UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF INJECTOR GUN DESIGN USING DESIGN FOR MANUFACTURING AND ASSEMBLY (DFMA) AT THE CONCEPTUAL DESIGN STAGE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering at UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory committee is as follow:

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ABSTRAK

Setiap syarikat mahu menghasilkan produk yang berkos rendah, berkualiti tinggi dan dipasarkan dalam waktu yang singkat. Rekabentuk untuk Pembuatan dan Pemasangan merupakan satu konsep yang boleh aplikasikan untuk kebanyakan produk dalam industri pembuatan. Kajian ini menumpukan kepada kaedah Rekabentuk untuk Pembuatan dan Pemasangan Boothroyd-Dewhurst bagi menganalisa produk pistol suntikan (*injector gun*), yang memberi penekanan kepada pengurangan kos dan komponen. Tujuan kajian ini adalah untuk mengoptimumkan rekabentuk asal pistol suntikan pada peringkat rekabentuk konsep. Kajian ini mengaplikasikan perisian Rekabentuk untuk Pembuatan dan Pemasangan Boothroyd-Dewhurst sepenuhnya melalui dua jenis aplikasi iaitu perisian *DFA* untuk mendapatkan jumlah masa pemasangan, kos pemasangan serta peratusan indeks rekabentuk untuk pemasangan dan perisian *DFM Concurrent Costing* digunakan untuk menganalisa kos pembuatan yang melibatkan bahan serta proses yang ditentukan bagi setiap komponen produk. Seterusnya, analisa *DFMA* yang dijalankan melalui penggunaan perisian *DFA* memberikan jumlah kesuluruhan kos pembuatan dan pemasangan bagi seunit produk. Berdasarkan keputusan yang diperolehi, rekabentuk asal telah diubahsuai. Menggunakan perisian dan kaedah yang sama, rekabentuk produk baru dianalisa. Hasil daripada kedua-dua analisa dibandingkan bagi melihat sejauhmana metodologi *DFMA* memberi impak kepada pengoptimuman rekabentuk produk pistol suntikan ini. Hasil kajian menunjukkan pengurangan masa pemasangan sebanyak 52%, penurunan kos keseluruhan bagi sebuah produk sebanyak 28% dan perubahan pada peratus indeks rekabentuk untuk pemasangan dari 34% kepada 72%, iaitu peningkatan sebanyak 53%. Penggunaan bersama beberapa metodologi lain seperti simulasi dan rekabentuk untuk alam sekitar dicadangkan untuk perlaksanaan kajian pada masa akan datang.

ABSTRACT

Every company wants to produce low cost products, high quality and faster time to market. Design for Manufacturing and Assembly (DMFA) is a methodology that can be applied to many products in the manufacturing industry. This study focuses on Boothroyd-Dewhurst DFMA method to analyze the injector gun, which emphasis on cost reduction and parts count reduction. The purpose of this study is to optimize the current design of injector gun for oil palm tree fertilization application at the conceptual design stage. This study applies the DFMA Boothroyd-Dewhurst software by using two types of applications. The original design of the product was analyzed using DFA software applications to get the total assembly time, assembly costs and the percentage of DFA index. Then, DFM Concurrent Costing software application was used to analyze the cost of manufacturing for each part of the product which the materials and processes involved. Lastly, the DFMA analysis was carried out by using the DFA software. It provides overall total cost per unit of manufacturing and assembly of the product. Based on the results obtained, the original design had been modified. Using the same software and methods, new product design is analyzed. Results of both analyzes are compared to identify the extent of DFMA methodologies impacting the design optimization of the injection gun. The results show a reduction of 52% assembly time, the total cost of a product reduced by 28% and the percentage of DFA index change from 34% to 72%, an increase of 53%. For future studies, a number of methodologies such as simulation and Design for Environment (DFE) should be implemented simultaneously with the DFMA method.

