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MODELLING AND SIMULATION OF IMPEDANCE-BASED DAMAGE MONITORING OF STRUCTURES

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Abstract
Electromechanical impedance (EMI) based monitoring techniques are successfully in use in current engineering structures. With the help of piezoelectric sensors, the EMI technique is used for monitoring the health of such structures. Generally, potential damage to the host structure is detected by examining the EMI signature and identifying changes in that unique signature. Since this technique has the potential to offer greater safety and reliability while lowering maintenance costs, it is becoming increasingly popular. This paper investigates the use of finite element method (FEM) to simulate the electro-mechanical impedance technique. A numerical analysis of simple models, such as free piezoelectric patches of various shapes and thicknesses is used to comprehend the fundamentals of this technique. Then, studies on different parts of the structure are conducted to find the effect on the output of system when both damage and loading co-exist, and investigate the effect of temperature for structural health monitoring based on EMI. The simulation results are then compared to experimental data and a very good agreement is observed. 22 refs.
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Key Words: *Structural Health Monitoring, Electromechanical Impedance, Piezoelectric Patch, Finite Element, Simulation*

Pages 409-422

ROBUST DESIGN OF THERMALLY ACTUATED MICRO-CANTILEVER USING NUMERICAL SIMULATIONS

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Abstract
Dynamic behaviour of a micro-cantilever beam under periodic electro-thermal loading is studied in this paper. For certain applications the beam is required to vibrate at a particular frequency. Modal analysis using 3D finite element is used in order to find the geometrical parameters that makes fundamental frequency of the beam match the required frequency. Then non-linear dynamic thermo-elastic analysis is conducted on the system to analyse the time-history (transient) behaviour of the beam and record its tip displacement. However, due to uncertainties and non-repeatabilities that are inherent properties of the system along with those associated with the manufacturing, final product is likely to have deviations from these estimated values (fundamental frequency and tip displacement). Thus, choosing a nominal (desired) design and studying the deviation in natural frequency and tip displacement via 2^k factorial Design-of-Experiments (DOE), effect of uncertainties on the overall performance of the system is investigated. This allows finding the significance of individual parameters on the overall robustness of the design as well as potential interactions between various parameters. Finally, the expected behaviour of the micro-cantilever and its robustness to design and implementation uncertainties are elaborated and statements for robust design of this system are made. 19 refs.
(Received in July 2015, accepted in December 2015. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Finite Element Method, Micro-Cantilever, Design of Experiments, Uncertainty, Robust Design*

Pages 423-435

ROBUST ADAPTIVE POSITION AND FORCE TRACKING CONTROL STRATEGY FOR DOOR-OPENING BEHAVIOUR

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Abstract
The door-opening task is a key step for the indoor rescue and monitoring of a mobile manipulator. However, the contact effect between the gripper and the door handle may produce excessive internal forces to damage mechanical devices because of position errors or the imprecise modelling of the robot and operation environment. To successfully suppress the excessive internal forces and assure the proper posture of the mobile manipulator under holonomic and non-holonomic constraints, a robust adaptive position/force control algorithm was proposed to track the desired posture and force in opening a door to avoid the complexity of compliant mechanism and the unpredictability of the contact stiffness in traditional impedance control. Dynamic simulation studies with MATLAB and RecurDyn were used to verify the dynamic model of the system and obtain the expected positions and forces during door opening. Simulation results and experiments show that the proposed method is robust in modelling errors, joint frictions and environment disturbances and meets the requirement for opening a door with a handle and suppressing excessive internal forces. This study offers reference data and the control method for future real-world door-opening operation in different environments. 22 refs.
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Key Words: *Tracking Simulation, Door Opening, Manipulator, Robust Adaptive Control*

Pages 436-449

DEVELOPMENT OF HIGH FIDELITY FINITE ELEMENT MODEL OF MOTORCYCLE TELESCOPIC FRONT FORK

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Abstract
This paper describes the development of a fully deformable finite element model of an upright telescopic motorcycle front fork in LS-DYNA environment. The modelling for each of the key components, overall assemblage, and contact interactions involved were presented. Comprehensive validation was performed by comparing the reaction forces in a quasi-static test performed on a universal testing machine with customised fixture, which was specially designed to impose compressive and bending load simultaneously on the fork unit throughout the process. The behaviour of the fork under such loading conditions was studied and explained. Significant localised deformations observed on the components were also identified and compared. The results from the simulations were found to be well agreed to that of the physical testing, with closely matching profile of the reaction forces and a deviation of 1.4 % based on the work done to deform the fork. Major considerations for establishing the full model were concluded and recommendations were suggested for improvement. 29 refs.
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Key Words: *Finite Element Modelling, Fully Deformable Model, Motorcycle Fork, Quasi-Static Simulations*

