Research Article

Application of Ergonomics in Product Design Based on Computer-Aided Design

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At present, China’s social economy has entered a new state of normalized development. Since green economy is the strategic goal pursued by sustainable economic development and the core development trend of the economy, industrial product design focuses on design humanization and green production above. The principle of ergonomics is applied in the design of industrial products, which has the function of optimizing the scientifi/city of industrial products, which makes industrial products more humanized. This paper firstly analyzes the basic concept of ergonomics, then expounds the thinking of ergonomics in industrial product design, and expounds the specific application of ergonomics in industrial product design.

1. Introduction

Ergonomics is mainly the study of the theory of the relationship between people, the environment, and products. With the development of my country’s economy, the green economy has gradually become the core of economic development, and the humanization and greening of industrial product design has become the focus of product design. Therefore, this paper analyzes and expounds on the specific application of ergonomics in industrial product design, and its main purpose is to optimize industrial products. As a necessary theory to achieve the goal of sustainable human development, ergonomics mainly studies the cross-theory of the relationship between people and the environment, people and products, and the environment and products [1]. Ergonomics integrates various types of scientific theories such as psychology, bloodless, engineering technology, and ecological concepts and organically combines the objective requirements of the ecological environment, the actual needs of human beings, and product functions, so as to realize the real environment. Industrial products can be more ecological, scientific, and humanized. The application of ergonomics in the process of industrial product design is mainly to guide the design process of industrial products and to determine the design results of industrial products. Faced with the background of continuous social and economic development, the demand for industrial products continues to increase, and the concept of ergonomics has been developed simultaneously. The concept of ergonomics is applied to the design of industrial products, and it is used in the application of industrial product design. Considering the strategy to be studied, the premise is to master the concept of advanced nature [2]. At present, in the design of industrial products in my country, green design is mainly used. There are two ergonomics concepts in virtual design, among which virtual design is the most widely used concept. The reason is that the design effect of virtual design can meet the needs of humanization and capital saving.

With the help of computer virtual technology, not only can the industrial product design be adjusted more accurately, but also the design time and material cost can be effectively saved. The concept of green design is based on the application of scientific principles, combined with the relevant national economic development policies and environmental factors, and its main purpose is to upgrade the humanized service function of industrial products from the individual level to the social level. Adopt the green design concept as the core of industrial product design guidance, and then design industrial products that meet the needs of the actual environment first, thereby significantly improving
the use value of industrial products in real life. The core principle of green design is to comprehensively coordinate the relationship between industrial products, the ecological environment, and human beings to surpass human-centered design with people as the center, so the designed industrial products can keep pace with the development of the times [3].

The basic link of industrial product design is the product appearance design. The basis of product appearance design mainly includes the practical application and internal structure of the product. After the application of ergonomics in the appearance design of industrial products, it not only realizes the aesthetic requirements of product appearance but also realizes the requirements of modern fashion trends, thereby reducing the loss caused by fashion trends to product replacement [4]. The application of ergonomics in the design of industrial products makes industrial products conform to the long-term aesthetic requirements of human beings, thereby providing a guarantee for the lasting competitiveness of products in the market environment. For example, the design of Apple series products, whose appearance looks relatively simple, is still loved by many consumers around the world and has maintained a long-term competitive advantage in the fierce market. According to the principle of mechanical engineering, although the appearance of the designed product seems simple, it lacks a very rich connotation. The Apple series of products designed by the company can induce people to feel joy from the heart and ensure that consumers can use them for a long time, so it not only meets the needs of humanization but also meets the needs of saving product consumption costs [5].

As far as industrial products are concerned, they are in a dynamic state or in a static state, and industrial products can still convey some kind of information just like human beings. Such information comes from the active observation of human beings rather than the active behavior of industrial products. People observe things through the senses of sight, hearing, smell, and touch. Therefore, the application of ergonomics in industrial product design should include all the above dimensions, and then three-dimensional and multidimensional industrial product design should be carried out. The main purpose of this is to ensure that industrial products can convey positive information to people and to achieve the consistency of the information transmission process with the human body’s receiving habits, so as to prevent the troubles caused by receiving information [6].

