

Research Article

Research on Green Design of Food Machinery

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Abstract: The green design of food machinery is to design and manufacture the food machinery of which life cycle environmental influence is the smallest. It also can be considered to be taking the green technology as the principle to design food machinery. In summary, the green design of food machinery is precisely in the whole life cycle of food machinery to focus on environmental attribute of food machinery, namely, detachability, retrievability, maintainability and reutilization and taking them as design goals, at the same time of meeting the requirements of environmental objectives, ensuring the function, service life and quality that food machinery should have. The purpose of this research is to explore green design methods of food machinery, thereby working out green food machinery, in order to make people feel healthy and comfortable in the process of using. It specifically researches the green design of food machinery material, green design of food machinery structure and green design of hydraulic system and power system in food machinery. And then the comprehensive assessment system of green design of food machinery is established, based on which the conclusion has been reached.

Keywords: Food machinery, green design, green material

INTRODUCTION

Green design idea was first put forward by Victor Papanek, the American design theorist, in the 1960s, who emphasized that design should seriously consider the use of the limited earth resources and serve to protect the environment of the earth in his book "Design for the Real World", which also caused great controversy at that time. Later, with the development of science and technology and the continuous improvement of human material and spiritual civilization, human realized that the survival environment was worsening, available resources were depleted and the further development of economy suffered serious constraints and these problems directly affected the reproduction of human civilization and thus put forward the strategy of sustainable development. In the late 1980s, the wave of green consumption firstly raised in the USA and then swept the world. The green products such as green refrigerator, environmental protection color television and green computer constantly emerged and the broad consumers also increasingly advocated the green products. In the 1990s the green design became a hot issue of modern design technology research (Zhou, 2010).

So-called green design can also be referred to as the environment conscious design, the design for the environment and the ecological design. Although there are different titles, but its connotation purport is the same. That is in the entire life cycle of product, giving full consideration to the influence of product what has been produced on resources and environment and

setting the environmental attribute such as the retrievability, reutilization, detachability and maintainability of product as the design goal and based on which, to ensure the quality, function, development cycle and service life of product to accord with the related requirements, insisting on the principles of reusing, recycling and reducing to design products, living up to minimizing the environment pollution and energy consumption and reusing and recycling components and products (Fu, 2013).

The development of the food machinery industry in China began in the 1970s, formed in the 80s. In the late 80s and early 90s it entered the stage of rapid development, initially forming an independent industrial system of complete category and supporting variety. Since the 80s, the average growth rate per annum of output value is about 24%. At present in our country the scientific research and teaching institutions specialized in food machinery are more than 500 and the food machinery enterprises are more than 1900, with an annual output value 13.5 billion Yuan (Chen, 2005).

With the improvement of living standards, food machinery has gradually tended to be intelligent, networked and greening, of which the modeling inclines to be pluralism (Zhan, 1999) and the emotional factors become the important factor that influences consumers to buy products. Delight-oriented design of food machinery is to make food machine emotional and make person pleasant, giving consumers relaxed, happy and humor emotional experiences, being helpful to realize the individuation and differentiation design

strategy of food machinery and producing higher added value in the competition of product homogeneity (Fang *et al.*, 2013).

Adopting green design to design food machinery is of prime importance, which concerns human health and sustainable living. At present, the scale of China's food processing industry from upriver agriculture, midstream food industry to downriver transportation and merchandising business and catering industry is expanding increasingly. These industries all have a certain scale and technical level and each enterprise turns from semi-hand and semi-mechanization to modern equipment and technical level to form modern food processing enterprise of large output and high efficiency (Jiang, 2013a). Food machinery, this particular product, is very important in human activities and is also important for the development of national economy, which makes the research on green design of food machinery more have theoretical and practical significance (Wang *et al.*, 2004).

The purpose of this research is to explore green design methods of food machinery, thereby working out green food machinery, in order to make people feel healthy and comfortable in the process of using. At the same time, through the green design of food machinery, it also will necessarily improve the market competitiveness, improving the self-sufficiency rate of food machinery in China.

MATERIALS AND METHODS

Currently, in order to conform to the trend of the age and strengthen the design concept of ecological environment consciousness, it is the common practices in the field of food machinery industry to apply the green design to the food machinery. The green design of food machinery includes the food machinery material, food machinery structure, hydraulic system and power system in food machinery, etc.

Green design of food machinery material: Green wave has swept across the world. Developing the nature to bring benefit to mankind is our duty, however, at the same time of taking advantage of nature, conserving nature, saving raw materials and energy is also our obligation. Green material is the necessity of material development and the enhancement of green consciousness will improve the value of product. Nowadays the green has gradually become the new standard of measuring material quality and green material has become a focused issue in academic and business circles at home and abroad (Li *et al.*, 2010).

