

USING SIMULATION TO IMPROVE MARBLE WAREHOUSE OPERATIONS IN HOUSING PROJECTS

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Abstract

The Saudi 2030 Vision Housing Program aims to deliver high-quality, affordable housing on time. On-site warehouses are essential to the Jeddah Housing Project, which includes 8,649 residential units across 440 towers. High daily order volumes, a small workforce, and limited transportation resources have caused persistent delays in the marble warehouse.

This study uses Simio simulation software to model the marble warehouse as a complex socio-technical system, analyse workflow, identify bottlenecks, and evaluate operational alternatives. A base model representing current operations was created for 1,760 orders and verified with historical data.

Three alternative configurations were simulated: increasing preparation unit capacity, adding preparation and transportation resources, and deploying knuckle boom trucks to improve delivery efficiency. Performance metrics included total time in system, preparation unit utilization, and average waiting times. Alternative 3 significantly reduces delays and total time, optimizing warehouse operations for large housing projects and supporting strategic decision-making. 18 refs.

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Key Words: *Warehouse Operations, Simulation, Marble Logistics, Jeddah Housing Project, Socio-Technical Systems*

THERMAL MANAGEMENT OF INTEGRATED PUMP MOTORS: DESIGN AND VALIDATION

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Abstract

This study investigates the temperature rise characteristics of permanent magnet synchronous motors (PMSMs) for integrated pumps under high-power-density operation. Losses were calculated using Joule's law and the Bertotti iron loss separation model. Computational fluid dynamics (CFD) simulations of multiple primary-secondary channel configurations were conducted to analyse flow velocity, pressure, and temperature field distributions. An experimental test bench was built for validation. Simulation and experimental results show that the full-spiral primary channel combined with a radial Z-shaped secondary channel (right inlet/left outlet) yields optimal cooling. Additionally, under typical engineering parameters, the maximum winding temperature was reduced to 49.6 °C. Notably, under rated conditions, the simulated winding temperature deviates by only 0.8 % from measurements, with all key parameter errors below 8 %, and the cooling structure ensures stable motor operation under overload. This study provides a theoretical and experimental basis for designing efficient cooling systems for compact, high-power-density PMSMs in integrated pumps. 23 refs.

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Key Words: *Integrated Pump, Fluid-Structure Interaction (FSI), Experimental Validation*

TURBULENCE MODELS FOR AMPHIBIOUS AIRCRAFT WITH CFD AND WIND TUNNEL

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Abstract

Indonesia is an archipelagic country that significantly depends on ships to connect several islands. However, these ships are considered to lack speed and flexibility, leading to the use of amphibious aircraft as an alternative to ships. The development of amphibious aircraft heavily relies on aerodynamic analysis, especially the turbulence model. The turbulence modelling methods that were analysed included K-Omega SST, K-Epsilon, and Spalart-Allmaras. The best turbulence model from the results of computing and CL/CD calculating for the amphibious aircraft model without a propeller has the Spalart-Allmaras model with a lower value, and the error results are less than 5.05 %. 31 refs.

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Key Words: *K-Omega SST, K-Epsilon, Spalart-Allmaras, Lift Coefficient, Drag Coefficient*

PROCESS SIMULATION FRAMEWORK FOR NUCLEAR DISMANTLEMENT INTEGRATED WITH LASER CUTTING

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Abstract

Process simulation is essential in nuclear facility dismantlement operations because high-radiation environments prevent human operators from making real-time interventions. Since all operations must be conducted remotely, rigorous planning of cutting paths, speeds, and sequences is required to ensure complete separation while minimising secondary waste. Furthermore, accurately pre-estimating the size and weight of cut pieces is crucial for the safe handling and disposal of radioactive materials. Process simulation serves to validate cutting plans and identify potential hazards prior to actual operations. In this study, we propose a process simulation methodology that accurately generates the geometric shapes of waste materials produced during cutting. Current simulation methods often fail to account for the variation in cutting depth as a function of the cutter's traverse speed. This limitation hinders the accurate prediction of outcomes for non-contact methods such as laser cutting. To address this, we developed a framework to simulate laser cutting operations and implemented a prototype module based on a commercial process simulation system. 21 refs.

