Development of a Model for Enabling Environmentally Conscious Design in an Indian Manufacturing Organization

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Abstract - An investigation is reported on the importance of integrating sustainability with manufacturing and design, along with other objectives such as function, competitiveness, profitability and productivity. The need of utilizing appropriate tools like design for environment, life cycle assessment and other environmentally sound practices that are entire life cycle of a process or product is highlighted. It is likely that sustainability and environmental stewardship will be increasingly important considerations in manufacturing and design in the future and are likely to influence the main priorities for advancing manufacturing operations and technologies. Designers and manufacturing decision makers who adopt a sustainability focus and establish a sustainability culture within companies are more likely to be successful in enhancing design and manufacturing. It is concluded that more extensive research and collaboration is needed to improve understanding of sustainability in manufacturing and design, and to enhance technology transfer and applications of sustainability. In this context, QFD for environment (QFDE) has been used in this research project. QFDE consists of four phases. QFDE phases I and II are concerned with the identification of components that are focused on product design considering both environmental and traditional requirements. QFDE phases III and IV enables the design engineers to examine the possibility of design improvements for components and determining the improvement effect of design changes.

Keywords - integrating sustainability with manufacturing and design, QFD for environment (QFDE), design for environment, life cycle assessment (LCA).

1. INTRODUCTION

Environmental consciousness regarded as a vital concept for survival in the competitive market scenario. Sustainability refers to the capability of an organization to maintain environmental safety and minimize resource utilization. For successfully implementing the sustainability, organizations needs to know where are there standing now and how far are they to reach the sustainable manufacturing performance. In this research work Environmentally Conscious Quality Function Deployment (ECQFD) to a manufacturing organization has been used to handle environmental and traditional quality requirements of the product to enable the organization to bring a sustainable product which will impart little impact on the environment during its life cycle. ECQFD consists of four phases. ECQFD phases I and II are concerned with the identification important parts of electric vehicle that are vital for improving the environmental consciousness. ECQFD phases III and IV are used to analyze which design changes among the formed design options of electric vehicle are most effective with regard to environmental improvement. ECQFD results indicate that it could be applied in early product design and development stages. Sustainability in the development and manufacture of new products is a strategy that is widely accepted in principle, although not yet widely practiced. The integration of environmental requirements throughout the entire lifetime of a product needs a new way of thinking and new decision tools to be applied. This paper describes the concept of an approach to product development, based on a paradigm for sustainable manufacturing.

- *AIMS OF THE STUDY*

The main purpose of this study is to examine the every aspects of industrial design from the view point of the sustainability. In traditional terms, the concern of the designer has ended with the launch of the product, but the environment-conscious designer should think about its complete life. Environmental problems become an increasingly important aspect of the designer's work to minimize the risks arising from the failure of a product or process. Because of the rapid technological development, environmental problems increase every day. On the other hand, new technologies often tend to be less polluting and dangerous than what they replace, and hence designers may find themselves in the forefront of identifying problems which must be addressed by technology. The aims of environment-conscious designer are to use the minimum resources throughout, to get the maximum possible use and

value out of the least quantity of materials and energy, and to minimize pollution created during the manufacture and life of the product

2. SYSTEM MODEL

Though researchers have contributed certain techniques for enabling environmental consciousness, few have explored the feasibility of deploying such techniques in an industrial scenario to ensure practical validity. In this context, the ECQFD contributed by Masui has been utilized in this research for infusing environmental aspects into the early design stage for rotary switches manufactured by an Indian organization. Integration of ECQFD and LCA has been made for infusing the environmental features into product development process. The research gap observed based on the literature review is that many of the approaches contributed are not practically feasible and adaptable in the industrial scenario. In this context, this research project has been carried out.

