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DESIGNING AGRICULTURAL MACHINERY FOR ENVIRONMENT

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Abstract

Design for Environment (DfE) has been defined as the systematic integration of environmental considerations into product and process design. And it has been discovered that resources can be conserved when several functions are integrated into a single product by taking advantage of common components. This paper highlights how agricultural machinery can be designed not only for multipurpose use but for multi-lifecycle by using design for environment concepts such as design for modularity, disassembly, demanufacturing and remanufacturing. The concept is illustrated with a completed design and development project on sustainable peanut processing machine. The product was found to be equally technically sound as the conventionally designed ones, more environmentally friendly, economically preferable and socio-culturally better than those developed by using the traditional design approach.

Keywords

Design for Environment, Agricultural Machinery, Disassembly, Demanufacturing, Remanufacturing, Appropriate Technology

Introduction

Agricultural work, whether on small or medium scale farms, plantations, or agro-industrial complexes, is by its nature physically demanding. It involves long period of standing, bending and /or repetitive movement in uncomfortable body postures. It also involves a lot of risks of exposure to disease carrying pests and accidents due to difficult terrain. Early recognition of these problems has led to the development of simple hand tools until the dawn of Industrial revolution of the 1700s. The industrial revolution led to progressive development of more sophisticated agricultural tools and machinery ranging from simple hand tools to automated mechanized agro-industrial systems. It resulted not only in rapid and simpler means of production but it also brought enormous increase in environmental pollution. The reason is because in developing a new agricultural tools and machinery, designers normally limit their design considerations to functionality, cost, aesthetics and other factors that are pertinent to its effective utilization.

Consequently, when these tools and machinery reach the end of their service life (Figure 1) or become obsolete, they constitute environmental burdens because they were designed without the end-of-life management consideration.

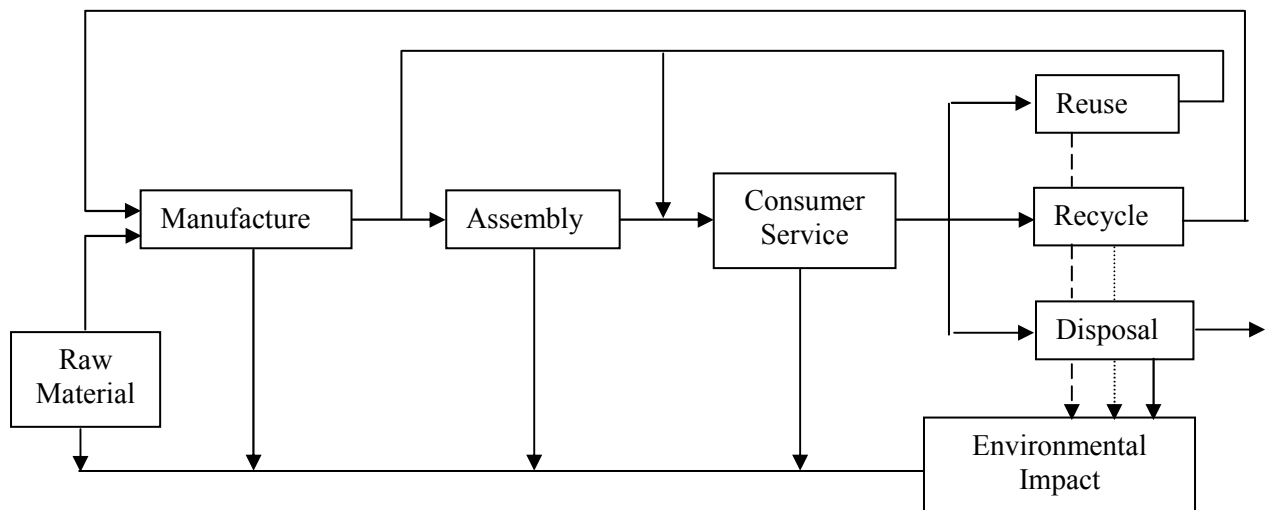


Figure 1 Product Life Cycle

Agricultural Machinery Design Characteristics

Agricultural machinery, in addition to other characteristics, must be rugged and corrosion resistant because of its peculiar service environment. Many times they are deployed in difficult terrains and they are handling biological materials. Some of these materials are corrosive. Furthermore, because they are at times used in remote areas where there may not be easy access to maintenance personnel, they must not easily breakdown. This necessitates their being designed for durability. The use of standard component parts is also a requirement in order to facilitate interchangeability of parts and for long service life of the machinery.

Necessity for Environmental consideration in Agricultural Machinery Design

Designing products with minimum impact on the environment is becoming increasingly important. The success of the agricultural sector depends on the environment's welfare. It is therefore reasonable for the agricultural machinery designer to incorporate principles that promote resource conservation, pollution prevention and environmental wellness in their designs. Doing this is not only good for the environment but also makes good economic sense.