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Key Words: *Dismantlement Process Simulation, Nuclear Facility Dismantlement, Laser Cutting*

CONTINUOUS VALIDATION OF DIGITAL TWINS: CONCEPTUAL AND APPLIED APPROACHES

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Abstract

The growing adoption of Digital Twins (DTs) in Industry 4.0 (I4.0) raises the challenge of ensuring model validity throughout the operational lifecycle. Unlike static validation, which is limited to the development phase, continuous validation aims to ensure that the DT remains representative of the physical system during operation. This paper presents a critical review of conceptual and applied approaches to continuous or recurrent DT validation. The studies are classified into continuous monitoring proposals, methods with potential for recurrent adaptation, and conceptually aligned approaches. For each group, methods, results, and limitations are discussed. A comparative analysis reveals relevant gaps, including the lack of formal criteria for selecting critical variables and difficulties in diagnosing the causes of deviations. Finally, emerging trends and future directions are outlined, highlighting the integration of statistical techniques, such as control charts, to enhance the reliability and traceability of DTs in dynamic industrial environments. 35 refs.

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Key Words: *Digital Twins, Continuous Validation, Industry 4.0, Model Monitoring*

AUTOMATED NEURAL ARCHITECTURE SEARCH FOR SIMULATION METAMODELLING OF CONWIP SYSTEMS

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Abstract

In this article, we present a methodology that enables the automatic creation of metamodels based on artificial neural networks. We use a neural network architecture search technique, known as NAS. Work in this area so far has mostly relied on manual design of the network architecture, which is time-consuming and the results depend on the researcher's experience. Our framework combines several interconnected steps: generating data using Latin Hypercube Sampling, automatically checking its quality, finding the best architecture using the Tree-structured Parzen Estimator (TPE) algorithm, and finally building a set of models that work together to make the final prediction. We have verified the entire procedure on a real production line controlled by the Constant Work-In-Progress (CONWIP) system. We achieved a prediction accuracy of $R^2 = 0.9955$ and an average percentage error of 1.34 %. Compared to direct simulation, our metamodel is 312 times faster, enabling optimization and scenario analysis directly during decision-making. 27 refs.

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Key Words: *Discrete Simulation, Neural Metamodel, Network Architecture Search, CONWIP, Multi-Criteria Optimization*

PROBABILITY MODELLING OF AIR DEFENCE PROCEDURES

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Abstract

Air defence operations are characterised by uncertainty at every stage of the engagement chain, from detection to destruction of aerial threats. Conventional deterministic analyses often overlook the stochastic nature of detection errors, classification uncertainty, system availability, and weapon effectiveness. This study introduces a probabilistic framework for modelling the air defence engagement process, structured according to the radar–command–fire unit cycle. Each decision point and transition is represented by an appropriate probability distribution, with parameters estimated from assumed or reported operational performance values. Using Monte Carlo simulation with several types of probability distributions in Python, the model evaluates the overall probability of successful target destruction under varying system configurations. Results highlight the sensitivity of the engagement chain to detection reliability, identification accuracy, and missile kill probability, offering valuable insights for system planners and operational analysts. 13 refs.

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Key Words: *Air Defence, Probabilistic Modelling, Monte Carlo Simulation, Engagement Chain, Stochastic Analysis*

MECHANISM ANALYSIS OF BIT STICK-SLIP VIBRATION IN NEAR-HORIZONTAL DRILLING

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Abstract

This study develops a numerical model using ABAQUS to investigate the stick-slip vibration mechanism of a near-horizontal drilling bit in underground mines, incorporating bit-rock cutting, drill string-hole wall interaction, and gravity. Key factors include feed speed, rotational speed, drill string length, and rock properties. Results show that stick-slip vibration consists of slow loading, sticking, slip, and high-speed rotation sections and is coupled with axial vibration. Higher feed speed increases torsional energy storage time, thereby prolonging the sticking section. Higher rotational speed raises the peak velocity of the bit during stick-slip, which can exceed twice the driving speed. Drill string flexibility is a root cause; shorter strings with higher stiffness reduce sticking tendency. Average drilling speed decreases with increasing string length, though the reduction rate diminishes. Increased rock hardness prolongs the sticking phase, but the increment gradually levels off. These findings provide a theoretical reference for safe and efficient near-horizontal drilling in underground mines. 27 refs.

