Ecological Design and Material Election for Furniture under the Philosophy of Green Manufacturing

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Abstract Based on the principles of green manufacturing, the ecological system of furniture design consists of the ecological furniture design analysis, implementation, evaluation, as well as supporting and maintenance. Compared to the traditional furniture material election, the material election subject to the green manufacturing presents a new philosophy. The principle of furniture material election subject to the green manufacturing involves the combination of technical principle, economical principle and environmental principle. This paper also discusses the minimization of life-cycle cost of furniture material election subject to green manufacturing.

Key words Green manufacturing; Ecological design of furniture; Furniture material election; Materials life cycle

1 Introduction

Furniture manufacturing is one of the most important basic industries to maintain the constant development of the national economy. However, while the furniture making has contributed to the material progress of the society, it has also led to possible ecological crisis like exhaustion of resources and environmental deterioration. Therefore, the learning circle carries out the study on ecological and green design of furniture, green manufacture technology and green material for furniture, hence an efficient way of solving for the ecological crisis in the furniture manufacturing. Compared with the above study, ecological design and material election for furniture under the philosophy of green manufacturing is a kind of brand-new concept and pattern. For the main purpose of improving the environmental properties of the furniture within the life-cycle and making its life-cycle cover the sections of design, manufacturing, delivery, usage, disposition and so on, the ecological design of furniture subject to green manufacturing combines the environmental philosophy and ecological furniture design. Material selection is the first step of implementing green design and manufacturing, the election of environmentally friendly material is therefore one of the key techniques of green manufacturing. It is significantly meaningful both theoretically and practically for realizing the harmonious between the furniture industry and environmental protection, to implement the research of ecological furniture design subject to green manufacturing, analyze the ecological furniture design system and formulate the principle of selection of environmentally friendly furniture material.

2 The Theory and Application of Green Manufacturing

2.1 The theory of green manufacturing

The American Society of Tool Manufacturing Engineers (ASTME) has firstly put forward the definition of Green Manufacturing in 1996. Green Manufacturing is also called Cleaning Manufacturing, the goal of which is to minimize the negative effects on the environment of the products design, production, delivery and disposition. The connotation of green manufacturing is to ensure the green nature of the whole life-cycle of the products [1]. Though constant research and development for years, the mode of green manufacturing has developed from original sole environment protection to the strategic representation of the sustainable human development in the modern manufacturing industry.

Only focusing on the production and profit making without the conscious of environment protection, traditional industry manufacturing mode can always be described as “resource-production -pollutants disposal”, a one-way linear and non-cyclical process. Green manufacturing is an advanced modern manufacturing mode that takes comprehensive consideration of environment effects and resource efficiency. The manufacturing process makes full use of resources, minimizes environmental pollution, and realizes the effective control of the implementation of green manufacturing. In each job of the whole life-cycle of production, including the product design, manufacturing, package, delivery, usage, disposal and recycling, the resource usage is optimized and the negative environmental effects minimized, taking into consideration of both resource efficiency and environmental protection [2].

2.2 The application of green manufacturing

On one hand, the environmental problem has become the focus of the nations' attention, on the other hand, the significant potential economic prospect underlying the green manufacturing mode has been discover. In this way, global manufacturing industry is making efforts to promote the technology of green manufacturing, raising a "green wave". The new philosophy of remanufacturing and Waste-free Process has been put forward in American relatively early. To implement the green manufacturing, the EU nations have presented three typical statutes: "The Instruction for Waste Electric and Electronic Equipment" (WEEE); "Restriction of Hazardous Substances" (ROHS); and "Instruction for Energy-using Products" (EUP) [3] . The requirement of environmental protection has been proposed for the whole industrial chain of the energy-consuming product, including product designing, manufacturing, usage, maintenance, recycling, after-disposal and so on. Japan has released a "green industry project" and a "basic law for the establishment of the society of the circulating-type". These measurements contemplated to realize green manufacturing through public education, environmental precursor and ISO14001 certification system so as to increase the competitive of the enterprises.

China is the nation with the most flourishing manufacturing industry in this world, but meanwhile one of the nations with significant resource consumption and serious environmental problems. The energy intensity per unit GDP of China is 7 times than that in Japan, 6 times than in American, and 2.8 times than in India. Energy, resource and environment have already directly affected our country's adjustment of economic structure and transform of the economic growth pattern, becoming a bottleneck against the national strategy of building a well-off society in an all-round way[4]. The development pattern of "Three Highs and One Lows" (High inputs, High consumption, and Low Benefit) of China has been facing a global pressure of the "green market" and so difficult to be carried on that the green design and green manufacturing are becoming or will turn to be the behavioral norms for the manufacturing industry of China.

