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Research on the Application of the Industrial Cycle Temperature Control Electromechanical Integration Technology in High Precision Weighing System

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Traditional design technology has been enriched and improved in content, model and methods thanks to the development of computational mathematics, engineering mechanics, mechanical dynamics, electronic information technology and computer technology, with the concept transforming from manufacturing-oriented design to user-oriented design. Typical electromechanical integration technology, based on electronic control, replaces the conventional control system with computer, and thus simplifies the mechanical structure. With high functionality and reliability, and improved operability and production efficiency, mechatronics technology has been extensively developed and used. With the substantial development and thorough integration of modern computer technology and mechanical design theory, the weighing technology in China has also been improved. It has become an inevitable trend to combine the new weighing design concept with electromechanical integration technology to be a new weighing system for more innovative and adaptive products.

1. Introduction

A company imported German electronic scale weighing system equipment for the weighing station in its automated production line (Feng et al., 2017; Wu and Fan, 2017). However, the equipment was unable to put into normal use since its installation. In addition, the inconvenience in maintenance coupling with system aging caused the weighing data distortion, sometimes resulting in a drift of hundreds of kilograms, and therefore impaired the production and management of banknote workshop (Marx et al., 2016). Consequently, this company dropped the use of imported equipment and turned to traditional scales, but its continuous production efficiency was seriously degraded. To meet the requirement of banknote production and equipment management, this company re-developed a high-precision electronic scale weighing system on the traditional machinery, which is a reliable and advanced weighing system integrating real-time online simulation, data display, data storage, man-machine dialogue, printing, alarm, network and security features (Loomis et al., 2013). They overcame many difficulties in upgrading the old production lines due to the structural difference between the two generations of machines. The mechatronics design approach is based on the system specification, under the guidance of concurrent engineering and system engineering, parallel virtual prototype design with mechanical design, electrical design, collaborative design of embedded hardware/software, control design as the main content, After the completion of the virtual prototype design, and then the physical prototype design and manufacturing and testing and verification of follow-up design process. The use of parallel prototyping techniques in the design reduces design risk and design costs, shortens design time and improves design efficiency.
In the early 90s of the 20th century, the main theories and methods involved in the development, parameter design and optimization, system performance optimization and simulation of mechanical and electrical integration product include the overall optimization design theory, intelligent design theory, flexible design theory, network design theory, integration principles and reliability principles (Gameros et al., 2017; Huang et al., 2017; Wang, 2017; Deng, 2017). Starting from the second half of the 20th century, product competition speeded up and the research focus of mechanical and electrical integration moved from the production stage

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to the design stage, and then to the conceptual design stage (Dhole and Kulkarni, 2015). The key of designing innovative product of mechanical and electrical integration technology is to explore the new concept design of the mechanical and electrical integration system (Eker, 2015). Therefore, the study of virtual prototype based on mechanical and electrical integration technology is highly important for the development of mechanical and electrical integration. Based on the virtual prototype of the mechatronic design technology, mechatronic virtual prototype and simulation platform design, as well as the mechatronic simulation design and prototype test deployment content, at the same time, for multi-domain interactive design based on the virtual prototype of electromechanical integration The simulation design technology is discussed. The whole study is based on the research of virtual prototype and its related design theory, and makes full use of the methods of induction, reasoning and deduction to finally establish the whole research framework and carry out practical verification. Practice shows that this method can effectively achieve the integrated simulation design of mechatronic products from mechanical to electrical, control and other fields, which provides a new effective way for the design of mechatronic products.

2. Improve the accuracy of the system

Typical electronic scale is composed of load-bearing force transmission agencies, weighing sensors, measuring devices and other secondary instrument components (Bar-Cohen et al., 2014). The load-bearing mechanism, also known as scale, is referred to as the mechanical transmission system between the object and the conversion element. It generally contains the load bearing surface, the bridge structure, the hanging connection part and the limit shock of load cell. Such mechanism includes a conversion element that converts the non-charged weight into electricity signal. The output power corresponds to the input weight as a single value. With good linear relationship and a higher sensitivity to the state of the object, such mechanism can be used in poor working conditions. It generates better frequency response and smaller inertia. Stable and reliable measuring device secondary instruments that consist of load cell signal electronic circuits, such as amplifier, converter, and microprocessors, are used for display, print data transmission, and other purposes.