When conducting the green design for food machinery materials, it should choose the materials of low consumption, low pollution, low cost, easy processing, easy processing, easy recycle, anti-corrosion, non-toxic and easy removal and cleaning. Because the food produced by the food machinery is to



Fig. 1: Cold noodle machine



Fig. 2: Juice extractor

let consumers directly eat and the food quality is related to people's health, it should make sure the selected food machinery material is safe when designing (Fu, 2013), as shown in Fig. 1.

Material of parts directly contacting with processed food:

Parts contacting with liquid: The material of such equipment should be treated respectively. Since liquid penetration is strong, it should take the corrosion resistance of materials as the key to consider, as shown in Fig. 2.

For the storage and transportation can of fruit juice, if the fruit juice acidity was not strong and the storage time was not long, it could choose 0Cr13 or 1Cr13 stainless steel. If the fruit juice acidity was stronger (such as sea buckthorn concentrate juice) and the corrosion capability was strong, it should choose 0Cr18Ni9 or 0Cr18Ni9Ti. For common equipment for fermentation engineering, as 0Cr13 is not resistant to acetic acid, it should choose 1Cr13, 2Cr13 or 1Cr18Ni9Ti (Xu and Yan, 1991).

For the parts that contact with food and need machining such as whisk and shaft, it generally chooses 1Cr13 and 2Cr13, because compared with 1Cr18Ni9, 1Cr13 and 2Cr13 have higher strength and better machinability.

The winery equipments such as wine transfer cask and cooler could adopt aluminum product of which the surface has oxide film, because that not only has the resistance to wear, but also has good thermal conductivity and is not easy to produce sparks and is particularly suitable for the volatile liquid like wine.



Fig. 3: Vertical dough sheeter



Fig. 4: Fruit and vegetable slicer

Many wineries still take over the method of manufacturing storage wine can with the carbon steel smeared with epoxy resin or pig blood. Although the cost is low, the influence on vinosity is larger and for a long time it is easy to produce the phenomena that the wine color becomes yellow and the can wall drops, so it had better adopt stainless steel basin.

The pipe fitting in evaporator or cooler should choose 1Cr17 cold-drawn steel pipe, because the expanding junction between pipe and tube sheet is easy to produce the stress corrosion. The external connection pipe fitting of equipment could choose all kinds of stainless steel pipe according to the specific situation and could also choose polyethylene or polyvinyl chloride food pipe, but it must be normal temperature or low temperature liquid.

Equipments that need to weld should choose chromium nickel stainless steel containing titanium as far as possible. General chromium nickel stainless steel is easy to cause intergranular corrosion within the range of 500~800°C, which possibly gives rise to sudden cracks in weld. This kind of corrosion is mainly because the grain boundary precipitates the carbide, forming the chromium carbide to reduce the chromium content near grain boundary. However, containing titanium or niobium with carbon could generate the compound near to stability, which prevents the carbon and chromium from producing the chromium carbide. Therefore, it generally still chooses 1Cr18Ni9Ti (Ti content 0.8%). Defect is that the oxygen and titanium generate the titanium oxide, which makes the polish-ability bad when descaling the stainless steel surface (Xu and Yan, 1991).

Parts contacting with solid powder and semifluid food: For this kind of large-scale parts such as spray

drying oven shell and cyclone separator shell, their surfaces contact with the hot-air and dried material and the temperature is generally under 120°C. It could achieve the goal of sanitation and rotproofness for the shells working under so damp and hot conditions to choose OCr13 steel plate to weld and manufacture.

The workbench and finished product work bin working in normal temperature could also adopt OCr13 stainless steel.

Material of parts not contacting with processed food or indirectly:

Equipment header and wrapper: Cover plate usually contacts with wet air and water, so it could adopt OCr13 or 1Cr13 steel plate to manufacture.

Because of involving material machining and welding performance, on header the flange, manhole and hand hole also should consider choosing 1Cr13 or 1Cr18Ni9Ti according to particular case.

It should choose cheap OCr13 or 1Cr13 to make equipment wrapper so as to strengthen the sanitation, anti-corrosion property and beauty of equipment surface.

Joint pipe, nut and the like: Joint pipe, nut and the like could use 1Cr13 or 2Cr13, because they have better mechanical strength, polish-ability and cut-ability. When using, unlike 1Cr18Ni9, the thread section is not easy to be bit. After thermal refining, 2Cr13 is not easy to prick knife when turning. It could adopt high-speed cutting and could obtain a better surface smoothness (Xu and Yan, 1991).

Bottom case and caster: Bottom case should consider the stability and economy of mechanical equipment and generally all adopts the cast iron or carbon steel. Caster of food machinery is generally small, so using carbon steel to process is more common, but in individual cases it also uses cast iron (Jiang, 2014), as shown in Fig. 3.