Pages 450-459

TURBULENCE IN MARKET DEMAND ON SUPPLY CHAIN NETWORKS

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Abstract
Recent works have shown that the dynamic performance (i.e., the so-called bullwhip effect) of serial and divergent Supply Chain Networks (SCNs) under a sudden increase in the average customer demand may be substantially different. However, the effect of customer demand variability has not been investigated despite the fact that, in real-world business, a turbulence condition on the market usually generates an increase of customer demand variability. Herein we focus on this particular market condition by studying the dynamic behaviour of both serial and divergent SCNs under a sudden increase both in mean demand and variance. Results show how an isolated impulse in the variability of customer's orders results in the same bullwhip effect for both serial and divergent SCNs. From a managerial view point, this finding provides new interesting insights for SCN managers. 16 refs.
(Received in September 2015, accepted in April 2016. This paper was with the authors 2 months for 2 revisions.)

Key Words: *Serial Supply Chains, Divergent Supply Chains, Agent-Based Simulation, Shock Demand, Demand Variability, Demand Impulse*

Pages 460-472

SIMULATION ON LOCAL OBSTACLE AVOIDANCE ALGORITHM FOR UNMANNED SURFACE VEHICLE

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Abstract
Unmanned surface vehicle (USV) is an important autonomous marine vehicle. The safe navigation of USV is directly determined by the local obstacle avoidance because it must avoid real-time local obstacle in the global path planning in a three-dimensional environment. Therefore, efficient algorithms of real-time local obstacle avoidance for USV are a critical issue. In this study, a new three-layered architecture for local obstacle avoidance algorithm was proposed to solve the local obstacle avoidance problem. First, real environment and obstacle models were established in the polar coordinate. The known static path-planning method was conducted based on particle swarm optimization (PSO). Second, the method was integrated with marine rules based on PSO. Third, an obstacle avoidance method under unknown environment was created based on rolling windows. Finally, a simulation experimental platform was developed to verify the feasibility and effectiveness of the aforementioned measure. Result shows that the proposed algorithm can effectively avoid local obstacles of USV at a computation time of less than 2 s. The USV avoids the obstacles smoothly and reaches the desired destination with complex requirements. The simulation results also demonstrate the promising application of the proposed method in studying the path planning of USV. This method can address the issues of real-time local obstacle avoidance of USV. 16 refs.
(Received in September 2015, accepted in March 2016. This paper was with the authors 2 months for 1 revision.)

Key Words: *Unmanned Surface Vehicle (USV), Path Planning, Dynamic Collision Avoidance, Particle Swarm Optimization (PSO), Marine Rules, Rolling Windows*

Pages 473-484

SIMULATION MODELLING OF A COMPANY PROVIDING TWO QUALITATIVELY DIFFERENT SERVICES TO MARKET

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Abstract
Simulation modelling is applied onto a market dynamics of a company conducting two qualitatively different services and has a bounded total daily volume. The model contains qualitatively and in a simplified form the characteristics of the dynamics of a general service providing company. The company applies a single strategy how to influence, thus minimise, the number of agents who wait for a given service. The strategy is realised by changing the relative proportion of the daily conducted services. Rather small modification of priority level between the two services influences considerably both the number and the type of end users who wait for a particular service. The model enables the researchers to test different strategies how to control the number of end users who wait for services, by proper changes in priority level of services conducted. The fact important for practitioners is that partial optimisation is achieved through slight difference in priorities between the services. 11 refs.
(Received in October 2015, accepted in January 2016. This paper was with the authors 1 week for 1 revision.)

Key Words: *Simulation Modelling, Service Providing Company, Adaptation, Market Demand*

Pages 485-496

SUSTAINABLE AGRI-FOOD SUPPLY CHAIN WITH UNCERTAIN DEMAND AND LEAD TIME

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Abstract
Food supply, safety and quality have become major concerns worldwide. Agri-food supply chains (ASC) possess special characteristics due to the perishability of their products and the high uncertainty of supply and demand. Furthermore, different sources of CO_2 emissions exist in an ASC due to storage, transportation, and disposal of fresh produce. Thus to ensure the sustainability of the supply chain, planning decisions have to be made with consideration of both economic and environmental aspects. This work studies the effect of changing the order quantity in a two-echelon agri-food supply chain on costs, emissions, and service level. A discrete-event simulation model is developed to include stochastic demand and lead-time, the amount of CO_2 emissions along the supply chain, service levels, and product lifetime effects. Simulation results show that reducing the order quantities can reduce costs and emissions by 27.42 % and 18.21 %; respectively, without sacrificing high service levels. Also, relying on costs or service level as sole objectives of the supply chain without consideration of emissions can result in greater economic and environmental inefficiencies in management of inventory levels. 28 refs.
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Key Words: *Agri-Food Supply Chain, Carbon Emissions, Perishable Goods, Modelling and Simulation*

