UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Sustainable Development of Coffeemaker Using Design for Environment (DFE) Methodology

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours

By

Shivarajh A/L Egambaram

Faculty of Manufacturing Engineering

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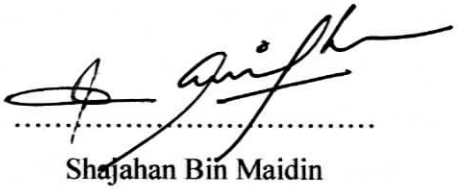

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ABSTRACT

Engineers are in an essential position to affect the environmental aspects of the product they design. Role of a design engineer has become increasingly vital not only to produce product to meet customers needs of quality and cost but also to produce products with as low environmental impact as possible. This report is about sustainable development of a coffeemaker by applying the Design for Environment (DFE) approach which aims to protect human health and preserve environment. In recent years, DFE has become an important approach since the world is facing problems of limited resources and serious environmental effects. DFE is an approach implemented at product design and development stage to avoid or minimize significant environmental impacts and increase resource efficiency at all phase of a product life cycle ranging from extraction of its material, manufacturing, packaging, transportation, product usage and finally to recycling or deposition of the used product. The methodology used in this report is by developing Philips' coffeemaker as a benchmark and implement DFE tools and guidelines to produce a sustainable coffeemaker. From the result obtained, the evaluation and comparison of environmental impact and effect on human health of the Philips coffeemaker and sustainable coffeemaker is carried out with life cycle assessment (LCA) method. LCA software, SimaPro is used to carry out the assessment. By adopting DFE, a certain company can achieve the ISO 14001 international specification for Environmental Management System (EMS) beside other benefits such as encouraging the customers to accept its product, reduce environmental effect and conserve energy or natural resources.

ABSTRAK

Peranan jurutera menjadi semakin penting bukan sahaja untuk merekebentuk produk yang memenuhi kehendak pelangan tetapi juga memastikan bahawa produk yang dihasilkan itu tidak memberi kesan buruk terhadap alam sekitar. Laporan ini adalah tentang memajukan produk yang mampan melalui aplikasi pendekatan rekabentuk untuk alam sekitar untuk melindungi kesihatan manusia dan memelihara alam sekitar. Pengamalam konsep ini menjadi semakin penting sejak kebelakangan ini kerana dunia kini menghadapan dengan masalah sumber terhad dan kesan persekitaran yang serius. Pendekatan rekabentuk untuk persekitaran diaplikasi pada peringkat rekabentuk produk dan mengembangkan sesuatu produk untuk mengelakkan atau mengurangkan kesan negatif terhadap persekitaran serta meningkatkan kecekapan sumber asli pada setiap peringkat jangka hayat produk bermula dengan melombong bahan mentah, pembuatan, pembungkusan, pengangkutan, pengunaan produk sehingga ke kitar semula atau pelupusan produk tersebut. Kaedah yang digunakan dalam laporan ini adalah dengan memajukan mesin pembancuh kopi Philips yang berperanan sebagai penanda aras serta mengaplikasi alat bantu dan garis panduan untuk pendekatan rekabentuk untuk persekitaran untuk menghasilkan mesin pembancuh kopi yang mampan. Daripada keputusan yang diperoehi, penilaian dan perbandingan kesan kedua-dua produk ini terhadap alam sekitar dan kesihatan manusia dilakukan dengan menggunakan kaedah penilaian jangka hayat produk. Perisian yang digunakan untuk mengendalikan tugas ini ialah perisian SimaPro. Melalui pengamalan kaedah rekabentuk untuk persekitaran, sesuatu syarikat boleh mendapatkan penganugerahan ISO 14001 yang merupakan piawaian pengurusan persekitaran selain menggalakkan pengguna menerima produk pengeluar, mengurangkan kesan buruk terhadap alam sekitar dan memelihara tenaga atau sumber asli.