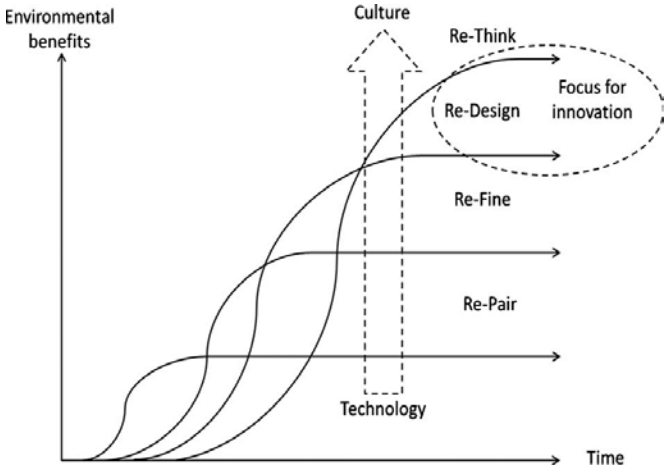


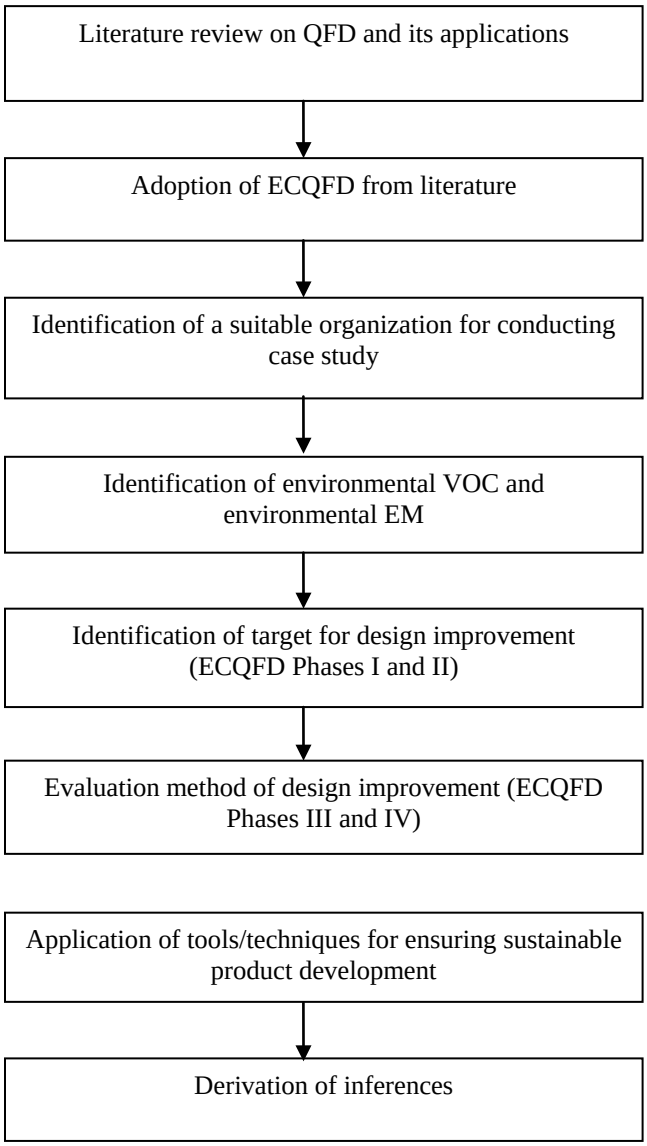
Fig. 1 Design for Environment

3. PREVIOUS WORK

Many of the literature nationally & internationally found this area are a working of interest, some of the reviewed literatures are mentioned below;

Akao and Mazur (2003) QFD emphasizes quality in the design process to prevent the likelihood of defects at the earliest stages thereby reducing cost and improving productivity [1].

Chen et al. (2005) have proposed a novel fuzzy expected value operator approach to model the QFD process in a fuzzy environment, and two fuzzy expected value models are established to determine the target values of engineering characteristics in handling different practical design scenarios[2].