Design for Environment (DfE) Principles

Design for Environment, also known as Lifecycle Design, Ecodesign and Green design, has been defined as "Systematic consideration of design performance with respect to environmental, health, and safety objectives over the full product and process life-cycle" (Fiksel, 1996). It is also defined as the process of incorporating various values (such as manufacturability, serviceability, recyclability, etc.) of a product in the early stages of design. This implies that at the product and process conception stage, the designer considers the potential impacts of materials selected and manufacturing methods to be used in developing the product on the environment. He/she also considers their potential impacts on the health and safety of the product users, factory workers as well as on the populace. The environmental, health and safety (EHS) effects of using the product is also considered at this stage. Furthermore, the EHS impact of the product's end-of-life management options is also evaluated when designing for environment. The reason for taking these steps at the design stage is because most of the environmental performances of a product are determined at the design stage and because the end-of-life management of a product depends to a large extent on whether the product can be taken apart or not. Moreover, the objectives of taking the aforementioned steps is to arrive at a choice of the best mix of options that will lead to the production of a product that is technically sound, environmentally friendly, economically sensible and social-culturally acceptable. Attainment of these objectives necessitated the development and utilization of a number of complimentary design paradigms (DfX) such as design for modularity; design for assembly/disassembly; design for manufacturing/remanufacturing; design for use/reuse; design for recycling; design for energy efficiency, design for multi-purpose use, and other DfXs (Figure 2).

Design for modularity is a concept that involves dividing a complex system into a manageable set of clumps called modules, and harmonizing the modules' communication through some sort of interface (Marks, Eubanks and Ishii). A "clump" is a collection of components and/or subassemblies that share a physical relationship, and some common characteristic based upon user intent (Ishii and Yang, 2002). Some of the required characteristics of clumps is that a clump should be removable as a unit and be made of the same material. This concept has the benefit of facilitating the isolation of problems, reducing the problem diagnosing/disassembly efforts, and consequently reducing maintenance and recycling costs.

Design for Assembly (DFA) is a process for improving product design for easy and low cost assembly by focusing on functionality and assemblability concurrently. This is achieved by simplifying the product configuration and minimizing part count. DFA involves analyzing both the part design and the whole product for any assembly problems early in the design process. In addition to reducing the cost of assembly, design for assembly also improves the product quality and reliability (Chan and Salustri, 2005; Dewhurst, 2005).

Closely related to DFA is design for disassembly (DFD). DFD considers the ease with which a product can be economically taken apart at the end of the service life or for maintenance. It enables the product and its parts to be easily reused, re-manufactured or recycled at end of life. Design for remanufacturing Design for material involves the evaluation of the feasible material options in terms of toxicity, durability, recyclability, biodegradability and so on. Design for use/resue and design for recycling involve the combination of a number of the aforementioned paradigms and consideration of other issues that facilitate ease of product use and resue as well as enhance product recycling. A lot of work has been done in the area of design for assembly (Boothroyd and Dewhurst, 1983); design for disassembly (Crow, K., 1998; da Silva, M.G.; Giasolli, R.; Cunningham, S. and DeRoo, D., 2002); design for remanufacturing (Jacobsson N., 2000; Kerr W., 1999); design for recycling (Ishii K., 1998), design for variety (Ishii, K., Juengel, C., Eubanks, C.F. (1995)), and design for multi-purpose use (Dunmade, 2004). Some other complimentary concepts are also in the process of development.

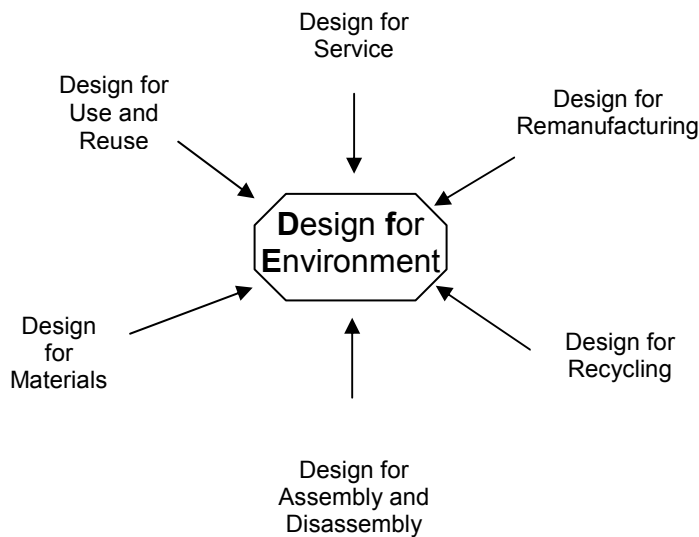


Figure 2 Design for Environment Paradigms

Application of DFE Principles in Agricultural Machinery Design and Development

All types of agricultural machinery, ranging from tillage implements to agro-processing equipment, can be designed for environment. Three areas that should be considered when designing for environment are process design, material design, and energy consumption design (. These can be achieved by considering the possibility of incorporating the following issues in the design:

- manufacture without producing hazardous waste
- use clean technologies
- reduce product chemical emissions
- reduce product energy consumption
- use renewable energy
- design product to use renewable energy
- use non-hazardous recyclable materials
- use recycled material and reused components
- use of biodegradable materials wherever possible
- use of homogenous materials rather than composite materials
- design for ease of disassembly
- part count minimization
- simplification of product geometry
- product reuse or recycling at end of life.

