DECLARATION

I hereby, declared this report entitled "Application Of Axiomatic Design And Additive Manufacturing: A Case Study Of A Door Knob" is the results of my own research except as cited in references.

Signature: .....

Author's Name: Muhammad Syazwan Bin Abdullah

Date: 5 June 2015

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APPROVAL

This Report is submitted to the Faculty Of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor Of Manufacturing Engineering (Manufacturing Design) (Hons). The member of the supervisory is as follow:

.....

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ABSTRAK

Ia adalah sukar untuk mencari tombol pintu yang sesuai hari ini kerana terdapat banyak jenis reka bentuk di pasaran. Setiap reka bentuk mempunyai ia memiliki spesifikasi yang menjadikannya sukar bagi pengguna untuk memilih. Masalah ini boleh diselesaikan dengan menggunakan disangkal Design untuk mencari tombol pintu sesuai digunakan di rumah. Selepas mengenal pasti tombol pintu yang sesuai, ia akan direka semula dan diuji untuk melihat sama ada ia akan menjadi berguna kepada pengguna.

Kaedah yang digunakan untuk projek ini adalah dengan menggunakan disangkal rekabentuk pintu tombol iaitu untuk mengenal pasti tombol pintu sesuai digunakan. Langkah pertama dalam disangkal Design (AD) mempunyai ciri-ciri keperluan yang pelanggan. Langkah kedua adalah keperluan fungsian. Langkah ketiga, mengenal pasti parameter reka bentuk untuk memenuhi keperluan fungsian yang ditetapkan. Keempat dan langkah terakhir adalah membangunkan satu proses yang mempunyai ciri-ciri pembolehubah proses. Kemudian membuat reka bentuk semula produk dan membuat prototaip dengan menggunakan mesin FDM.

Keperluan fungsian dijangka ditakrifkan melalui QFD. Berdasarkan HOQ, korelasi teknikal boleh ditentukan. Reka bentuk konsep baru dibangunkan dengan gabungan parameter reka bentuk dan keperluan fungsian berdasarkan VOC. Reka bentuk baru pintu tombol dihasilkan dengan perisian CADD seperti SolidWork atau CATIA.

Kaji selidik dalam talian terdiri daripada 40 responden telah dijalankan. Dari kajian ini, majoriti daripada pengguna memilih jenis tuil mengendalikan, pertimbangkan tentang harga, saiz biasa tombol pintu, pelbagai harga dan tolak mekanisme kunci

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ABSTRACT

It is hard to find a suitable door knob today since there are many type of design in market. Every design has it owns specifications that make it hard for user to choose. This problem can be solved by using Axiomatic Design to find the suitable door knob to be used at home. After identifying the suitable door knob, it will be redesigned and tested to see whether it will become useful to user.

The methodology used for this project is by applying Axiomatic Design to door knob which is to identify the suitable door knob to be used. The first step in Axiomatic Design (AD) is characterized the needs that the customer . Second step is functional requirements. Third step, identify the design parameters to satisfied the specified functional requirements. Fourth and last step is develop a process that is characterized by process variables. Then make a redesign of the product and make a prototype by using FDM machine.

The functional requirements are expected to be defined through QFD. Based on HOQ, the technical correlation can be determined. The new concept design is developed with the combination of design parameters and functional requirements based on VOC. The new design of door knob is generated with the CADD software such as SolidWork or CATIA.

Online survey consists of 40 respondents been conducted. From the survey, majorities of the users pick lever handle type, consider about the price, normal size of a door knob, range of price and push lock mechanism.

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DEDICATION

Dedicated to my beloved parents

Dearest siblings

Honorable lecturers

Loyal friends

My prayers upon you will be embedded in my heart wherever I go and whenever I think of you

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ACKNOWLEDGEMENT

Alhamdulillah and thank to Allah S.W.T with all gracious and merciful for giving me strength and ability to accomplish this project successfully. I would like to express my gratitude to my supervisor, Dr. Shajahan Bin Maidin whose help, stimulating suggestions, encouragement and guidance to complete this report.