Green design of food machinery structure: When designing the structure of food machinery, it equally should adhere to the concept of green design to assemble, manufacture and disassemble easily. Under the condition of ensuring the product quality improved continuously, it should reduce the number of parts as much as possible; in the assembly and manufacturing process, it should as much as possible achieve the clean production and reduce environmental pollution to prolong the service life of equipment. At the same time, to achieve the improvement of the production process, after the product reaches service life, its part components could be refurbished and reused or safely put away (Jiang, 2013b). Detachability design not only could reduce the cost of dealing with waste, but also reuse the part components, as shown in Fig. 4.



Fig. 5: Household noodle maker



Fig. 6: Soybean milk machine

Design easy to manufacture and assemble: Design For Manufacturing (DFM) refers to how to make use of existing equipment and process capability at hand to realize the product from principle design, which focuses on the manufacturing process, such as stamping, machining, injection molding, casting, etc.; Design For Assembly (DFA) places particular emphasis on the assembly, which not only considers whether it could be made, but also considers the design of convenience in the process of assembly and as far as possible avoiding appearing the design that is not convenient for production, combining the needs of production. The design goal between the two makes no difference, that in product development phase the process design should be taken into consideration, through the comparison and optimization of scheme, improving the convenience and economy of manufacturing and assembling (Huang, 2014).

DFM or DFA of green product will make products more easy to manufacture and assemble, improve the production quality and maintainability of equipment, prolong the service life of mechanical equipment, save unnecessary processes, tools and manpower, reduce the number of parts, reduce cost, avoid the repetitive design modification and shorten the development cycle. And it takes the environmental protection as the goal, which reduces environmental pollution, implements cleaner production and lets people eat the secure food, thus winning customers and improving the market share, as shown in Fig. 5. Providing the feasible plan to establish the development strategy of future products of

enterprise makes enterprise achieve the sustainable development ultimately (Huang, 2014).

Design for disassembly: At present in food machinery design, the design for disassembly hasn't been paid much attention. When food machinery is damaged and cannot be used, it is forced to discard because it cannot be disassembled, which causes resource waste and environmental pollution. This phenomenon can be found everywhere, as shown in Fig. 6. In recent years, waste disposal expenses have been also increasing year by year and the character that it is easy to destroy has become a vacancy of product design. So in the design of food machinery, it is especially important to sufficiently considerate the design for disassembly.

Design for disassembly has many benefits. Firstly, operators could disassemble food machinery, which facilitates better maintenance and a full range of cleaning, ensuring safety and health of food machinery. Secondly, it could also promote the resource recycling. In the long run, when equipment cannot be maintained and is faced with elimination, it could reuse selectively or renovate parts, replacing the damaged parts and making mechanical equipment running again. Thirdly, for the parts that cannot be reused, it could make environmentally safe pollution-free disposal. Through the above these designs for disassembly, it could more improve the production links of food processing industry (Huang, 2014).

Green design of hydraulic system and power system in food machinery: Applying the green design to the hydraulic system and power system of food machinery has a very important function. The hydraulic system is the main transmission system of food machinery, but there are many problems exist in this system, such as noise pollution and oil pollution and other issues. These problems will affect the quality of food and also become the obstacle factors of influencing the food industry development. Using water and vegetable oil instead of mineral oil could solve the problem of oil pollution and adopting the voice control system could solve the problem of noise pollution. Therefore, it should speed up the research on ecological hydraulic system, such as water pressure, vegetable oil and others and put into use as soon as possible, improving the existing problems. In the power system of food machinery, through the consumption of primary energy oil to produce food, equally there will also be the potential risk such as the oil pollution, noise pollution and thermal emission pollution. Using electricity instead of oil as the power is the embodiment of the green design in the power system of food machinery. It should accelerate the development to the vegetable oil, solar energy, natural gas and hydrogen energy so as to make them be applied in the food machinery (Fu, 2013).

RESULTS AND DISCUSSION

Food machinery design is a complex system, so it should follow the viewpoint of systematics to evaluate its combination property. Traditional evaluation system of food machinery design has operability index, maintenance index and economy index. In this index system there is not environmental protection index, but through the analysis to food machinery green design, it can be seen that the environmental pollution level index should be taken into account as the primary index, setting up the comprehensive evaluation system on food machinery green design, as shown in Fig. 7.

Among them, operability index is combining the function rationality and security index in traditional evaluation system; maintenance index is the extension of reliability; economy index should consider that the green design of product may lead to the increase of cost and social cost considers some negative influences given by food machinery to social environment, as

pollution and waste recycling cause what is necessary cost increase to reduce the negative influences; environmental protection index is peculiar important evaluation index to the comprehensive evaluation system of green design, which makes objective and comprehensive evaluation for environmental burden and environmental impact within the whole life cycle of food machinery, including the indexes of many aspects such as resource, energy and environment (Wang *et al.*, 2004).