The key part of the direct contact between industrial products and people is the operating device. On the one hand, the humanized design can provide convenience to the operator, and on the other hand, it can effectively exert the performance of the industrial product itself. Most industrial products use human hands as the design basis to carry out product design work in the design of operating levers, touch screens, and other links [7]. Taking ergonomics as a consideration, the industrial product operating device fully demonstrates the added value beyond the product’s own function, and in terms of the product’s own added value, it mainly reflects fairness and convenience. Among industrial products, there are some products with complex operability that better meet the requirements of humanized product design, and such products are more competitive; that is, they are more suitable for the needs of the market environment [8]. For example, there are too many complex operations in agricultural machinery and equipment. These operations are difficult for farmers to master. Therefore, agricultural machinery and equipment with simple and convenient designs are more in demand in the market. For example, the shape design of the position of the backpack is mainly based on the shoulder structure and bearing capacity of the human body. Such a detailed design can better reflect humanization and provide the convenient application. Therefore, this type of engineering product has significant market competitiveness [9].

2. An Overview of Ergonomics Theory

2.1. The Concept of Ergonomics. Regarding the International Association of Ergonomics (IEA), ergonomics is the study of various factors in human anatomy, physiology, and psychology in a certain working environment. Interaction with machines and the environment in which they are used is a discipline that studies how to consider issues such as work efficiency, human health, safety, and comfort at work, in family life, and on vacation [10].

Ergonomics is a comprehensive frontier discipline that studies the interaction between people, machines, and their working environments and has an extremely wide range of research and applications. In the course of its own development, the discipline has continuously improved its basic theories, theoretical systems, research methods, and technical standards and norms, gradually breaking the boundaries between various disciplines, and organically integrating the theories of various related disciplines. In addition to being closely related to related engineering technology disciplines, ergonomics is also closely related to physiology, psychology, anthropometrics, environmental protection, cybernetics, and information theory [11].

Ergonomics is based on people’s physiological and psychological characteristics, aiming to improve people’s work and life quality, using the viewpoints and methods of systems engineering and information processing psychology to study people and machinery, people and environment in the field of production. The interaction between machinery and the environment provides a more comprehensive basis for the design and use of the human-machine system by revealing the law of the relationship between the three elements of human, machine, and environment, thereby ensuring the optimization of the overall performance of the human-machine system. It provides a theoretical basis and method for designing a “man-machine-environment” system that is easy and labor-saving, accurate, safe, efficient, and comfortable [12].

2.2. The Origin and Development of Ergonomics. As an independent discipline, modern ergonomics originated in Europe in the 20th century, formed in the United States, and developed during the Second World War. The development
of industrialized mass production prompted the gradual formation of this discipline. In the process of formation and development of this discipline, it has experienced three periods: empirical ergonomics, scientific ergonomics, and modern ergonomics.

2.2.1. Experience Ergonomics. Beginning at the end of the 19th century, in order to improve production efficiency, a group of pioneer scholars represented by Taylor in the United States began to study the relationship between people and tools, operation methods, and work efficiency. At that time, most of ergonomics scholars were psychologists, and their research also focused on psychology. In production practice, they advocated the use of psychological methods to select and train workers. To improve labor productivity and increase production efficiency, the research focuses on “how people adapt to machines” [13].

2.2.2. Scientific Ergonomics. During World War II, weapon systems became increasingly large and complex. However, due to the one-sided focus on the functional research of new weapons and equipment, personnel have been unable to adapt to the performance requirements of new weapons that are constantly developing, so a large number of accidents are often caused due to operational errors, resulting in great material and personnel losses [14]. Through analysis and research, people realize that to design high-efficiency equipment, only engineering and technical knowledge is far from enough, and knowledge of physiology, psychology, anthropometrics, biomechanics, and other disciplines is also necessary. The research and application of “human factors” in the military field have had a huge impact on automobiles, aircraft, electronic equipment, household appliances, highway signs, aerospace medicine, and other disciplines and industries, so ergonomics gained rapid development in the 1950s. Development of scientific ergonomics was as follows. In 1949, the United Kingdom first established the Ergonomics Research Society, which issued the journal “Ergonomics” in 1957, which has now become an international publication. The International Ergonomics Association (IEA) was established in 1960, the first International Ergonomics Conference was held in 1961, the All-Soviet Institute of Technical Aesthetics of the former Soviet Union was established in 1962, and the Department of Ergonomics was established in 1963. In the same year, Japan established the Ergonomics Society, and France also established the Ergonomics Society in the same year. These institutions and academic exchange conferences have played a strong role in promoting the research and development of ergonomics, bringing international ergonomics research to a new level. At this stage, the two elements of “human” and “machine” have simultaneously become the focus and main content of ergonomics research [15].