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Key Words: *Near-Horizontal Drilling, Bit, Stick-Slip Vibration, Mechanism, Axial Vibration*

LARGE INHOMOGENEOUS ROADWAY DEFORMATION MECHANISM AND CONTROL UNDER MINING EFFECTS

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Abstract

To reveal the mechanism of large inhomogeneous roadway deformation under mining effects and realize effective control, this study employed multiple research methods to analyse the evolution laws of the stress environment and plastic zones of the 5105 roadway in service under the engineering background of the gob-side entry in Selian No. 1 Coal Mine, China. The mechanism of the large inhomogeneous deformation of the mining roadway was revealed, and a full-section differentiated control technique was proposed. Results demonstrate that the roadway at 5 m in front of the working face is under a stress environment, in which the principal stress ratio is 3.77 and the included angle between the maximum principal stress and the horizontal direction is 64°. This stress state induces inhomogeneous malignant extension in the plastic zone in the roof at the coal-rib side and in the floor at the coal-pillar side. A full-section differentiated control technique involving roof and rib reinforcement with asymmetric bolt/cable support and floor pressure relief by hole drilling and cable bolting was developed. Numerical simulation revealed the technique's good control effect. 24 refs.

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Key Words: *Gob-Side Entry, Inhomogeneous Deformation, Numerical Simulation, Plastic Zone, Surrounding Rock Control*

OPTIMIZATION OF MACHINING PERFORMANCE IN DRY END MILLING OF INCONEL 601

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Abstract

This study investigates the influence of helix angle, cutting speed, feed per tooth, radial depth of cut and axial depth of cut on surface roughness and material removal rate during dry end milling of Inconel 601. An I-optimal design of experiments was employed to develop a quadratic regression-based simulation model for surface roughness, while material removal rate was determined analytically. Multi-objective optimization was performed to maximize material removal rate while satisfying target surface roughness levels corresponding to previously defined machining quality grades. The results indicate that higher helix angles, moderate cutting speeds, lower feed per tooth and lower depths of cut lead to improved surface roughness. Conversely, a reduction in the stringency of surface roughness requirements enables a significant increase in productivity by permitting the use of more aggressive milling parameters, including higher cutting speeds, feed per tooth and depths of cut. Confirmation experiments demonstrated good agreement between predicted and measured surface roughness values, with low prediction errors, confirming high predictive accuracy and model stability. 27 refs.

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Key Words: *End Milling, Dry Conditions, Surface Roughness, Material Removal Rate*

RESEARCH ON SPINNING FORMING TECHNOLOGY OF D406A ULTRA-HIGH STRENGTH STEEL

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Abstract

To address issues such as significant wall thickness deviation, diameter expansion, and cracking during the spinning of D406A ultra-high strength steel cylindrical parts due to improper process parameter combinations, a finite element model for power spinning was established using ABAQUS/Explicit software. The orthogonal experiment range analysis method was employed to investigate the influence of process parameters, including spinning roller feed per revolution (1–3 mm/r), thinning ratio (30–50%), and spinning roller nose radius (4–8 mm), on wall thickness deviation. The results indicate that the order of influence of each parameter on wall thickness deviation is as follows: thinning ratio > spinning roller feed per revolution > spinning roller nose radius. Based on simulation results, spinning experiments using the optimal parameter combination: spinning roller feed per revolution of 2 mm/r, thinning ratio of 40%, and spinning roller nose radius of 4 mm, successfully produced a cylindrical part with a wall thickness deviation of 0.053 mm, further verifying the accuracy of the finite element simulation analysis. 22 refs.

