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Editorial

Emerging Scientific and Technical Challenges and Developments in Key Power Electronics and Mechanical Engineering

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1. Introduction

In celebration of the 70th anniversary of the University of Science and Technology Beijing (USTB), this Special Issue presents the electrical and mechanical engineering research of the USTB, with the aim of providing timely solutions to emerging scientific and technical challenges in key power electronics and mechanical engineering at the frontier of modern industrial development. High-quality original technical papers and advanced review papers are included herein.

This Special Issue contains thirteen articles, of which twelve are research articles and one is a review. The next section will provide a brief introduction to each article.

2. Brief Description of the Published Articles

Lu et al. [1] proposed a multi-signal vehicle speed prediction model based on the long short-term memory (LSTM) network, improving the accuracy of vehicle speed prediction by considering multiple signals. First, various signals were collected by simulating the vehicle model, and a Pearson correlation analysis was performed on the collected multiple signals in order to improve the model's prediction accuracy, and the appropriate signal was selected as the input of the prediction model. The experimental results indicated that the prediction method greatly improves the predictive effect compared with the support vector machine (SVM) vehicle speed prediction method. Secondly, the method was combined with the model predictive control–equivalent consumption strategy (MPC-ECMS) to form a control strategy suitable for power maintenance conditions, enabling the equivalent factor to be adjusted adaptively in real time and the target state of charge (SoC) value to be set. Pontryagin's minimum principle (PMP) enables the battery to calculate the range extender output power at each moment. PMP, as the core algorithm of the ECMS, is a common real-time optimal control algorithm. Then, taking into account the engine's operating characteristics, the calculated range extender power was filtered to make the engine run smoothly. Finally, hardware-in-the-loop simulation (HIL) was used to verify the model.

Wu et al. [2] proposed a skin pathological mirror classification method based on discrete wavelet down-sampling feature reconstruction. The wavelet down-sampling method was introduced first, and the multichannel attention mechanism was then introduced to realize the pathological feature reconstruction of high-frequency and low-frequency components, which reduces the loss of pathological feature information due to down-sampling and effectively utilizes the channel information. A skin cancer classification model is presented, using a combination of depth-separable convolution and 3×3 standard convolution and wavelet down-sampling as the input backbone of the model to ensure the perceptual field while reducing the number of parameters; the residual module of the model was optimized using wavelet down-sampling and the Hard-Swish activation function to enhance the feature representation capability of the model. The network weight

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parameters were initialized on ImageNet using transfer learning and then debugged on the augmentation HAM10000 dataset. The experimental results showed that the accuracy of the proposed method for skin cancer pathological mirror classification significantly improved, reaching 95.84%.

Xu et al. [3] simulated the thermal runaway triggering process of Li-ion batteries and analyzed the relationship between the local heating of the cathode collector surface and the change in the high-temperature area distribution of the diaphragm layer. The thermal runaway mechanism is further revealed. Based on the simulation results, the following conclusions can be drawn: phosphonitene compounds can delay the decomposition of the solid electrolyte interphase membrane and reduce the energy yield of battery-side reactions. Compared with the phosphonitene compound, the optimized structure of adding phosphonitene has little effect on the thermal stability of the battery.

Zhao et al. [4] developed an integrated vibration elimination system (IVES) containing a dynamic vibration-absorbing structure between the IWM and the suspension. It also includes an active suspension system based on a delay-dependent H∞ controller. Furthermore, a novel frequency-compatible tire (FCT) model was constructed to improve the IVES's accuracy. The mechanical–electrical–magnetic coupling effects of IWMD EVs were theoretically analyzed. A virtual prototype for the IVES was created by combining CATIA, ADAMS, and MatLab/Simulink, resulting in a high-fidelity multi-body model, validating the IVES's accuracy and practicability. Simulations for the IVES considering three different suspension structure types and time delay considerations were performed. Analyses in frequency and time domains for the simulation results showed that the root mean square of sprung mass acceleration and the eccentricity were significantly reduced via the IVES, indicating an improvement in ride comfort and IWM vibration suppression.