2.2.3. Modern Ergonomics. In the late 1960s, due to the advancement of science and technology, such as the establishment of new theories such as cybernetics, information theory, and system theory, it provided a new theoretical basis for human engineering and also put forward new requirements for the research of this discipline. The subject of ergonomics has entered the research stage of the system; that is, the development stage of modern ergonomics [16]. At this stage, people have carried out new research and interpretation on the three elements of human, machine, and environment in ergonomics through various aspects of human science, behavioral science, technical science, environmental science, and social science. The overall coordination and interaction among several elements are emphasized to maximize the comprehensive effect.

My country’s ergonomics as a discipline started late but developed rapidly. In 1980, the National Ergonomics Standardization Technical Committee was established, and in 1989, the Chinese Society of Ergonomics (CES) was established, under which the Ergonomic Professional Committee was established. The Institute of Psychology of the Chinese Academy of Sciences and some institutions of higher learning have established ergonomics research institutions. At present, the application of ergonomics in various fields in China is also increasingly extensive and in-depth.

In recent years, with the widespread application of computer technology, especially the development of computer graphics, virtual reality technology, and high-performance graphics systems, a large amount of new experimental equipment and methods have emerged, and people’s research on ergonomics is not easy. It is limited to simple applications based on data accumulation and statistics, but makes full use of the high-performance graphics computing capabilities of computers to establish a graphical, interactive, realistic, physical model-based virtual environment design evaluation and simulation verification platform [17]. The research direction of international ergonomics focuses on workload research, work environment research (physiological and psychological effects of people in the work environment), information display, especially computer terminal, human factors research in the terminal display, computer design and use of people Mechanical engineering research, safety management and human reliability research, measurement and evaluation of work effectiveness, intelligent simulation of robot design, etc. [18].

2.3. The Research Content of Ergonomics. The main content of ergonomics research is the “human-machine-environment” system, referred to as the human-machine system. Human, machine, and environment, which constitute the three major elements of the human-machine system, can be regarded as three relatively independent subsystems in the human-machine system, which belong to the research categories of behavioral science, technical science, and environmental science, respectively. According to the first law of systematics, we know that the overall attribute of the system is not equal to the sum of the attributes of each part, and its specific situation depends on the organization of the system and the degree of synergy within the system [19]. Therefore, the study of ergonomics should not only study the properties
of each subsystem of human, machine, and environment, but also study the overall structure and properties of the human-machine system. The ultimate goal is to make the overall performance of the human-machine-environment system reach the best state, that is, to meet the indicators of comfort, pleasantness, safety, efficiency, and economy. Figure 1 shows the three elements of ergonomic design.

The research content of ergonomics includes several aspects.

### 2.3.1. The Study of Human Characteristics
It mainly studies human body morphological characteristics, human perception characteristics, human response characteristics, and human psychological characteristics in labor. It is the basis for human-machine system design.

### 2.3.2. Research on the Overall Design of Human-Machine System
It is to adapt the "machine" to the human body as a whole and reasonably allocate the functions of the human and the machine according to the respective characteristics of the human and the machine, so that they can play their respective strengths in the human-machine system, learn from each other's strengths and weaknesses, and organically cooperate to ensure the system function is optimal.

### 2.3.3. Design Research on Workplaces and Information Delivery Devices
Workplace design generally includes workspace design, seating design, workbench and console design, and the overall layout of the workplace. The purpose of studying the design of the workplace is to ensure that the physical environment is suitable for the characteristics of the person, so that people can work in a posture that is not harmful to health. The information exchange between man, machine, and environment is accomplished through the display and controller on the man-machine interface [20]. In order to exchange information between man and machine quickly and accurately and not to easily make people tired, it is necessary to study the display to match the characteristics of the human sense organs, the controller to match the human effector, and the relationship between their inter-coordination issues.