2.1 Analysis of the error sources of electronic scales

The error of the electronic scale refers to the difference between the indicated and the true value of the object. This difference can be positive or negative, and its absolute value is often used to determine the weighing point and access the measurement accuracy of the electronic scale (Jaber and Bicker, 2014). The error of the electronic scale is due to the error of the load cell, which consists of several aspects. The error of the mechanical measurement system is caused by the error of the dynamic load disturbance. The force felt by the sensor determines the voltage of the electrical signal. Normally the voltage output change linearly with the sensed force. But if the force sensed is indeed linearly related to the electrical signal output, such coefficient is not able to indicate the accuracy of the sensor. In addition, different sensor capacity selection also tends to cause linear changes, which may also be resulted from the weighing error. Meanwhile, the increasing usage period, the aging of components, and the temperature changes may lead to the sensor output drift. For example, as to the commonly used resistance strain gauge load cell, the error usually results from its own nonlinearity, non-repetition and hysteresis, as well as zero drift and sensor coefficient change (Figure 1).

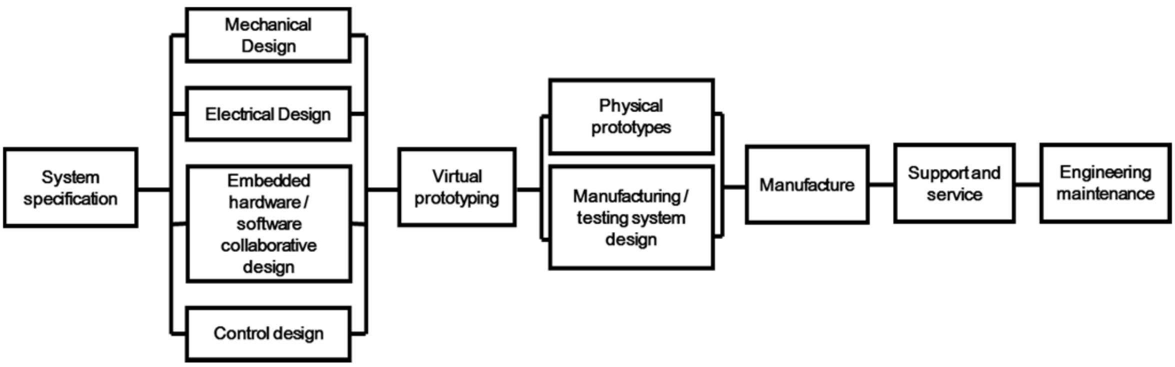

Figure 1: Product Electromechanical Integration Design

2.2 Improve the weighing accuracy method

The above analysis provides us a systematic understanding of the source of error and thus an effective way to go to overcome such error. In the simplest condition, weighing should occur in static status, but in actual application, the weighing scale is not always in the ideal state of work. Static status, which can be seen as a special case of dynamic condition, is only a special state of the working process (Figure 2). The initial state of the system is a dynamic working process. In the dynamic weighing, due to the impact of vibration and shock of the object, weighing is exposed to greater error. The primary problem that dynamic weighing should solve to obtain higher accuracy is to eliminate the above impact. The current approach to improve the weighing accuracy usually starts with the signal data processing electronic device, and the main focus is the detection circuit part of the hardware and mechanical bearing part of other links.
Due to the sensor and instrument amplification and conversion and other reasons, electronic weighing system may experience various degrees of non-linear condition, resulting in non-linear system error. In the past, complex hardware circuits were used for error correction. Now simple software can meet such requirements. When calibrating an electronic scale, software enable us to accurately measure the relationship between the actual load and the indication at each calibration point, and thus draw a transmission curve. Such characteristic curve is then used in weighing, to calculate and display an indication that corresponds to the actual weight value.