3 The Analysis of the Ecological Furniture Design System Based on the Concept of Green Manufacturing

3.1 The composition of the ecological furniture design system subject to green manufacturing

The concept of the ecological furniture design subject to green manufacturing primarily involves two implications. From the perspective of environmental protection, it means decreasing resources consumption and realizing the strategy of sustainable development. From the perspective of commerce and business, it means cost saving, decreasing the potential liability risk, and increasing competitive strength. The ecological furniture design system subject green manufacturing takes the consideration of the concept of product life-cycle and supply chain management into the process of furniture design. The requirement of energy-conservation and environment-protection is proposed to impenetrate through the whole life cycle of the product. The entire ecological design system consists of four subsystems: technical analysis system, implementation of the design, the performance evaluation system, and the supporting and maintenance system. (See Figure1)

3.2 The subsystem for technical analysis

The technique of ecological furniture design requires complete compliance to the following principles: ①Take the environmental design of the furniture products into consideration when establishing the whole supply chain, by selecting more environmental friendly raw materials and process design; ②Take measurement to reduce the negative effect of the furniture design on the environment; ③Minimize the consumption of the raw material and the public utilities(such as water-supply and Electrical service), forbid the use of hazardous substance, improve the functionality and extend the useful life of the furniture products as much as possible, so as to reduce pollution and wastes significantly.

3.3 The subsystem for the implementation of the ecological design system

The implementation of the ecological design system emphasizes on the environmental requirement, and are divided into 5 phases: ①The planning for the ecological design. The furniture manufacturing enterprise normally establishes the specialized project team, which is responsible for drawing up a design plan as well as a proper budget through related technical analysis. ② Preliminary ecological design of furniture. This phase analyzes the primary environmental problems generated through the life cycle of the furniture produces, and then make the "Strength and Weakness" analysis. The preliminary design could adopt certain new ideas or methods of design such as removable design, recoverable design, building block design and so on, determine the preliminary design, formulate the principles of selecting

furniture products, and undertake the model analysis of the whole life-cycle of furniture. ③ The integration of ecological design of furniture. This phase mainly consists of the design of the structure of furniture products, the selection of materials of the furniture products, the design of the furniture manufacturing environment, the furniture manufacturing process, furniture packaging and furniture recycling. The integration plan and the list of ecological design are then generated. ④ The implementation of furniture ecological design. The environmental management system and the plan for furniture products services are implemented according to the integration of furniture ecological design. in this phase, the new furniture products are formally put into production and the ecological archives for the furniture products are established. ⑤ The check for the effect of the implementation. The environmental factors of the design for the furniture products are detailed to examine whether they are in constant with the he test results of the ecological design after the production of furniture products.

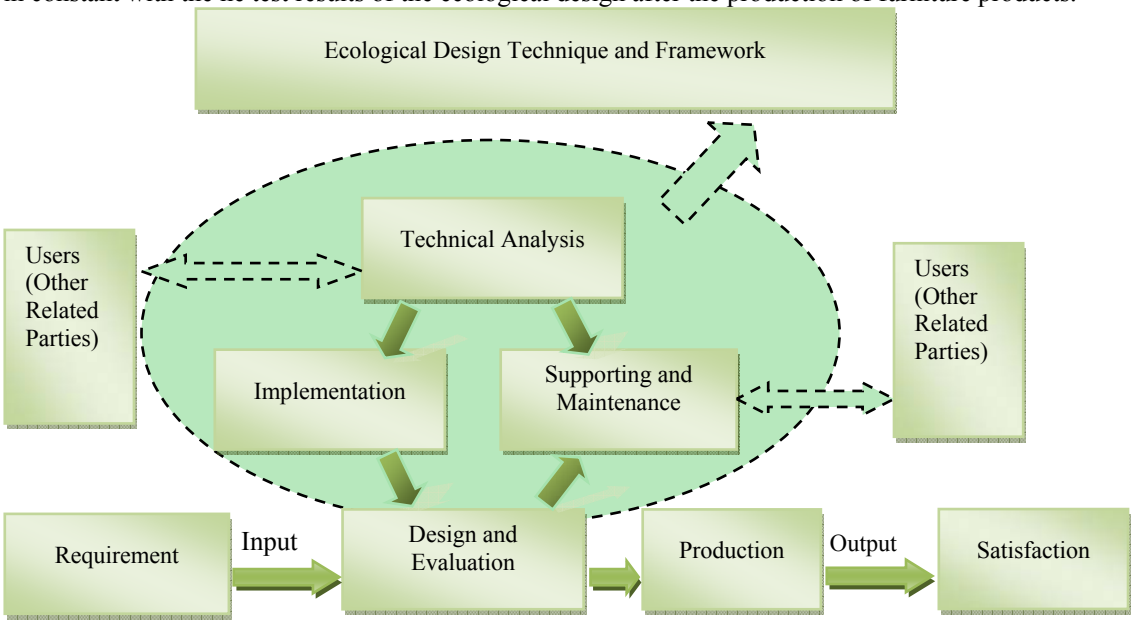

Figure 1 The Ecological Design System of Furniture Subject to Green Manufacturing

3.4 The subsystem for the evaluation of the ecological design system

The subsystem for the evaluation of the ecological design system is used in the whole life cycle of the furniture products, including the obtaining of raw materials, the manufacturing and disposing furniture products as well as the effect on the environment. The evaluation consists mainly of three aspects: ① The evaluation of environmental effect. This includes the ecological environmental and professional health effect, waste recycling as well as the disposition of final waste. ② The evaluation of resource optimization. This aspect is focused on the evaluation of machinability, usability and the effect on the environment of the furniture products. The extent of the energy and resource conservation is analyzed base on the consumption and effective utilization. ③ The evaluation of the improvement on the ecological design. The improvement consists of the manufacturing materials, energy consumption, manufacturing process, using process as well as the environment pollution after the life cycle.