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Key Words: *D406A Ultra-High Strength Steel, Spinning Forming, Process Parameters, Wall Thickness Deviation, Thinning Ratio*

SIMULATION-DRIVEN OPTIMIZATION FOR PRODUCTION PLANNING IN EQUIPMENT MANUFACTURING

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Abstract

Equipment manufacturing is characterized by multi-variety, small-batch production and frequent dynamic disturbances. Conventional production simulation is mainly used for offline validation and is rarely integrated with production planning, which limits its applicability in dynamic environments. This study develops a simulation-driven closed-loop rolling optimization framework based on a multi-agent discrete event simulation model. The framework integrates rolling horizon control, real-time interaction between simulation and optimization, and disturbance-triggered rescheduling. A coupling mechanism between the simulation clock and optimization process is established to support continuous plan adjustment. Simulation experiments in a real manufacturing workshop show that the proposed approach reduces order tardiness and makespan while maintaining stable equipment utilization under dynamic disturbances, compared with offline simulation-based optimization and conventional scheduling methods. The results indicate that production simulation can be integrated into planning decisions and used for dynamic adjustment in complex manufacturing environments. 17 refs.

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Key Words: *Equipment Manufacturing, Production Planning Optimization, Multi-Agent Discrete Event Simulation, Simulation-Optimization Closed Loop, Rolling Horizon Optimization, Dynamic Production Scheduling*

CARBON-EFFICIENCY COUPLED SCHEDULING FOR NEW ENERGY MANUFACTURING SYSTEMS

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Abstract

This study addresses the coordination of production efficiency and carbon emissions in new energy manufacturing systems, where fluctuating energy use and carbon intensity complicate scheduling decisions. Conventional simulation-based approaches treat emissions as post-process indicators and fail to capture their interaction with production dynamics. A carbon-efficiency coupled scheduling framework is developed by embedding carbon emissions into the simulation process as dynamic resources. A dual-layer multi-agent structure is constructed, linking load aggregation with manufacturing units. An improved multi-agent reinforcement learning strategy is introduced to coordinate scheduling decisions with real-time carbon signals. A digital twin-based platform is established for validation, and comparative experiments are conducted under multiple scenarios. The results show that carbon emission peaks and total emissions can be reduced while maintaining stable production performance. The proposed framework provides a practical basis for integrating carbon constraints into production scheduling. 21 refs.

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Key Words: *New Energy Manufacturing Systems, Production Scheduling, Carbon Mitigation Coordination, Production Simulation, Multi-Agent Reinforcement Learning, Digital Twin*

PRODUCTION-INVENTORY COORDINATION UNDER UNCERTAIN DEMAND

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Abstract

Coordinating production and inventory decisions under uncertain demand remains difficult, as most existing approaches rely on predefined demand assumptions and loosely connect simulation with optimization. This study develops a reinforcement learning framework to support joint decision-making in such environments. The system is described as a Markov decision process, where demand dynamics are incorporated into the state representation and linked to a profit-oriented reward structure. Policy learning is implemented using a modified proximal policy optimization scheme to improve stability and responsiveness under demand fluctuations. The learning process is embedded within a discrete-event simulation environment, allowing continuous interaction between decision updates and system evolution. Experiments across multiple demand scenarios show that the proposed approach achieves consistently higher profit levels while reducing stockout risk and improving inventory stability compared with conventional policies and standard reinforcement learning methods. 15 refs.

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Key Words: *Uncertain Demand, Production-Inventory-Profit Coordination, Deep Reinforcement Learning, Discrete-Event Simulation, Adaptive Optimization, Production System Simulation*

A PSO-BASED SIMULATION OPTIMIZATION FOR A COLLABORATIVE PRODUCTION SCHEDULING PROBLEM

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Abstract

This study addresses collaborative production scheduling in a resource-constrained three-tier equipment manufacturing supply chain. A bilevel optimization model captures interactions between centralized penalty/incentive policies and decentralized operational decisions regarding equipment utilization, pricing, and quantity. A particle swarm optimization (PSO)-based procedure solves the nonlinear bilevel problem. Numerical simulations examine convergence, optimal scheduling, and parameter sensitivity. Results show scheduling performance jointly depends on equipment utilization elasticity, switching cost, working-hour adjustment price, and demand. Low switching costs and moderate elasticity raise efficiency and profit; adverse parameter combinations lead to low-performance regimes. Properly designed penalties and incentives improve coordination, though their effectiveness hinges on operational flexibility and demand. The study offers a simulation-optimization framework for collaborative scheduling analysis in constrained equipment supply chains and supports decision-making for scheduling centres and enterprise planning. 26 refs.

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Key Words: *Three-Tier Supply Chain, Simulation Optimization, Production Scheduling, PSO, Equipment Manufacturing*