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LIST OF ABBREVIATIONS, SYMBOL AND NOMENCLATURE

AD	-	Axiomatic Design
AM	-	Additive Manufacturing
QFD	-	Quality Function Deployment
HOQ	-	House of Quality
VOC	-	Voice of Customer
DPs	-	Design Parameter
FRs	-	Functional Requirements
PVs	-	Process Variable
Cs	-	Constraints
FDM	-	Fused Deposition Modeling
CAD	-	Computer Aided Design
LCD	-	Liquid Crystal Display
DSM	-	Design Structure Matrix
FF	-	Freeform Fabrication
SLA	-	Stereolithography
UV	-	Ultraviolet
SGC	-	Solid Ground Curing
SLS	-	Selective Laser Sintering
LOM	-	Laminated Object Manufacturing
RM	-	Ringgit Malaysia
RULA	-	Rapid Upper Limb Assessment
FEA	-	Finite Element Analysis

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CHAPTER 1

INTRODUCTION

This chapter introduces the project as well as briefly describes the aims, objectivesand its scope. This chapter will also provide an overview of the project'simplementation.

1.1 Introduction

This project focus on Axiomatic Design in term to identify the suitable door knob. From the existing product, this project will look at design development of a new design concept for a door knob. From the online survey that has been conducted in this project, majorities of respondents claimed have a problem when use this product. Thus, by applying axiomatic concepts might help those problems to be solved. This project proposesfour design concepts of door knob based on user reviews. After that, the analysis was performed to optimize the proposed solution.Then, a 3D solid model was made.

After that, the projectproceeds by making a prototype of the door knob by using a Fused Deposition Modeling (FDM) machine. By making the prototype, the detail and the function of the door knob can be seen and felt.

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1.2 Problem Statement

Nowadays, there are many designs of door knob on the market. Every design has it owns specifications. From the online survey that has been conducte, majorities of respondents claimed have a problem when use this product. This problem can be solved by using Axiomatic Design to find the suitable door knob to be used at home. After identifying the suitable door knob, it will be redesigned and tested to see whether it will become useful to user.

1.3 Aims

The aims of this project are to identify the suitable door knob by using Axiomatic Design and also to redesign the existing door knob to make it suitable to use and make a prototype by using the FDM machine.

1.4 Objectives

The objectives of this project are:

1. To apply the axiomatic design to an existing door knob.
2. To produce a CAD model of a new door knob design on objective number 1.
3. To make a prototype of the new door knob by using the FDM machine.

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1.5 Scope

The scope of this project focused on redesign the existing product. The AD used in this project only focussed on four domain which are customer domain, functional domain, physical domain and process domain. Study about three types of door knob which are lever type, handleset types and also knob type. SolidWork will be used to make a CAD drawing. Also make a prototype by using FDM machine called MOJO.

1.6 Project Planning

1.6.1 Gantt Chart

Table 1.1 and 1.2 shows the Gantt chart of the project. As a project planning, the monitoring of project conducted can be followed by visually graph that easy to understand. The estimated time already been stated in Gantt Chart have to be followed in order to finish the project within the period given.

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Table 1.1: Gantt chart for PSM 1

Title : Study on physical form of consumer products in product designing towards brand recognition.