Zhou et al. [5] proposed a wavelet transform longitudinal denoising method, combined with a genetic algorithm (GA-WT), which was proposed to handle the big noise of the measured data from each signal channel of the flatness meter, and Legendre orthogonal polynomial fitting was employed to extract the effective flatness features. Based on the preprocessed actual production data, the adaptive moment estimation (Adam) optimization algorithm was applied to intelligently identify the flatness control efficiency. This paper takes the actual production data of a 1420 mm tandem cold mill as an example to verify the performance of the new method. Compared with the control efficiency determined by the empirical method, the flatness residual MSE 0.035 was 5.4% lower. The test results indicated that the GA-WT–Legendre–Adam method can effectively reduce the noise, extract the flatness features, and achieve the intelligent determination of the flatness control efficiency.

Li et al. [6] proposed a novel liquid cooling plate with mini-channels and improved it with disturbance structures. First, an accurate battery heat generation model was established and verified by experiments. The error was less than 4%, indicating that the heat generation power is reliable. Then, five designs are proposed first to determine the suitable number of disturbance structures, and plan 3 with five disturbance structures showed satisfactory performance in heat dissipation and flow field. Moreover, four layout plans were proposed, namely uniform, interlaced, thinning, and gradually denser distribution. The results showed that plan 5 (uniform) achieved the best performance: the maximum average temperature was 36.33 °C and the maximum average temperature difference was 0.16 °C. Last, an orthogonal experiment and range analysis were adopted to optimize the structure parameters. The results showed that the best combination for the space between the adjacent disturbance structures was d1 = 20 mm, length d2 = 5 mm, width d3 = 1.5 mm, and tilt angle $\beta = 60^{\circ}$.

Zhang et al. [7] studied the spiral climbing motion of a snake-like robot on the outer surface of a cylindrical object based on the three-dimensional motion of a biological snake and then carried out the analysis and optimization of the motion-influencing factors. First, the spiral climbing motion of the snake-like robot was implemented by the angle control method, and the target motion was studied and analyzed by combining numerical and environmental simulations. We integrated the influence of kinematics and dynamics factors

on the spiral climbing motion. Based on this, we established a multi-objective optimization function that utilized the influence factors to optimize the joint module. In addition, through dynamics simulation analysis, the change in the general clamping force of the snake-like robot's spiral climbing motion was transformed into the analysis of the contact force between the joint module and the cylinder. On the basis of the results, the effect of the control strategy adopted in this paper on the motion and change rule of the spiral climbing motion was analyzed. This paper presents the analysis of the spiral climbing motion, which is of great theoretical significance and engineering value for the realization of the three-dimensional motion of the snake-like robot.

Zhang et al. [8] proposed a strain rate-dependent material model for accurately evaluating the dynamic response of CFRTP laminates with different stacking sequences. The model was composed of three components: a strain-rate-dependent constitute model, a strain-rate-related damage initiation model, and an energy-based damage evolution model. The strain rate effect of modulus and strength was described by a stacking-sequence-related matrix, and the damage initiation model could describe the matrix, fiber, and delamination damage of CFRTP laminates without introducing cohesive elements. The material model was implemented into finite element software ABAQUS by user-defined subroutine VUMAT. The low-velocity impact tests of CFRTP laminates with quasi-isotropic and angle-ply stacking sequences were used to provide validation data. The dynamic response of CFRTP laminates from the numerical results was highly consistent with the experimental results. The mechanical response of CFRTP laminates was affected by the stacking sequence and impact energy, and the numerical error of the proposed material model significantly decreased with the increasing impact energy, especially for the laminae where the damage had occurred.

Yang et al. [9] proposed a collaborative multi-vehicle localization scheme based on GNSS and vehicle networks. The vehicle first estimates the location based on GNSS positioning information and then shares this information with the environmental vehicles through vehicle network communication. The vehicle further integrates the relative position of the ambient vehicle observed by the radar with the ambient vehicle position information obtained by communication. A smaller error estimate of the position of self-vehicle and environmental vehicles is obtained by correcting the positioning of self-vehicle and environmental vehicles. The proposed method is validated by simulating multi-vehicle motion scenarios in both lane change and straight-ahead scenarios. The root-mean-square error of the co-location method is below 0.5 m. The results demonstrate that the combined vehicle network communication approach has higher accuracy than single GNSS positioning in both scenarios.

