Application of green concept in mechanical design and manufacture

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Abstract. With the development of productive forces, the relationship between human and nature is becoming tight increasingly, especially environmental pollution and resource consumption that comes from equipment manufacturing industry mainly. Green development concept is a new concept which can solve the current ecological environment. The philosophical foundation and theoretical basis of green idea are expounded through the study of scientific development and green concept. The difference between the traditional design and the green design is analyzed; the meaning and content of the mechanical design for green concept are discussed. And the evaluation method of green design is discussed too. The significance of green development concept in the mechanical design and manufacturing science is pinpointed clearly. The results show that the implementation of green design under the mechanical design, from the source of pollution control to achieve green manufacturing, is the only way to achieve sustainable development.

1. Introduction
With the rapid development of human society over the past 100 years, productivity has improved unprecedentedly. For a long time, the predatory exploitation and utilization of natural resources make the environment and resource problems become increasingly prominent which is threatening the human’s survival and development. While it not only how to use the limited resources, but also a major origin of environmental problems. The level and scale of mechanical manufacturing technology is an important symbol of national industrialization and comprehensive strength of national economy. The equipment manufacturing industry in large volume is the major origin of environmental pollution and resource consumption. At the same time, due to the growth of consumer goods and the reduction of product life cycle, the amount of waste products also increased sharply. The survival of the human environment is facing the pressure from lots of obsolete mechanical and electrical products. Manufacturing products is caused by emissions from the manufacturing industry, which produced 5.5 billion ton and 700 million ton harmless and harmful wastes annually [1].

For environmental pollution, previous concept of machine design has some responsibility. The traditional method of environmental governance is the end-of-pipe treatment, and the global worsening reality proves that it can’t protect environment fundamentally. Therefore, improving from origin of pollution and implementing sustainable manufacturing are the inevitable requirement for human’s development. Green design is getting people’s attention and recognition increasingly. For example, the TV of Sony in European market before 1997, because of not using green design technology, leading sales quota reduced 13.5% directly (WBCSD, 1997).

Thus it can be seen that green products will become the inevitable demand of the future market and sustainable design will also become an important technical specification for product. Green design is the
core technology of sustainable manufacturing. It presents sustainable development strategy which coordinates the society, economy, resources and environment.

2. Philosophical basis of green development concept
At present, green development has become a new concept on economic and social development. The green development concept is based on the inevitable demand of economic transformation and upgrading. It is also the inheritance and development of Marx’s view of nature. Since the reform and opening up, Chinese economy has got great achievements, but a series of ecological problems has become a bottleneck of economic and social sustainable development with the traditional pattern. Therefore the mode and concept of development must be transformed, and the correct relationship between human and nature should be reestablished.

The relationship between human and nature is the most basic relation in human social [2]. How to deal with the relationship is the eternal theme for human. Green development is relative to traditional development, it reflects the symbiosis and harmony between man and nature, which is a manifestation of Marx’s view of nature. Marx regards human as part of nature [3]. Human must depend on natural product to live and unable to be separated from the natural. However, human can understand, transform, even conquer nature continuously through their practice. While, with the improvement of practical ability, the relationship between human and nature will be caused serious alienation when the practice breaks through the limit of nature. Just as Engels says: we should not revel in our victory in nature, for each victory, nature will take revenge on us [4].

So, the green development is the harmonious development between human and nature, which should fully play human dynamic role through practice and follow the law of nature [5].

Green development is the development and deepening of Scientific Development and it is also the basic requirement of ecological civilization. In the macro-theory, it requires us to take the green development road, pay more attentions to green science and technology, and advocate green lifestyle. In the micro-theory, product from design to use and recycle must reflect the requirement of green development. Product’s design with green and innovative model is the inevitable requirement of the modern machinery manufacturing industry.

Green design is towards to sustainable development, it refers to satisfy contemporary needs and without hindering the needs of future generations. In other words, it refers to the harmonious development of society, economy, resources and environment. The concept of green mechanical design can solve ecological environment problems from the source; it can maximize the role of material, and let every part of the product recycle as much as possible.

