions, Simulation*