Xiang et al. [10] investigated the fatigue fracture of bilateral drive drum shafts in casting bridge cranes including their fracture morphology and other factors, such as materials, manufacturing processes, and loads. Seven conditions were designed to test the effects of changes in the speed and torque of the drum shafts during start-up, commissioning, and braking under different loads. A dynamic model was developed for the structure and control system of the hoisting mechanism. Changes in the speed and torque of the motor and drum shafts were simulated under common operating conditions such as the speed and load changes of the motor, control asynchrony, and single-motor towing. The results showed that asynchronous motor starting and braking, motor dragging, and other behaviors led the left and right drum shafts to undergo oscillated torque with a value reaching 2×10^5 N·m in a period of approximately 13 s, and a residual torque of about 3×10^4 N·m was retained after braking. The torques on the drum shafts changed suddenly during the processes of starting, shifting, and braking. Dynamic loading was the root cause of the fatigue fracture of the drum shafts.

Zhang et al. [11] designed a new, three-dimensional honeycomb with a negative Poisson's ratio. A honeycomb cell was first designed by out-of-plane stretching of a re-entrant honeycomb, and the honeycomb was built by spatially combining the cells. The in-plane response and energy absorption characteristics of the honeycomb were studied

through the finite element method (FEM). Some important characteristics were studied and are listed as follows: (1) the effects of cell angle and impact velocity on the dynamic response were tested. The results show that the honeycomb exhibits an obvious negative Poisson's ratio and unique platform stress enhancement effect under the conditions of low and medium velocity. An obvious necking phenomenon appears when the cell angle parameter is 75°. (2) Based on the one-dimensional shock wave theory, the empirical formula of the platform stress was proposed to predict the dynamic bearing capacity of the honeycomb. (3) The energy absorption under different conditions was investigated. The results showed that as the impact velocity increases, the energy absorption efficiency gradually decreases. In addition, with the increase in the cell angle, the energy absorption efficiency is gradually improved. The above study shows that the honeycomb studied has good potential for use in the automotive industry as an energy absorption material. It also provides a new strategy for the multi-objective optimization of mechanical structure design.

Lu et al. [12] proposed a 3D-based breast ultrasound system, which can automatically diagnose ultrasound images of the breasts and generate a representative 3D breast lesion model through typical ultrasonography. In this system, the authors used a weighted ensemble method to combine three different neural networks and explore different combinations of the neural networks. On this basis, a breast locator was designed to measure and transform the spatial position of lesions. The breast ultrasound software generates a 3D visualization report through the selection and geometric transformation of the nodular model. The ensemble neural network improved in all metrics compared with the classical neural networks (DenseNet, AlexNet, GoogLeNet, etc.). The results proved that the ensemble neural network proposed in this work can be used for the intelligent diagnosis of breast ultrasound images. For 3D visualization, magnetic resonance imaging (MRI) scans were performed to achieve their 3D reconstructions. By comparing two types of visualized results (MRI and the 3D model), the authors determined that the models generated by the 3D-based breast ultrasound system have similar nodule characteristics and spatial relationships with MRI. In summary, this system implements the automatic diagnosis of ultrasound images and presents lesions through 3D models, which can obtain complete and accurate ultrasound image information. Thus, the system has clinical potential.

Wu et al. [13] described the EMI sources and coupling paths of EMI in third-generation semiconductor devices used in power electronic converters. The modeling methods of EMI are summarized from the perspectives of power devices and coupling paths. The suppression methods of conducted noise are summarized by suppressing EMI sources and improving the coupling path characteristics. This paper provides a reference for the electromagnetic compatibility design of power electronic converters for third-generation semiconductor devices.

3. Future Directions

Electrical and mechanical engineering has developed rapidly in recent years. One obvious trend is digitization and intelligence. This is reflected in the emergence and development of technologies such as artificial intelligence, big data, and digital twins. These technologies can increase the efficiency of equipment operation, extend operation times, and provide more information services. As a practitioner in the relevant industries, it is of positive significance to understand and observe the development of the field.

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