The original design concept mainly considered the functional attributes of product, such as cost, quality, life, etc, while the environmental attributes are considered less. According to the traditional concept, the product would bring waste and environment pollution at the end of life. The important difference of Mechanical design between green concept and traditional concept is considering the environmental properties of mechanical products, such as consumption, re-manufacturing, recycling and other related aspects of environmental protection. It has broken away from the traditional simple and extensive form, and constructed a new design concept of radiating from the database to environmental assessment to the design and development to the packing and shipping, it would be beneficial to optimize all process of design.

3. Content of the green concept in mechanical design

3.1 Selection of material in Green mechanical design
Selection of material is very important in mechanical design, it should ensure the environmental protection. The traditional way pays more attentions to the technological performance of the products, but ignores the environment performance. There always emerge some materials containing special chemicals in the process of mechanical design and manufacture, such as lead, mercury and other harmful substances. The choice of these substances will cause some environmental problems inevitably
for the future. The damage to the environment is very prodigious if being handled improperly in the later stage. Firstly, in green design, some materials should be avoided in the selection of materials, such as heavy metals, asbestos, polychlorinated biphenyls (PCBs), mercury, cyanide, fluorocarbon, etc. It should consider the compatibility, economy, safety and analyze the influence on environment. secondly, try to choose the ecological materials, mainly including environmental compatible materials (such as pure natural materials, wood, stone, etc), bionic materials (such as artificial bone, artificial organs, etc), green packaging materials (such as green packaging bags, packaging containers), ecology building materials (such as non-toxic decoration materials, etc), degradable environmental materials (such as biodegradable plastics, etc.), environmental engineering materials (such as environmental remediation materials), environmental purification materials (such as molecular sieve, ion sieve material), environmental substitute materials (such as phosphate free detergent additives). For example, now the TV manufacturing materials can select poly-carbonate material completely which can be recycled. Combining with wood shell, it will minimize the use of toxic and harmful materials. And the packaging can use recyclable paper, and the shockproof can be lined with the foam materials. The technological structure of the TV set can be designed removable and recyclable modules. And the whole TV set can be divided into several parts to facilitate the assembly, maintenance and recycling. Therefore, far-sighted selection of materials is the most important part of the green concept in machinery design.

3.2 Consumption of resources should be reduced in the design of green machinery

There are three central principles of green design: lessening environmental pollution; reducing energy consumption; and recycling of product. Comparing with the traditional mechanical design, the advantage of the green mechanical design concept is it can be designed according to the natural environment and the reasonable choice of raw materials. Not only can the advantages of traditional design be brought into play, but also the consumption of raw materials and the rational use of resources can be reduced. At the same time, it should consider how to modify the been-sold product reasonably and economically for improving the performance after the advancing of technology, such as air conditioning, refrigerators and other household products which has large output and longer duration [6]. With the advancing of technology, the consumption of power has been reduced significantly as compared with the previous year. For example, a few years ago the amount of electricity for ordinary refrigerators in 24h is about 1kwh, but now it can reach about 0.4kwh. If these old refrigerators can be modified properly and refitted to achieve energy saving at a convenient manner and at an acceptable price to the user, it will save enormous resources for the society.

3.3 Recycling and re-manufacturing should be considered in the design of green machinery

People hope to realize the goal of the recycling through green design and manufacturing. According to traditional concept of the mechanical design, the used products will become a mess of waste metal, but it has nothing to do with the manufacturing enterprises. Green design should consider the entire life cycle of a product and the effect on the environment from design to material selection, manufacture, using, scrap and recycling, that hoping to achieve reuse with minimum cost. Green design demands re-manufacturing design for components of product. Theory of inventive problem solving provides effective methods for active re-manufacturing design. JUSTEL provided the method of able-dismantled design which from the view of TRIZ’s evolutionary theory and conflicts resolving principle [7]. CHEN gave the method of active able-dismantled design using TRIZ’s conflicts resolving principle and the material-field analysis principle [8]. CHENG combined the analysis of the green performance in the conceptual design phase, solved design problem based on TRIZ’s evolution pattern, and accelerated the design process with case-based reasoning method, then judged the improvement of environmental performance with simplified model of life cycle [9]. ATHAKORN combined technology trend analysis, life cycle design and TRIZ’s theory to establish a decision support framework for green concept design and evaluation based on ISO/TR14062 standard [10].