Resource attribute index: Resource attribute index is making full use of material resources, equipment resources and social resources and is the basic condition of green production:

- Material resource could be expressed from material type and material usage used by food machinery and what it reflects is the effective utilization level of material resources in the production of food

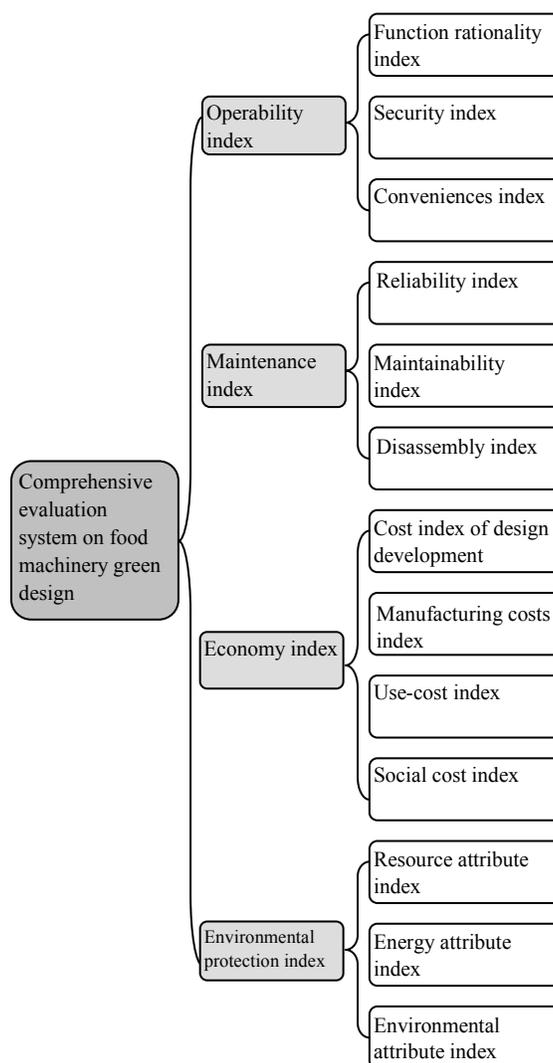


Fig. 7: Comprehensive evaluation system on food machinery green design

machinery. It could use these indexes such as compatibility, toxicity and personality characteristics of materials to evaluate the choice of material type and it could use these indexes such as utilization, recovery and reuse degree of material to evaluate the material usage (Wang *et al.*, 2004).

- Equipment resource index includes the equipment usage, optimal allocation of equipment resource, etc. and what it reflects is the rationality degree of production organization of food machinery. Among them, it could use these indexes such as equipment utilization rate, failure rate and repair rate to evaluate the equipment usage; it could use these indexes such as advanced degree of equipment and disposal measures of worn-out equipment to evaluate the optimal allocation of equipment resource.
- Social resource includes the human resource and information resource and others that are involved in the process of green design, production and consumption of food machinery. It could use these indexes such as the utilization rate of personnel, personnel quality characteristics and information wide range degree and refresh rate to evaluate the social resource.

Energy attribute index: Considering how to save and use energy as much as possible is a major feature of green design of food machinery, for reducing energy usage amount, namely, saving resources and reducing environmental pollution. In the green evaluation of food machinery, the main indexes related to energy have the energy type, toxicity and consumption consumed by food machinery during use and the energy mining cost, power cost, pollution treatment cost and other industrial applications (Wang *et al.*, 2004).

Environmental attribute index: Environmental attribute index reflects the degree of harmful impact of food machinery on environment in the entire life cycle, including the emission situation of rubbish and noise pollution situation in the process of production. It could use these indexes such as the physical pollution, chemical pollution, biological pollution and noise grade to evaluate environmental attribute index.

CONCLUSION

Green design is the design based on ecology. Setting up green concept complies with the time request and could promote the sustainable development of enterprises and even the entire industry. But still there are some problems:

- In order to make the public afford green products consumption generally, in the research and

development of product life cycle, how to decrease the cost of each stage is the most critical problem.

- The existing standards and guide specifications about food machinery in China have not adapted to the requirements of globalization development. It lacks the technical standards and specifications that are advanced and applicable and meet the internationally accepted requirements to a great extent. Especially the green manufacturing technology as a new concept has not yet the unified standard definition and technology method.

Green design has a long way. Designers certainly should become the vanguard of green design, consciously implementing it in the process of design. But it is not enough, after all, the strength of designers is relatively thin, the propaganda of public opinion and policy support are also crucial. Enterprise decision-makers should also have a heart of environmental protection and at the same time in the pursuit of commercial value, also should give attention to both social value and ecological harmony.

ACKNOWLEDGMENT

This research is supported by the Twelfth Five-Year Science and Technology Research Project of Education Department of Jilin Province under the grant No. 2014530.

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