Incorporating these DFE aspects will make products never to become waste, but instead become inputs into new products at the end of their useful lives, thereby facilitating multi-lifecycle use of the product and for multipurpose use.

An illustrative example

The aforementioned DFE precepts has been successfully applied in designing a multi-purpose thresher/ sheller for multi-lifecycle (Figure 3). To attain the goals of designing for multi-purpose use, the machine was configured into modules of three functional units, namely: the threshing unit; the separation unit, and grading unit. The modularity of the functional unit also facilitates multi-lifecycle use of machine and/or its component parts. The ease of use and maintenance is promoted by using minimum number and only two varieties of fasteners. The uniformity of the liaisons and simplification of the configuration reduces both the disassembly times and maintenance cost. Furthermore, the component parts of each of the functional units were made accessible and structurally versatile in order to make the product durable and to enable it withstand various harsh service environment. In designing for materials two materials, namely: galvanized steel and carbon steel, were used because they satisfied the service requirements, they are locally available and their prices are reasonably affordable.

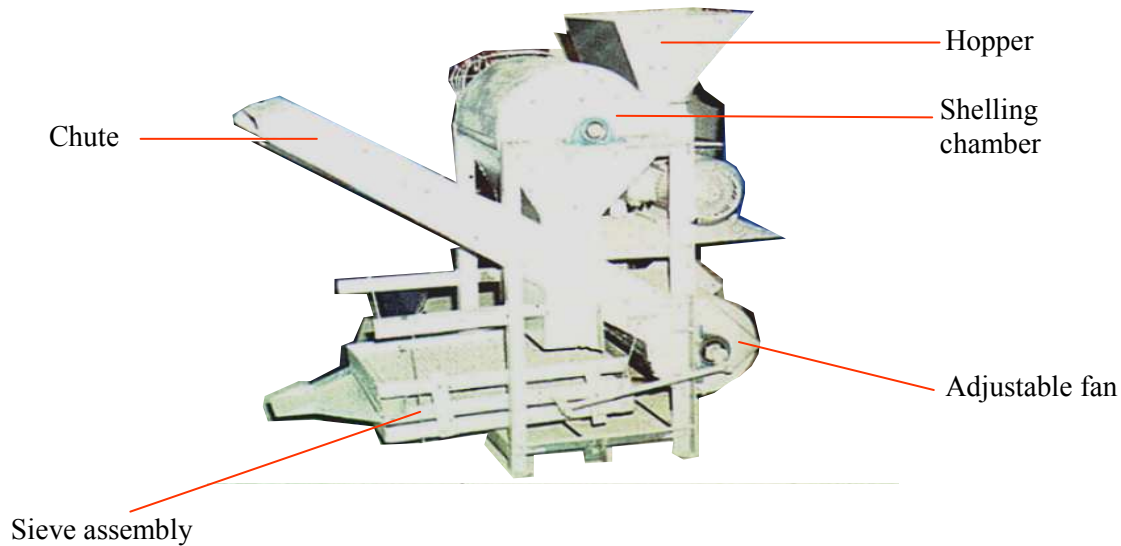


Figure 3 A Multi-purpose Thresher

Furthermore, the shelling unit consisting of shelling drum and concave were designed in such a way that they can be easily changed to the configurations that suit the processing of different crop produce. Moreover, the separation unit and grading unit were adapted for multipurpose use by making the fan speed adjustable and the sieve assembly exchangeable respectively. Consequently, the adjustability of the feeding rate and fan speed as well as the variability of the cylinder's rotating speed have resulted in high performance efficiency of the machine.

Challenges of Designing Agricultural Machinery for Environment

Designing agricultural machinery for environment is essential, particularly considering the increasing strictness in environmental regulations and increasing consumer pressure. However, the attainment of DFE goals require adequate manpower training. It would therefore be necessary to include design for environment in the agricultural engineering curriculum. It is also essential that important infrastructures such as viable product take-back networks and product structural condition monitoring facilities be made available. Furthermore, there is a need to expand resource base in the area of viable renewable energy and material options. These will enable the designers to find it easier to make design decisions and consequently facilitate the achievement of design for environment goals.

Conclusion

Design for environment is fast gaining widespread acceptance in the product and process design community not only because it improves products' environmental performance but also because it is economically beneficial. It is essential that agricultural tools and machinery designers incorporate the design concept in their design process. The modularity of the functional unit will

facilitate multi-lifecycle use of machine and/or its component parts because the faulty parts can easily be identified and fixed or replaced at a lower cost. Utilizing the concept of design for assembly/disassembly by employing uniform liaisons and by simplifying product configuration will reduce both the disassembly times and maintenance cost. By adapting the machinery design for multi-purpose use, the material requirements for four different machines are conserved, environmental emissions that would be associated with the manufacture, transportation and disposal of four machines are eliminated while the capital requirements by farmers for machinery are reduced to about a quarter. Consequently the total lifecycle cost is reduced while the eco-efficiency is maximized.

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