DEDICATION

To my beloved husband
Mohammad Aizrulshah bin Kamaruddin

my children
Muhammad Izzu Syahmi & Maryam Kayyisah

my mother
Rufiah binti Jaafar

and all my family members.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile Butadiene Styrene
AHP	-	Analytical Hierarchy Process
BOM	-	Bills of Material
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CTQ	-	Critical to Quality
DFA	-	Design for Assembly
DFM	-	Design for Manufacturing
DFMA	-	Design for Manufacturing and Assembly
FYP	-	Final Year Project
HDPE	-	High Density Polyethylene
PDP	-	Product Design Process
PDS	-	Product Design Specification
RM	-	Ringgit Malaysia
UTeM	-	Universiti Teknikal Malaysia Melaka
%	-	Percentage
C_m	-	Assembly Cost
E_{ma}	-	Design Efficiency
kg	-	Kilogram
N_{min}	-	Theoretical Minimum Number Of Parts
s	-	Second
T_a	-	Theoretical Lowest Assembly Time for One Part
T_{ma}	-	Assembly Time

CHAPTER 1
INTRODUCTION

This chapter overall discusses about design optimization through implementing Design for Manufacturing and Assembly (DFMA) at the conceptual design stage. In this part, the briefing of the background, problem statement, objectives and scopes of the study are discussed.

1.1 Project Background

Nowadays, people are more demanding on something that simple and less costly in their daily requirement. In order to meet customer needs, more companies struggling with competitive markets to produce low cost products with high quality and faster to market. Many researchers and innovators have been carried out that focusing on increasing the efficiency and simplify the operation especially both assembly and manufacturing process and cost.

Improvement in many company’s operations is made by using a specific method. Usually, in industry the improvement they made are based on cost reduction. The reduction of cost could be made in the early stage of the design cycle. This means that cost estimation is an essential aspect in the design stage. Moreover, this is accepted that over 70% of final product costs is determined during the design stage (Boothroyd et al., 2002)

Design for Manufacturing and Assembly (DFMA) is a method used by designers in a way to reduce part count, reduce assembly time or even during simplify the sub-assemblies. It is a combination of Design for Manufacturing (DFM) and the Design for Assembly (DFA). DFM is a tool used to select the most cost effective material and process to be used in the production in the early stages of product design. DFA is a tool used to assist the product design teams to ensure the productions at a minimum cost, focusing on the number of parts, handling and ease of assembly.

Two different stages of DFMA implementation process are when existing design need improvement in order to achieve design optimization and in an early stage of the new design requirement is established. At the initial design stage, the designer develops a simple conceptual design by focusing on an assembly that requires a minimum of parts to perform and easy for installation. In the second stage the designer redesigns existing assemblies in order to optimize the design for ease manufacturing and installation (Herrera, 1997). Besides, in order to implement DFMA, the designer must have a good knowledge of the manufacturing process so that no additional unnecessary cost during the design development. Ease of manufacturing and assembly is important for cost, productivity and quality (Huang, 2001).

1.2 Problem Statement

Liquid injector gun (Figure 1.1) is one of the consumer products that used in industry and distributed by COX North America, an exclusive distributor of COX hand-held sealant and adhesive applicators located in Haslett, Michigan. The selection of this product is intended to meet the demand of a company that requires a design tool that can handle viscous liquid fertilizer injection for oil palm trees.

Figure 1.1: Injector Gun (Cox North America, 2012)

Quantum Agro Solution is a supplier of special grade fertilizers for oil palm tree located in Petaling Jaya, Selangor. Currently, growers use only medical syringe for fertilizing as shown in Figure 1.2.

Figure 1.2: Syringe for oil palm tree fertilization

However, the use of a medical syringe cause some problems due to the equipment not durable and ergonomic design for users. Even though the liquid injector gun is used for different purpose, but adaptation of this product as a liquid fertilizer injector gun for the oil palm tree is appropriate. Because of the complicated existing design as shown in Figure 1.3, DFMA concept will implement in redesigning this product with the aim to save the cost and ease of assembly and manufacture.

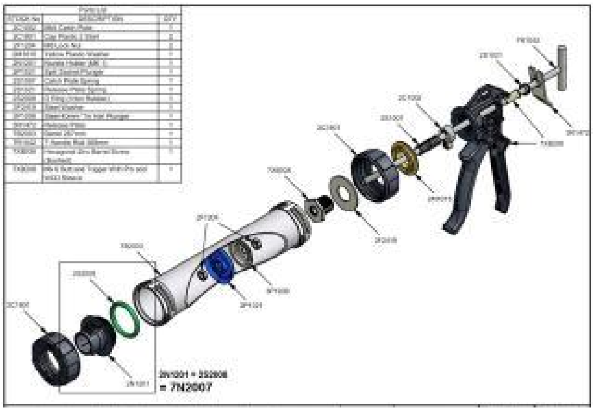

Figure 1.3: Exploded View of Injector Gun Product Modelling (Cox North America, 2012)

1.3 Objectives

The main objective of this project is to design and develop a new conceptual design of injector gun. The specific objectives are as follows:

a) To analyze the current product of an injector gun using Boothroyd-Dewhurst DFMA software.

b) To design and analyze the improved injector gun using Boothroyd-Dewhurst DFMA software.

c) To evaluate the original design efficiency over new design efficiency.