Gungor and Gupta (1999) have presented Environmentally Conscious Manufacturing and Product Recovery (ECMPRO). ECMPRO involves integrating environmental thinking into new product development including design, material selection, manufacturing processes and delivery of the product to the consumers, plus the end-of-life management of the product after its useful life [3].

Masui et al. (2003) presented a concept called QFDE or ECQFD in which QFD has been applied to environmentally-conscious design [4].

Pun et al. (2006) have presented the determinants of environmentally-responsible operations and suggested Green QFD as one of the tools for environmentally-responsible operations [5].

Senthilkumaran et al. (2001) have presented Life Cycle Environmental Cost Analysis (LCECA) model to include eco-cost into the total cost of the products. LCECA model identifies the feasible alternative for cost-effective, eco-friendly parts/products [6].

4. METHODOLOGY

This project started with a literature review on QFD and its application on environmentally-friendly aspects. This was followed by the adoption of the ECQFD model suggested in the literature. A suitable organization for conducting the case study was identified that demonstrated the aspiration to attain world class status by means of implementing environmentally-friendly strategies. Phase I was concerned with the application of ECQFD for the rotary switches. Phase II was concerned with the deployment of Engineering Metrics (EM) items to product components. In phase III, the effect of a set of design changes on EM items was estimated. The goal of phase IV was to translate the effect of design changes on EM into environmental quality requirements. This is followed by the application of tools/techniques for ensuring sustainable product development. Then the practical inferences are derived.

5. RESULTS & DISCUSSION

In many situations people have to deal with uncertainties and the risks associated with these uncertainties. Particularly in reuse strategy, the existence of uncertainties is obvious. For instance, industries have no idea when and why exactly the customer will dispose of their goods. Uncertainty of the usage intensity of customers' site is also hidden from industries, and this will heavily influence the quality of the products at the end of their first life. Furthermore, uncertainties are also involved in the cost calculation. For instance, the unknown location of the disposal site will affect the transportation cost. The physical condition of used products – they can be rusty, bent, broken, or good – will also vary, thus influencing the disassembly cost. Methods to deal with uncertainties vary from group decision to the use of multi-attribute indices and statistical tools. Simulation is the classic approach to handle uncertainties. In this research, simulation is carried out using Simquick software. The model is developed based on the assessment model as explained in LCA, and the uncertainties are defined using relevant probability distributions from past practical experiences.

- *Life Cycle Assessment (LCA)*

Traditional product development cycle consists of gathering customer requirements, identification of design objectives, design, engineering analysis, manufacturing, usage and dispose. In the sustainable product development cycle, environmental requirements need to be introduced into the development phases. The various issues associated with sustainable product development cycle consist of introduction of environmental awareness to customer requirements, assessment of environmental performance as a design objective and evaluation of the potential of product for reuse and recycling. In this research project, Environmentally Conscious Quality Function Deployment (QFDE) and Life cycle assessment (LCA) is used for assessing the environmental impact of products and processes. Since the detailed assessment of LCA is time consuming, simplified LCA methodology proposed by Kaebernick has been used in this project LCA methodologies are widely used for assessing the environmental impact of products and processes. A common problem with LCA is that a full assessment is very time consuming, and it needs very specific data, which is normally not available in the early stages of product development. Therefore, a number of simplified LCA methodologies have been suggested for the early estimation of the environmental impact of a product.

- *Results from ECQFD*

In order to evaluate the design for environment option from ECQFD, the improvement effect for the VOCs with their weights was calculated for each design from an environment perspective through ECQFD phase III and phase IV. In this case study, the scores 3.012 and 3.576 were obtained for options I and II respectively and it was concluded that option II was the best.