DEDICATION

To My beloved mum

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It gives me utmost pleasure to express my gratitude to who have directly or indirectly contributed to the fruition of the project compilation. They include;

My supervisor, Mr. Shajahan Bin Maidin of which we had an excellent working relationship, and who offered tremendous help and encouragement,

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

CAD	-	Computer-Aided Design
CAE	-	Computer-Aided Engineering
CR	-	Customer Requirements
DFA	-	Design for Assembly
DFD	-	Design for Disassembly
DFE	-	Design for Environment
DFMA	-	Design for manufacturing and Assembly
ECQFD	-	Environmentally Conscious Quality Function Deployment
EM	-	Engineering Matrices
EMS	-	Environmental Management System
EPD	-	Environmental Product Declaration
EPI	-	Environmental Performance Indicator
ERA	-	Environmental Risk Assessment
FEM	-	Finite Element Analysis
ISO	-	International Standards Organization
LCA	-	Life Cycle Assessment
LCC	-	Life Cycle Cost Assessment
LCD	-	Life Cycle Design
SDS	-	Safety Data Sheet
SPI	-	Sustainability Performance Indicator
Std	-	Standard
TR	-	Technical Requirement
UTeM	-	Universiti Teknikal Malaysia Melaka
VOC	-	Voice of Customers
QFD	-	Quality Function Deployment
WEEE	-	Waste Electronic and Electronic Equipments

DEFINITION OF TERMS

The following are the terms that frequently used in this report so it is important to understand their definitions.

I) Sustainable product ~ product which will give as little impact on the environment as possible during its life cycle (Ljungberg, 2007);

II) DFE ~ systematic way of incorporating environmental consideration into the design of a product (Manuilova *et al.*, 2005);

III) Product life cycle ~ product phases ranging from extraction of raw material, product manufacturing, packaging, usage and final disposal (Kurk and Eagan, 2008);

IV) LCA ~ DFE tool to evaluate environmental performance of a certain product (Rebitzer *et al.*, 2004).

CHAPTER 1

INTRODUCTION

1.1 Background

The world is facing problem with the limited resources and serious environmental impacts, so it is important to live a more sustainable life style. It is not only designers' but also responsibility for every inhabitant to overcome these environmental problems. During the last century, the environmental problem faced at the end of life cycle of certain product during its disposal or recycling. But today the environmental performances of a product are taken into consideration in very early stages of product design and development.

Basically, there are four environmental challenges need to be faced and overcome by the mankind which are over-consumption, resource utilization, pollution and over-population (Ljungberg, 2007). Over consumption refers to use of many different materials which demands for transportation. Thus, increases the energy consumption around the world. Resource utilization requires a product not to be "over-designed" or having unnecessary parts. Pollution is a common challenge in industry resulting from emissions. Over-population refers to ever increasing world inhabitants that demand for less consumption for resources or energy otherwise the mankind will face an exhaustion of those resources and energy.

Besides meeting the customers' need for better quality and price demands and employees demand for economic competitiveness, the design engineers also have to take into consideration the environmental impact during designing phase of a product (Schvaneveldt, 2003). Fundamentally, it is impossible to design a product which has zero impact on environment and human health (Kurk and Eagan, 2008). However, this drawback can be solved by implementing DFE at early stages of product design and development.

Design of the product according to DFE enables companies or firms to be recognized according to International Standards Organization 14001 for Environmental Management System. Adopting DFE into their product actually benefits the companies in many areas such as broadening market access, reducing liability, expediting permits, improve public acceptance of the product, decreasing pollution and conserve energy or natural resources (DeMendonça and Baxter, 2001).

In this project, a non ISO 14001 certified product will be chosen and the products' performance will be analyzed as a benchmark. The product then will be developed using DFE tools to obtain a sustainable product status. Finally, the performance of both products will be analyzed with LCA method.

The sustainable product will be designed to reduce a product's energy consumption, material usage, recycle-ability or toxicity compared to its originally designed performance level by the implementation of DFE. The expected outcome for this project is the sustainable product will have less impact than the benchmark on human health, resource usage and environment.

1.2 Statement of the Problem

When a product is designed and introduced to the market, the environmental value of the product is given less priority and this has led to lack of sustainable products in market. These products will face the risk of disposal difficulties at the end of products' life cycle (Kurk and Eagan, 2008). Thus, the overall cost of the product will be raised due to the disposal difficulties. The emissions and waste produced during the manufacturing phase and service of the product eventually harm the environment and human health. Besides the issue of disposal, emission and waste, another crucial issue is the ever decreasing resources for the natural resources and material urging the necessity to produce a sustainable product. This project will look into implementation of DFE method and tools to obtain a sustainable product that will have less impact to environment, resource and human health than benchmark product of same kind.