### 2.3.4. Environmental Control and Safety Protection Design
In terms of environmental control, it should be ensured that common operating environments such as temperature, humidity, lighting, noise, vibration, color, and air quality are suitable for the requirements of operators. The safety protection design shall ensure that the operator is protected from pain, disease, injury, or casualty caused by the operation.

### 2.4. Research Methods and Application Fields of Ergonomics
The common methods of ergonomics research are observation method, actual measurement method, experimental method, simulation and model test method, computer numerical simulation method, analysis method, investigation and research method, etc. In practical research and application, it is generally a comprehensive application of a variety of methods. As modern man-machine systems become more and more complex, not only is the use of physical simulation and model methods to study complex man-machine systems costly and time-consuming, but also it is difficult to modify and change the simulation and model devices once they are finalized. With the help of modern computer technology and sensor technology, the method of virtual simulation analysis of 3D measurement has become a scientific and efficient means of ergonomics research [21].

Ergonomics has a dual role in product system design, not only applying the collected empirical data to product design, but also evaluating the quality of the design. Therefore, ergonomics has been applied to varying degrees in the following fields: (1) work accidents, health, and safety; (2) human work behavior anatomy and anthropometric measurements; (3) human-machine interface design and evaluation; (4) display and control layout design; (5) office ergonomics and design; (6) user requirements and user guidance; (7) vehicle, aircraft, traffic ergonomics, etc.

### 3. Research Methods and Ideas

#### 3.1. Research Methods
This paper focuses on theoretical research, analyzes the problems of actual products, discusses the influence of modern product design ideas on products and the environment in design and development, and has guiding significance for the future development of products. By analyzing the products under the standardized commercial production mode, the feasibility study of product customization and individualization is realized, and the relationship between family product design, environment, and living space is explored, and theoretical research is carried out to build a more harmonious dialectical relationship between product function and artistic design [22].

This paper hopes to provide product designers with help in the theoretical research of human-machine design methods in the design process and also hopes to find a method of organically combining product design and human-machine design, hoping to bring people a new design concept. Figure 2 shows the research method and technology roadmap.
3.2. Research Ideas. As a highly interdisciplinary subject, ergonomics has become an important scientific basis for guiding design disciplines to conduct design research. In the case of satisfying human perception, considering the load capacity of physical and mental strength, combined with the influence of environmental factors, the design of ergonomics will play a more active role in various fields. Figure 3 shows the systematic study of ergonomics.

(1) The main research contents include the following:
   (1) In realistic design, consider the relationship between human and machine in terms of division of labor and cooperation.
   (2) In the actual design, consider the design of information transmission, man-machine interface, and controller.
   (3) In the actual design, consider realizing the most perfect cooperation between machines and people in a certain environment.

2. The main method in ergonomics in solving the “human” problem of the system is as follows:
   (1) Create machines and environments suitable for people to use.
   (2) Design better machines to adapt to the environment. In the process of the development of ergonomics, consider changing the way of thinking and adjusting the ideological foundation, taking people as the premise for optimization consideration, which greatly reflects the interests of human beings and puts forward the concept of “interaction,” which is more prominent and in line with the trend of ergonomic development.

4. Basic Theoretical Models of Ergonomics

4.1. Theoretical Model. The existing theoretical models of ergonomics are mainly set from three aspects: the operating system, the human-machine interface, and the work efficiency of people in the system.

The important concept of ergonomics is “operating system,” which is also the ideological basis of ergonomics. One of the characteristics of ergonomics is that it does not isolate people, machines, and the environment. The system regards people, machines, and the environment as interactive content with specific goals, interdependent, and restrictive [23]. As an organic whole, “system” has its special functions and goals and is composed of multiple components, which interact and depend on each other. Ergonomic research is divided into four levels in the system: comfort, safety, sensitivity, and efficiency. Figure 4 shows the relationship between interaction design and various disciplines.

As the direct contact level of human-machine relationship, its form and content serve as the representation of...
human-machine relationship, and it is also the core content of ergonomics research. In terms of human-machine interface, ergonomics research can be divided into focus on the perception of human body, cognition, and emotion [24].