3.5 The subsystem for the supporting and maintenance of the ecological design system

Supported and directed by the government, this subsystem is co-operated by the furniture research institute, industry associations and related certification body. The goal is, on the one hand, to realize the optimal allocation of resources so as to provide the development trend of the ecological design of the domestic and foreign furniture products as well as the technology, thus enhancing the design competence of the furniture enterprise. On the other, this subsystem facilitate the establishment of the service platform for the furniture enterprise, contributing to the provision of professional services of information, technological, credit, intellectual property rights and training for the furniture enterprises.

4 The Selection Principles for the Furniture Materials of Green Manufacturing

Traditional selection of the furniture material mainly emphases on its technical and economic principle, with little of effect on the external environment taken into consideration. However, treating the whole life cycle of the furniture products and its external environment as one system, the selection of

green manufacturing is a completely new idea and thinking. Each of the phases is environmentally evaluated on the furniture material flow to achieve the harmonization between the furniture products and whole life cycle. It is the integration of the technical, economic and environmental principle [5].

4.1 The technical principle of the furniture material selection

The technical principle mostly consists of the physical properties (density, electric conductivity), mechanical properties (The hardness, strength, ductility, toughness, wear resistance) and chemical properties (Oxidation resistance, corrosion resistance).

4.2 The economic principle of the furniture material selection

Meeting the technical requirement of the furniture products, the enterprise should minimize the cost to enhance the market competitiveness of the furniture produces. The total cost includes raw material costs, processing costs, recycling costs and supply chain management costs, and so on.

4.3 The environmental harmony principle of the furniture material selection

Based on the key features of the green manufacturing, this principle mainly considers the abundance of material resources, environment friendliness, and recyclable aspect.

5 Minimum Material Life Cycle Costs for Green Manufacturing

Suppose alternative material furniture collection is Ω and is composed of 4 parts which are direct cost C_D, manufacturing cost C_M, recycling cost C_R and supply chain management cost C_S.

$$C = C_{D+}C_M + C_R + C_S \tag{1}$$

5.1 The direct cost for the furniture materials

$$C_D = C_D(x)W \tag{2}$$

Where $C_D(x)$ is the direct cost for the material unit mass and W is the design mass for the furniture component.

5.2 The manufacturing cost for the furniture materials

$$C_m = \sum_{i=1}^{n} C_{im}(x)W \tag{3}$$

Where n is the number of manufacturing process and $C_{im}(x)$ is the material unit cost for the i manufacturing process. (yuan / kg).

5.3 The recycling cost for the furniture materials

$$C_R = C_R(x)W \tag{4}$$

Where $C_R(x)$ is the unit recycling cost for the material mass. (yuan/kg).

5.4 The supply chain management cost for the furniture materials

$$C_S = C_S(x)W \tag{5}$$

Where $C_S(x)$ is the unit supply chain management cost for the material mass (yuan/kg).

The constraint condition for the minimum life cycle cost is:

$$\min \ C = \min \left(C_D + C_M + C_R + C_S\right) \quad x \in \Omega \tag{6}$$

6 Conclusion

With the spread of the energy crisis and the deteriorating natural environment, green manufacturing is all the rage. The ecological design for furniture products of green manufacturing examine the whole life cycle of the products from the view of sustainable development. The basis for furniture green manufacturing, the green materials is selected in line with a completely new idea and thinking compared to the traditional one. The rebuilt design for green-made furniture will help to realize ecology and sustainable development, especial for the lowest life-cycle cost of furniture material, and an effective method for circular economy in the furniture industry. The research for the ecological design and material selection is of great importance to promote the sustainable development of the resources, environment and society and establish a resource-saving and environment-friendly society. It is also meaningful for the development of circular economy and improvement of core competitiveness of the furniture manufacturing industry.

References

[1] Liu Fei, Cao Junhua, Zhang Hua. The Theory and Technique of Green Manufacturing[M]. Beijing: Science Press, 2005 (In Chinese)

[2] Zheng Jiliang, Chen Weiping, Fu Hong. Green Integrated Manufacturing System: Concept and Structure Model[J]. Science and Technology Management Research, 2008, (10): 34 (In Chinese)

[3] Xia Shaomin, He Lingyan. Significant Use for Reference of to the Legal and Regulatory Systems Subject to Energy-Saving and Emission-Reduction in China[J]. Research on Rule of Law, 2008, (6): 21 (In Chinese)

[4] Chen Qi. EU's EuP Directive and Trends in China's Development of Green Manufacturing Technology[J]. Light Industry Machinery, 2007, (2): 42 (In Chinese)

[5] Zhang Liang, Liu Guangfu, Liu Zhifeng. Research on the Two Steps of the Material Selecting Method with Client Driving in Consideration of Green Design[J]. Journal of Hefei University of Technology, Natural Science, 2006, 29(2): 209 (In Chinese)