Pages 497-510

MODELLING OF COMPUTER-ASSISTED MACHINE TOOL VOLUMETRIC VERIFICATION PROCESS

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Abstract
Nowadays, the accuracy of machining parts is essential in order to compete in a global market as demanding as machining. Due to the high cost of these machines continuous operation is required, with a reduction of the downtime owing to production readiness, maintenance or breakdowns. Among all the sources of error that affect the accuracy of machining parts, this paper is focused on improving the positioning accuracy of the machine. This requires periodic inspection of the machine tool, which should be included in maintenance operations.

Volumetric verification is a novel technique that is being progressively introduced in machine tool maintenance operations, significantly reducing the time required. Unlike other techniques, this is based on non-linear mathematical models and the optimization process increases the influence factors. This modelling provides a re-creation of the whole verification process for all the influence factors; this allows the determination of the best measurement system distribution and the identification of techniques to use to characterize geometric errors. Thus, the verification time required is reduced, unnecessary tests are eliminated, the conditions under which real tests should be carried out are obtained in advance and machine tool accuracy is improved. 27 refs.
(Received in November 2015, accepted in March 2016. This paper was with the authors 1 week for 1 revision.)

Key Words: *Laser Interferometry, Volumetric Verification, Simulation, Influence Factors, Accuracy, Machine Tool*

Pages 511-521

EXPERIMENTAL EVALUATION OF BALL BAR STANDARD THERMAL PROPERTIES BY SIMULATING REAL SHOP FLOOR CONDITIONS

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Abstract
Monitoring quality of production processes is a complex task consisting of different measurements of product properties and process parameters, as well as visual checks and other activities. One of the most important measurement tasks is measuring complex product geometry. In order to get information about measured quantities as quickly as possible, measurements are made directly on the shop floor. However, assuring traceability of complex co-ordinate measurements in uncontrolled shop floor conditions is an advanced metrological task requiring special measurement standards and procedures. European project EMRP IND62 TIM that was agreed between EC and European metrology association Euramet is aimed to introduce a traceability chain into in-process geometrical measurements by offering different solutions for calibrating machine tools in harsh environmental conditions. One of the tasks of this project was to develop a highly accurate robust 1D measurement standard with very low expansion coefficient. The article presents basic design of this standard and experimental verification of its thermal expansion characteristics in a laboratory, as well as in harsh environment in production companies. Thermal expansion verification was performed by means of measurements on a co-ordinate measuring machine at different temperatures simulating real shop floor conditions. 15 refs.
(Received in December 2015, accepted in March 2016. This paper was with the authors 1 month for 1 revision.)

Key Words: *Traceability, Co-Ordinate Measurement, Measurement Standard, Thermal Expansion*

Pages 522-531

NUMERICAL ANALYSIS OF CONTINUOUS CASTING OF NiTi SHAPE MEMORY ALLOY

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Abstract
The present study deals with the numerical analysis of the solidification process of NiTi binary alloy in a lab-scale continuous casting device. The physical medium is taken as an incompressible fluid where the heat is transferred by conduction and convection, including the thermal phase change phenomenon. The energy equation which includes both convection-diffusion heat transfer and a mushy region for the phase-change (solidification) is modelled by using an enthalpy-based formulation. The numerical approach is based on the finite volume method in body fitted coordinates with a SIMPLE scheme to couple the pressure and velocity fields.

Results show that the casting speed has a significant effect on the temperature distribution and, consequently on the solidification as well as metallurgical length. High casting speed may cause inadequate thickness of the solidified material at the mould exit to withstand the hydrostatic pressure of the molten NiTi below the mould and may also lead to breakout due to sticking of the solidified shell and mould because of lack of slag film for lubrication between the two. 24 refs.
(Received in December 2015, accepted in April 2016. This paper was with the authors 2 months for 1 revision.)