As one of the criteria for judging the pros and cons of products, human work efficiency can be divided into three forms: the first is the high-efficiency work form, which is characterized by the “people” with the highest skills, who can complete the most efficient work under the most favorable “conditions.” “Skilled” work: this is the “expectation in advance” that is expected to be achieved in the design; the second is the best efficiency form; the best efficiency is the effect of basically satisfying the system operation requirements under normal “people” under normal “conditions.” The third is acceptable efficiency [25]. Although the system design is optimally designed, the optimal human-machine system matching level cannot usually be obtained. Therefore, “fault tolerance” is an important concept and technology in system design. As long as the errors that appear are within the acceptable and accommodating range of the system, “people” can make mistakes, “conditions” may not be met, but “ability” is not the strongest. Under the different psychological and physiological states of different “people,” according to the different “environments and conditions” used in the work and the differences in the requirements of the task, a work efficiency model of someone, a certain time, and something will inevitably be formed.

In the process of interaction design, we understand user needs and consider how to interact and respond to specific events and consider how users and events interact with each other, which is a very important key in interaction design. Since interaction design is closely related to various disciplines, the entire design process requires the participation of various people from many disciplines. For example, when considering user psychology and feelings, we need to invite psychologists and sociologists to participate; in order to provide better effect, we also need to ask software engineers to design various types of interactive media; in order to reflect the visual beauty and provide an effective and beautiful interactive interface, we need more artists to participate. At the same time, more needs require the participation of more experts, and more accurate designs have been provided. Conduct psychological pleasure factor research on users who use this type of product, and summarize the user experience factors in the research. The experience content includes satisfaction, excitement, entertainment, freedom, self-confidence, pride, and safety; at the same time, some users do not like it for factors such as being cheated, invaded, anxious, and troubled.

The memory system is composed of three subsystems, including sensory memory, short-term memory, and long-term memory. These three subsystems are in different stages of information processing. The information that enters the short-term memory comes from the sensory memory and the long-term memory. Sensory memory and short-term memory processing must occur first, and in each case, different stages must be processed to adapt to the next stage.

There is a certain contradiction between the user’s experience and usability, which requires a balance in the design, and the actual design is particularly important. Of course, in actual interaction design, there will be products whose usability and experience are mutually exclusive, so the
most important goal in design is user needs, and the design should be suitable for the environment. In order to achieve some specific goals in the design, designers and users have to sacrifice other goals to increase the design cost. In the design, according to the specific requirements of the task and the specific environment of the user, the two goals are balanced to meet the needs of the user to the greatest extent and truly achieve the goal of interactive design.

4.2. Emotional Design and Product Design. Emotional design is the personalized needs of product design, people’s pursuit of the spiritual world, the difference in the emotional nature of different human personalities, and an outstanding performance of the human spiritual world, as shown in Figure 5.

The beginning of personalized consumption means the end of material homogenization. The popular consumption patterns in the original industrial age have been gradually replaced, and the existing personalized consumption has become a new consumption hotspot. The market retention rate of customized products is increasing year by year, and people’s spiritual and cultural needs have highlighted the importance of emotional design in product design. When designing products, fully consider the individual requirements of users, carry out personalized designs according to the differences of users in various aspects such as age, gender, social experience, etc., and focus on emotional design, so as to truly achieve the “people-oriented” design.

Emotional design is divided into three levels, namely, reflection level, behavior level, and instinct level, which is mentioned by Professor Donald A. Norman in the book Emotional Design: instinct level (visceral level) is the automatic preset level; the behavioral level (behavioral level) contains the part that controls the daily behavior of the brain activity; the reflective level (reflective level) is the part of the brain thinking. Through the above part, we have learned that “people’s emotional needs are actually expectations that objective things conform to their own physiology, behavior, thinking and judgment standards, so as to achieve perceptual identity and obtain a good overall experience.” As psychologist BN Donohoff said, “Human emotion is a complex state formed by the integration of various emotions of appropriate intensity, and the pursuit of personality is actually part of the emotional pursuit.”

5. Conclusion

After decades of development, ergonomics has formed a relatively mature concept system, and various types of application methods have appeared in practical applications, which not only provide auxiliary functions for industrial design, but also effectively promote the development of industrial design. With the goal of the development of science and technology and the improvement of economic level, the theory of ergonomics has been perfected, and it has included a variety of disciplinary research methods to carry out research on the characteristics of human body structure and skill characteristics. The influencing factors of psychological state and work efficiency are discussed.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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