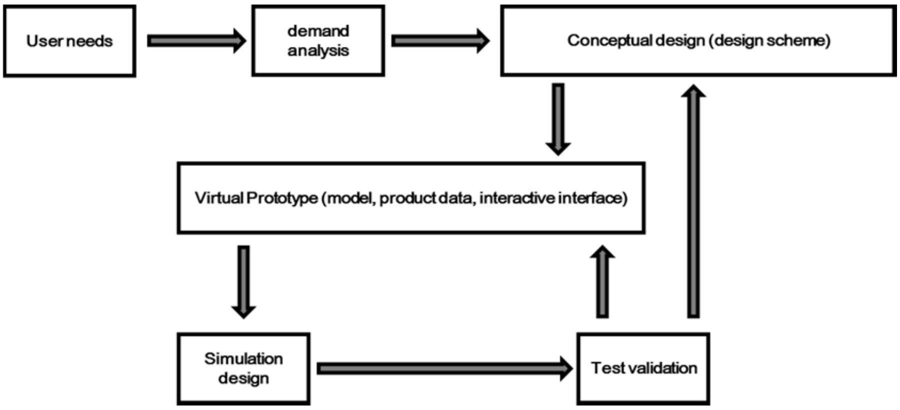

Figure 2: Design Process of Mechatronics Product Based on Virtual Prototype

3. Mechanical structure design

Mechanical design is the foundation of and guarantees the mechanical and electrical integration technology. The introduction of high-tech machinery in the industry brings challenges and changes to the mechanical technology. The connection among the systems in mechatronics products has important influence on the system structure, mass, volume, stiffness and durability of the product. The focus of mechanical technology is to be adapt to and apply mechatronics technology, integrating it with other advanced new technology to create new concept, to change and improve the structure, materials, performance, and functionality, and thus to improve quality, reduce size and improve the stiffness and performance and meet the functional requirements.

3.1 Principles of mechanical design

Mechanical design is complex yet meticulous work. Scientific work methods and procedures should be applied to create with lower cost a popular product of higher quality, better performance, and stronger market competitiveness. Such procedure usually includes four phases, i.e. the research and design phase, and decision-making phase, the trial production phase and the sales phase (Figure 3). The research and design phase consist of two steps. The first step is mainly functional design research, which solves the key issues in technology. The second step is the technical design of the product. The drawings of the design is finished in this step, which includes the assembly drawings, parts assembly drawings, parts operation drawings, diagrams of a variety of systems including transmission system, lubrication system, hydraulic system and circuit system, and the detailed calculation manual.