Key Words: *NiTi, Solidification, Continuous Casting, Numerical Modelling, Heat Transfer*

Pages 532-541

A MECHANICAL-HYDRAULIC VIRTUAL PROTOTYPE CO-SIMULATION MODEL FOR A SEABED REMOTELY OPERATED VEHICLE

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Abstract
In this study, a virtual prototype model of a seabed tracked remotely operated vehicle (ROV) is established using the program RecurDyn/Track with the integration of a user-defined subroutine for a sediment terramechanics model. Laboratory tests for evaluating the mobility performances of a small tracked vehicle are conducted to validate the computational accuracy of the new virtual prototype model. A simulation model of a load independent flow distribution (LUDV) hydraulic control system for the tracked ROV is built using the program AMESim. Based on the combined RecurDyn–AMESim interface program design, a new virtual prototype co-simulation model for the mechanical-hydraulic system of the tracked ROV is developed. Co-simulations are conducted to analyse the dynamic performances of the motor actuators in the LUDV hydraulic system and the tracked ROV mobility performances. The co-simulation results demonstrate that the developed virtual prototype model of the ROV mechanical system can accurately simulate the load of the hydraulic control system, while the LUDV hydraulic controlling method can effectively improve the operational performance of a tracked ROV multi-actuator system. This research provides an effective and valuable co-simulation modelling method for mechanical-hydraulic system optimization, performance evaluation and operational control of the seabed tracked ROV. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Seabed Tracked Remotely Operated Vehicle (ROV), Virtual Prototype Model, Mechanical-Hydraulic Co-Simulation, Load Independent Flow Distribution (LUDV), Joint Operation Performance*

Pages 542-552

CARBON-CONSTRAINED PERISHABLE INVENTORY MANAGEMENT WITH FRESHNESS-DEPENDENT DEMAND

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Abstract
We consider perishable inventory control with freshness-dependent demand under carbon emissions constraints. We propose two deteriorating inventory models with carbon emissions tax and the cap-and-trade mechanism, in which the demand is freshness dependent, carbon emissions come from inventory holding, shipping, and item deteriorating, and the objective is to maximize the profit per unit time. We characterize the existence and uniqueness of the solutions for the models. We analyse the impacts of carbon emissions tax, carbon emissions quota, and carbon price on inventory decisions, carbon emissions, and profit. We conduct simulation to generate managerial insights from our analytical results. 27 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Deteriorating Inventory, Carbon Emissions Tax, Cap-and-Trade, Perishable Items, Freshness-Dependent Demand*

Pages 553-565

CONSTRAINED STOCHASTIC JOINT REPLENISHMENT PROBLEM WITH OPTION CONTRACTS IN SPARE PARTS REMANUFACTURING SUPPLY CHAIN

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Abstract
In a real business environment, the stochastic joint replenishment with resource restrictions commonly adopts the wholesale sales mechanism. The mechanism causes conflicts of interest between the supplier and the service provider. In order to effectively compete in an uncertain business environment, the option contract is a viable mechanism for coordination between the supplier and the service provider. This paper proposes a fixed-cycle joint replenishment policy based on the option contracts. Stochastic joint replenishment problem of spare parts considers the forward supply process and the reverse recycling process in the remanufacturing supply chain. The optimization model of stochastic joint replenishment problem is developed with a fixed-cycle joint replenishment policy based on the option contracts. According to characteristics of the optimization model, the adaptive immune genetic algorithm is established for solving the optimization problem. Finally, the validity of the optimization model and algorithm are illustrated by data. 41 refs.
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Key Words: *Stochastic Joint Replenishment Problem, Resource Restriction, Option Contracts, Adaptive Immune Genetic Algorithm*

Pages 566-576

SIMULATION STUDY OF FLEXIBLE MANUFACTURING CELL BASED ON TOKEN-ORIENTED PETRI NET MODEL

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Abstract
An initial manufacturing plan may not consider the particular implementation of flexible manufacturing cells (FMCs). Therefore, the FMC is subject to modelling and simulation to evaluate and correct the production plan using feedback. In the case of highly shared resource contention, deadlock and blocking present an inevitable, unavoidable problem, and corrections may be required for production plans. However, by using existing Petri net model theories and certain simulation software for model establishment, the structure and scale of the model may vary with changes in the parts, machines, and robots. This results in a cumbersome and complicated model building process. To address this practical problem, a token-oriented Petri net model theory is therefore proposed. The movable directions of a token are detected to determine if the firing conditions are satisfied. To avoid deadlock, the token first predicts the status of resource utilization prior to decision-making when entering the transporting-transition state. Accordingly, during the model run, events are triggered against the expected time, and transitions are thereby enabled and fired. An improved machine processing plan and robotic transporting plan may be obtained via path scenario deduction. In this study, classic case data were processed for simulation analysis of the manufacturing job, which verified the validity of the model algorithm. 15 refs.
(Received, processed and accepted by the Chinese Representative Office.)

Key Words: *Flexible Manufacturing Cell (FMC), Petri Net, Transporting Robots, Simulation*