1.4 Scopes of Project

The scopes of the project are as follows:

a) The use of injector gun as a case study product.

b) The use of Boothroyd-Dewhurst DFMA softwares for product evaluations.

c) Product improvement for product structure simplification.

d) Comparison of product design efficiencies (DFA index).

e) The use of SolidWorks CAD software for product design drawing.

CHAPTER 2
LITERATURE REVIEW

This chapter covers the areas that need to be reviewed and understood before optimizing the product design by applying the DFMA concept. All information collected is derived from the findings of other peoples. In addition, it explains about DFMA software by Boothroyd-Dewhurst method and related matters in this study.

2.1 Product Design

Product design is generally conducted by a manufacturing enterprise whose primary purpose is to manufacture and sell products for a profit (Stoll, 1999). According to Chitale and Gupta (2007), product design deals with conversion of ideas into reality and fulfilling human needs. Product development and design are closely linked with industrial activity and production. When a new product is planned, the designer has to bear in mind the available resources of the plant and the possible impact of the firm having acquire, modify or substitute existing machines and equipment or buy various components from other suppliers. The important of product development and design for long-range planning by management is further emphasized by the amount of time that elapses from the inception of the idea for the new design until production starts. Table 2.1 shows the period or time to market for several products.

Table 2.1: Products design and time to market or incubation period (Chitale & Gupta, 2007)

Product	Time to Market
Automation bodies	2 years
Automobile engines	4-7 years
Radios and television sets	6-12 months
Telecommunications equipment	4 years
Aircraft	10-15 years
Household equipment	2 years
Fashion	Several weeks

In defense projects, where development and design take somewhat long time, because of the complexity of the problems involved, some design may become obsolete .

2.2 Design Optimization

According to Rao (1996), optimization is the act of obtaining the best result under given circumstance. Optimization can be defined as the process of finding the conditions that give the maximum or minimum value of the function. There is no single method available for solving all optimization problems efficiently and it can be applied to solve any engineering problem.

The goal of design optimization is to identify a design solution that satisfies all design requirements and is best in some sense. It can be based on cost, weight, strength, capacity and so forth.in most design situations, the design team is constantly striving to optimize the design. Often, this is done on a subjective basis using engineering experience and general principles (Stoll, 1999).

In analytical optimization, the design objective such as to minimize costs as well as all of the design requirements or constraints are expressed mathematically in terms of design variables. Solution methods are then employed to determine the optimum numerical value for each design variable. When this is possible, analytical optimization can be an excellent design improvement tool for performing parametric design (Stoll, 1999).

Chitale and Gupta (2007) identify four classifications of optimization in design approaches:

a) Optimization by Evolution

There is a close parallel between technological evolution and biological evolution. Most designs in the past have been optimized by an attempt to improve on an existing similar design. Survival of the resulting variations depends on the natural selection of user acceptance.

b) Optimization by Intuition

The art of engineering is the ability to make good decisions, without being able to provide a justification. Intuition is knowing what to do, without knowing why one does it. The gift of intuition seems to be closely related to the unconscious mind.

c) Optimization by Trial-and-Error Modelling

This refers to the usual situation in modern engineering design, where it is recognized that the first feasible design is not always the best. Therefore, the design model is exercised for a few iterations, in the hope of finding an improved design.

d) Optimization by Numerical Algorithm

This is the area of current active development in which mathematically based strategies are used to search for an optimum. The computer is widely used for such an approach.

There is no unique technique for optimization in engineering design. How well a technique works, depends on the nature of the functions represented in the problem. It has been a natural development to combine computer-aided-engineering (CAE) analysis and simulation tools with computer based optimization algorithms. Linking optimization with analysis tools creates CAE design tool by replacing traditional