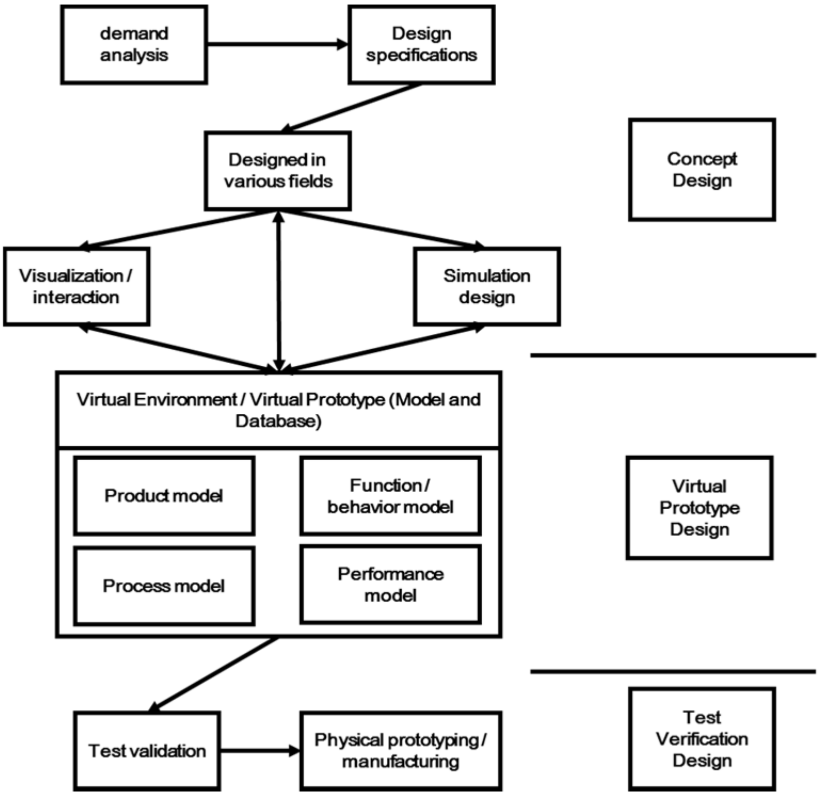

Figure 3: Design Principle of Virtual Prototype High Precision Weighing System.

3.2 Installation program design

Shear stress principle and normal stress principle are widely used in the domestic load cells design. The shear stress type load cells mainly adopt a bridge structure, while cantilever positive stress type load cells use structure of parallel double beam and column. When installing the cantilever load cell, fix the multi-purpose high-strength bolts to one end of the frame and the carrier to the other end (Figure 4).

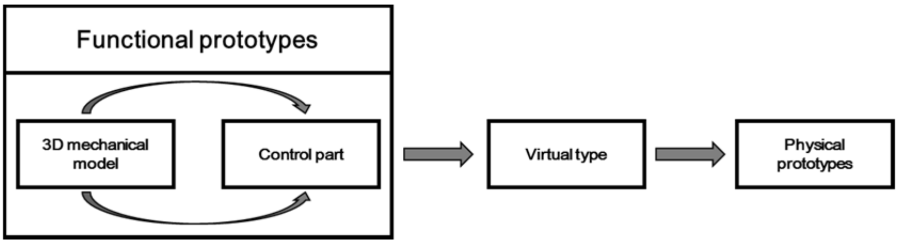

Figure 4: Conceptual Design Stage Functional Prototype Design.

Functional prototype design, developed on the basis of conceptual design, reflects the overall design requirements and is a breakdown and a summary of a specific design. Functional prototype design enables the comparison between the current design and the original design specifications at the beginning of the product design, enhances in a visual way the communication between different design areas and thus facilitates the design improvements and corrections. It is an effective method for product design and evaluation. It comprehensively reflects the product's conceptual design and is the basis of and guidance for virtual prototyping.

3.3 Parts design and strength check

As an important part of mechanical design process, selection of materials is the first consideration in mechanical parts design. Same parts manufactured with different materials require different standards in size, structure, processing technology and other aspects. The cost and manufacturing cycle will also be different.

Performance selection method is used for material selection and the main considerations are the usage performance and the process performance (Figure 5). The usage performance relates to the load of the parts, which refers to the volume of the load, the nature of the load and the pressure type in its working environment. The working environment consists of the environmental pressure, working temperature, medium type of the parts and the size of other parts. Such factors may affect the quality of the important parts of the machine and lead to the failure of the part.