1.3 Objectives

The objectives of this project are:

(a) to identify a non ISO 14001 certified, carry out study and analysis about the product necessary for sustainable development;
(b) to integrate design for environment (DFE) tools into product design and development process;
(c) to carry out customer survey and develop an environmentally conscious quality function deployment (ECQFD);
(d) to produce a detailed design of the product with a computer-aided design (CAD) software;
(e) to carry out assessment and comparison of environmental impact of benchmark product and sustainable product designed with life cycle assessment (LCA) method.

1.4 Scope

The product design and development is based on the DFE guidelines, method and tools obtained through the literature studies. Tools such as DFA, ECQFD and *The Ten Golden Rules* are integrated during different phases of product design and development. The environmental performance of the products is evaluated with SimaPro which is software for LCA studies. CAD software SolidWork will be used for designing the detailed design for the product.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature search was performed to study, implement, design and analyze the sustainable product through implementation of Design for Environment (DFE). This study also includes the areas of product design and development of a sustainable product.

2.2 Background of Design for Environment (DFE)

DFE is a concept originated from industry's effort to incorporate environmental consideration during the product development stage (Sroufe *et al.*, 2000). It is also known as eco-design and life cycle design (LCD). According to ISO 14062, the aim of integrating environmental aspects into product development stage is to reduce the total amount of environmental impact of products during its life cycle (Lindahl, 2006).

The objective of DFE is to produce sustainable product which satisfy human needs and requirement for the product which will increase the positive value and decrease the negative values of a certain product pose on the environment (Karlsson and Luttropp, 2006). In order to achieve these goals, there are necessary methods and

tools to systematically implement DFE into products such as the LCA tool to quantify and compare environmental impacts (Rebitzer *et al.,* 2004).

2.2.1 Definition for DFE

Since DFE is a new term in product design and development, there are many definitions to describe the concept of DFE. One of the sources define DFE as integrating environmental aspect at every product design criteria including the function-ability, cost, aesthetics, safety, reliability and ergonomics (Kurk and Eagan, 2008).

Another source states that DFE is an integral part of a product development phase that taken into account by the designers to understand and reduce a products' impact on the environment during its life cycle from material selection, manufacturing, usage and deposition (Schvaneveldt, 2003).

DFE is an attempt taken to minimize the environmental impact of a product during its life cycle ranging from extraction of raw material through processing, manufacturing and transportation to reuse, recycling and final disposal. This is important to decrease the consumption of raw materials and energy, reduce cost and make the process environment friendly (Manuilova *et al.*, 2005).

DFE can be concluded as an approach implemented during the design and development of a product to minimize its environmental impacts during a products' life cycle.

2.2.2 Aims and Benefits of DFE

At early stage of DFE implementation in product development, it is often causes problems to companies rather than benefits as environmental assessment tools are very complex, time consuming and need expertise to perform the task (Manuilova *et al.*, 2005). After further improvement made on DFE tools and techniques, the benefits of DFE is seen through good reputation among the customers and better saving by using recycled material (Ljungberg, 2007).

Manufacturing firms now are beginning to benefit from DFE which provides opportunity for cost saving and reduced responsibility to for environmental and human health protection (Kurk and Eagan, 2008). The application of DFE during the product development stage has proved beneficial by reducing manufacturing cycle time and distinguishes products with added value of environmental feature to provide competitive advantage in the market (Kurk and Eagan, 2008). Apart from that, DFE is giving an opportunity to design or develop sustainable products without influencing the products market competitiveness and profitability (DeMendonça and Baxter, 2001).

Practicing DFE actually benefits the industry itself by widening the market access as well as customer base and expediting permits. This is done through good reputation to preserve nature. Thus, improves customer acceptance of the product. Beside that implementation of DFE reduces record keeping and less inspection. DFE also decreases emission or pollution, conserve energy or natural resource. All of this will contribute to economical advantage and reducing control cost to a manufacturer (DeMendonça and Baxter, 2001).