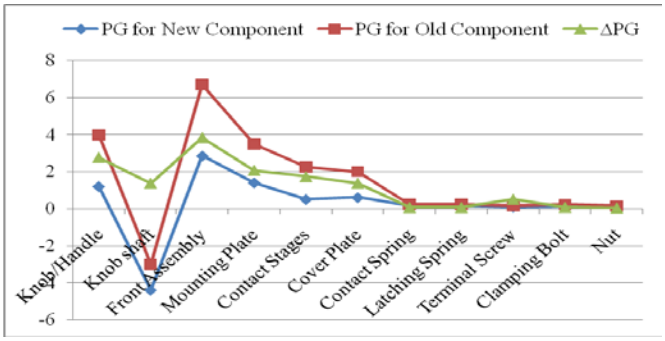


Fig. 2 Comparison of PG, ΔPG for old and new component

- *Result from LCA*

The comparison results for all parts of PG are shown in Fig. 2 shows that all components have the positive values of ΔPG, which means they are feasible for re-use. If any components

contain the negative ΔPG, which indicates those components are not feasible for re-manufacturing.

- *Results from Simulation*

Fig. 3 plots the mean, minimum, and maximum values of PE for all components. The variation of technical feasibility is clearly shown in the Fig. below. In summary, the results show that 6 components, 54.5% of total components, have technical potential of around 90 to100% of reuse, while 2 components, 18.2% of total components, have the technical potential of around 80 to 90% of reuse, whereas 3 components, 27.3% of total components, have the technical potential of around 50 to 80% of reuse under simulation scenario.

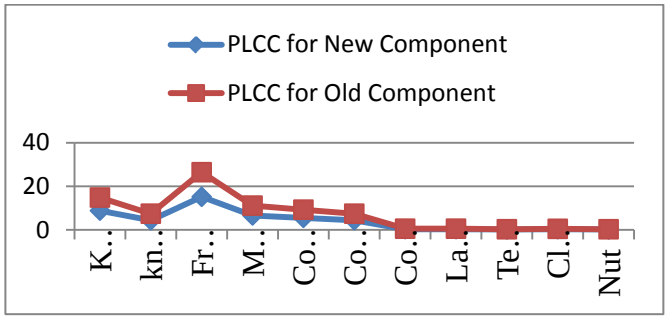


Fig. 3 Comparison of PLCC for old and new component

6. CONCLUSION

The reduction of production cost and prevention of environmental problems for ensuring clean and green atmosphere is the focus of contemporary manufacturing organizations. Sustainable system tries to maximize resources efficiency for the production of sustained components. Introduction of environmental requirements into the stages of product development is necessary for sustainable manufacturing paradigm. In the contemporary manufacturing scenario, the environmental requirements must be treated equal importance to traditional product requirements. In this context, this project reports a case study in which ECQFD and LCA has been integrated for enabling sustainable product development.

The model described in this project provides a useful tool to decide upon the potential of reuse of components at the end of their life. The use of simulation significantly enhances the understanding of the impacts of the contributing factors or parameters in the model. The implementation of the model in the case of an electronic device like a rotary switch shows that there is a potential for parts reuse. Including the environmental cost in the model can only increase the positive component of Δ PG. Therefore the model can be used in an economy driven environment, but still indicating the environmental friendliness of a component. Today, the concept of sustainability has become more important. The challenge of sustainable design is to alter conventional design and manufacturing procedures to incorporate environmental considerations systematically and effectively the importance of integrating sustainability with manufacturing and design is highlighted, along with the need to utilize appropriate tools, like design for environment and life cycle assessment.

7. FUTURE SCOPES

Continued trends in sustainability applications for products and processes indicate the need for identifying relevant sustainability metrics and for developing science-based methodologies for quantification of these factors. Achieving global sustainability is a major challenge and this requires international cooperative research and applications.

Related research on residual product value at the end of the first consumer use phase will also be needed. Design methods which take this value into account for product design, material choice, manufacturing process design, and remanufacturing could potentially improve both the economic and environmental efficiency of the entire life cycle. To summarize, future research in the realm of integrated sustainable design will be directed towards the following: Development of uncertainty models that are representative of LCA data used in the interpretation of environmental impact; implementation of these results in regards to eco-design Integration of socio-economic modeling with eco-design and LCA.

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