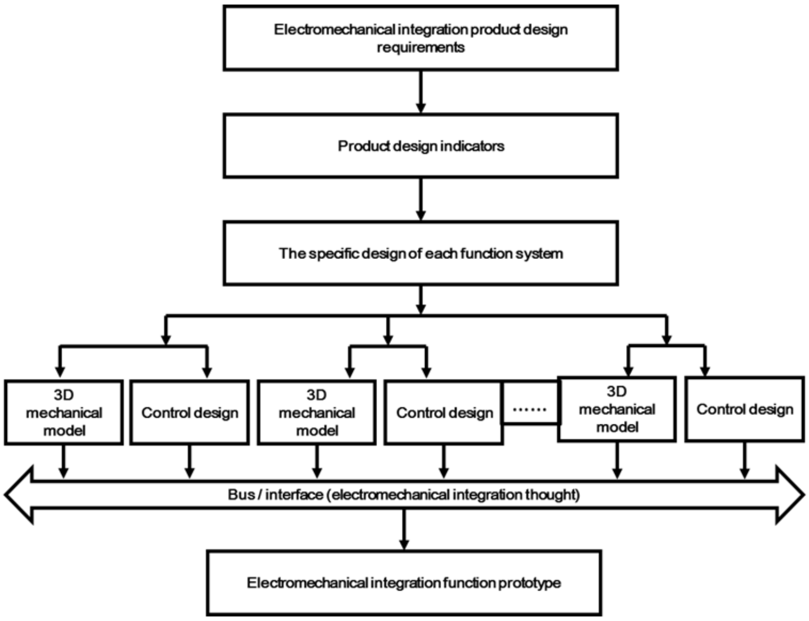

Figure 5: Mechanical and Electrical Integration Product Functional Prototype Development Model.

3.4 Design summary

"Design" has a long history. The theory and method of design are gradually improved along with the development of society. In terms of the different development process, design can be divided into four stages: intuitive design, experiential design, auxiliary design and innovative design. The so-called innovative design refers to the research on modern design principles and models with innovative point of view and approaches. It gives full play to the designer's creativity, reveals new theories, creates new technologies, and designs more competitive products (Figure 6). Innovative design integrates the essence of a variety of design methods and reflects the diversity of emerging science. Such design, including a variety of contemporary creative technology, is both flexible and accurate.

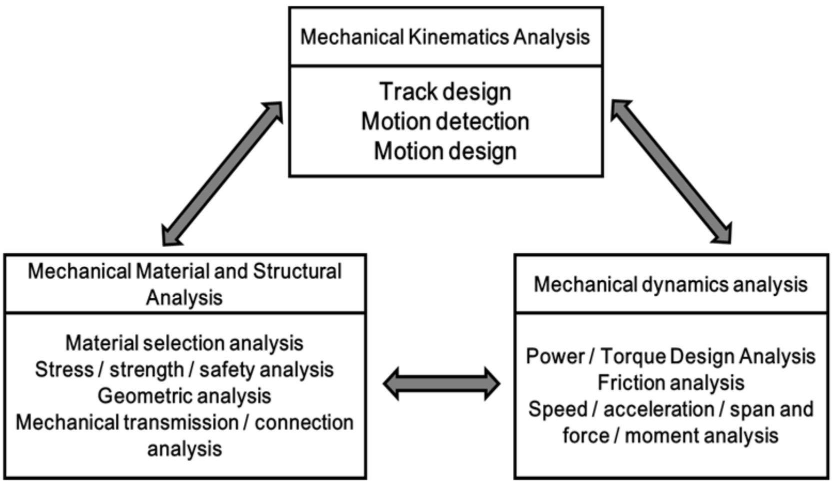

Figure 6: Mechanical Simulation Design Basic Process.

4. Conclusions

Based on electromechanical integration technology, the high precision weighing system converts the mechanical quantity into usable digital value and analog value. This stable on-line weighing system can give accurate real-time results. Advanced mechanical and electrical integration control theories are used to design the high-precision metering functionality in this system. This integrative system does not have defects of manual operation and simple measurement mode, and the applicability and reliability is therefore improved. The high-precision weighing system perfectly applies the mechatronics technology, and combines the high-precision metering function with production equipment. Its optimized mechanical design eliminates circuit interference and the integration of manual measurement into advanced automated metering marks a brand new start of electrical, mechanical and other system design. This comprehensive and clever design takes into account the environmental adaptability, stability, anti-jamming ability and applicability, and generates accurate real-time online results. The system filled the gaps in the paper production industry, and at the same time facilitated the automation and information technologies in China's weighing industry.

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