In the design, modern design technique should be used extensively, such as serialized, modularization and standardization design technology. The inheritance of technology and structure
should be considered in product design, it lays foundations on re-manufacturing technology after end-of-life. For example, design-for-disassembly (DFD) should be considered in order to facilitate the recycling and re-manufacturing of lathe. According to the DFD standard, it should reduce the amount of demolition work as much as possible, having stable structure, being easy to disassemble and separate. The use of welding method to connect every parts and the type of materials should be minimized, and the structures of disassembly should be combined [11]. Yang Ming assessed life-cycle on one type of remanufacture engine. The results show that comparing to produce a new engine, a remanufacturing engine can save steel 58.2kg, aluminum 16kg, electricity 116kwh, reduce emissions of CO2 565kg, CO 6.09kg, SOx 3.985kg, NOx 1.01 kg and 288.725kg of solid waste emissions [12]. Remanufacturing engine could be improved largely in economy and practicability.

4. Evaluation method of Green design
Green design evaluation is a multi-stage process, composing four steps: target definition, scope definition, inventory analysis, impact assessment and result interpretation. Target definition and scope definition are the stages of LCA (Life Cycle Assessment) to develop research objectives and methods. Impact assessment is a quantitative or qualitative approach to assess the potential impact of resource and energy consumption on environmental impacts and emissions on human health and eco-health in inventory analysis results. Life-cycle impact assessment requires the establishment of the relationship between the object of assessment and its potential environmental impact and recommendations and improvements to its deficiencies.

In addition to different evaluation methods, many countries have developed software for the green design evaluation. It can select the appropriate evaluation method automatically basing on user’s needs. Ga Bi, Sima Pro and E-Balance are three common life-cycle assessment tools which being applied interiorly. Ga Bi software is a tool for quantifying the material and process and making a reasonable evaluation. Ga Bi in operation is more complex and demanding, the process is also very complicated in the reference of database. Sima Pro software can automatically select different methods of characterization, standardization and weighting for environmental evaluation. The data source is clear, the menu-type instructions are easy to learn and operate, and the practicality and confidentiality are taken into account. E-Balance is Universal Life Cycle Assessment (LCA) software, it includes high quality database supporting in China and worldwide [13]. It is suitable for LCA analysis of various products. Comparing to Ga Bi and Simapro, the E-Balance database is closer to China’s national condition, because it has small size, quick response, and low costs. But the comprehensiveness has yet to be improved. Hossein Mousazadeh used LCA method to evaluate the traditional multi-purpose vehicle and electric multi-purpose vehicle. The results show that comparing with the traditional multi-purpose vehicle, the multi-purpose vehicle life cycle reduced 28.4%, and the comprehensive environmental impact reduced 34.7% [14]. Jens Warsen established the original manufacturing transmission and remanufacturing transmission life-cycle evaluation model, the results show that the consumption of remanufacturing transmission life-cycle reduced 33% [15].

5. Conclusion
Green design concept is an important practice in the process of human exploration of sustainable development. It is a milestone in the history of the development of mechanical design. And it is also a revolution and leap in the mechanical design concept. In essence, Green design is an optimization problem with restraint of environmental protection to minimize consumption and maximize efficiency. Green design concept reflects people self-examination which be caused by the ecological and environmental damage on modern methods and lifestyle, It makes more demands on designer and enterprises from the moral content. And it presents that designer and enterprise should assume the social responsibility consciously on historical process of the environment protection, resources saving, achieving harmony between human and nature. It represents a new design culture, reflects the improvement of the level for human moral awareness. This improvement and deepening of understanding will promote the progress of social civilization and achieve the pursuit of the sustainable
development on a higher level.

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