STAGE	No	ACTIVITIES	MONTHLY	Sept' 2014				Oct ' 2014				Nov' 2014				Dec' 2014				Jan' 2015				Feb' 2015				Mac' 2015				Apr' 2015				May' 2015				June' 2015			
			DATE	6	13	20	27	4	11	18	25	8	15	22	29	6	13	20	27	10	17	24	31	7	14	21	28	7	14	21	28	4	11	18	25	9	16	23	30	6	13	20	27
			WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
PSM 1 STAGE	1	Propose and register project title	Plan																																								
			Actual																																								
	2	Discussion with supervisor about the project (selecting the product)	Plan																																								
			Actual																																								
	3	Find the literature review and / or related resources to the project title	Plan																																								
			Actual																																								
	4	Identify the problem statement	Plan																																								
			Actual																																								
	5	Define objective and scope	Plan																																								
			Actual																																								
	6	Write introduction (Chapter 1)	Plan																																								
			Actual																																								
	7	Presentation Chapter 1	Plan																																								
			Actual																																								
	8	Write Literature Review (Chapter 2)	Plan																																								
			Actual																																								
	9	Write methodology (Chapter 3)	Plan																																								
			Actual																																								
	10	Submit the full drafts of PSM 1 for final finishing checking	Plan																																								
			Actual																																								
	11	Submit PSM 1 Report	Plan																																								
			Actual																																								
	12	Oral Presentation Preparation with supervisors for PSM 1	Plan																																								
			Actual																																								
	13	Presentation for PSM 1	Plan																																								
			Actual																																								

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Table 1.2: Gantt Chart for PSM 2

Title : Study on physical form of consumer products in product designing towards brand recognition.																																											
STAGE	No	ACTIVITIES	MONTHLY	Sept' 2014				Oct ' 2014				Nov' 2014				Dec' 2014				Jan' 2015				Feb' 2015				Mac' 2015				Apr' 2015				May' 2015				June' 2015			
			DATE	6	13	20	27	4	11	18	25	8	15	22	29	6	13	20	27	10	17	24	31	7	14	21	28	7	14	21	28	4	11	18	25	9	16	23	30	6	13	20	27
			WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
PSM 2 STAGE	14	Product Functional & Characteristic identification (Questionnaire)	Plan																																								
			Actual																																								
	15	Distribute the questionnaire	Plan																																								
			Actual																																								
	16	Collect the data	Plan																																								
			Actual																																								
	17	Process and Manipulate the Data	Plan																																								
			Actual																																								
	18	Analysis design characteristics	Plan																																								
			Actual																																								
	19	Analyze image processing	Plan																																								
			Actual																																								
	20	Justification &analysis design profile using Mathematical Approach	Plan																																								
			Actual																																								
	21	Analyzed data using SPSS	Plan																																								
			Actual																																								
	22	Develop new design (Drawing)	Plan																																								
			Actual																																								
	23	Report writing for PSM 2	Plan																																								
			Actual																																								
	24	PSM 2 Report Review	Plan																																								
			Actual																																								
	25	Oral Presentation Preparation with supervisors for PSM 2	Plan																																								
			Actual																																								
	26	PSM 2 presentation (27 May 2015)	Plan																																								
			Actual																																								
	27	Full report submitting	Plan																																								
			Actual																																								

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction/Background

This chapter will provide a preliminary insight regarding the history of AD, AM and door knob. The basic steps in AM system, types of AD and the techniques known to the public will also be describe.

2.1 Axiomatic Design (AD)

Axiomatic design is a systems design that used matrix methods to systematically analyze the transformation of customer needs into functional requirements, design parameters, and process variables. Specifically, functional requirements (FRs) are associated to design parameters (DPs):

$$\begin{bmatrix} . \\ FR_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \end{bmatrix} \quad \text{.....(1)}$$

where:

FR = Functional requirement vector

DP = Design parameter vector

A = Design matrix that characterizes the design

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There are several term that need to know. The definitions are as follows: (Suh, 2001)

Axiom: Self-evident truth or fundamental truth for which there are no counterexamples or exemption. An axiom cannot be derived from other laws or principles of nature.

Corollary: Inference derived from axioms or from propositions that follow from axioms or from other propositions that have been proven.

Theorem: A proposition that is not self-evident but that can be proved from accepted premises or axioms and so is established as a law or principle.

Functional Requirements: Functional Requirements (FRs) are minimum set of independent requirements that completely characterizes the functional needs of the product (or software, organizations, systems, etc.) in the functional domain. By definition, each FR independent of every other FR at the time the FRs are established.

Constraints: Constraints (Cs) are bounds on acceptable solutions. There are two kinds of constraints: input constraint and system constraint. Input constraint are imposed as part of design specifications. System constraint are constraints imposed by the system in which the design solution must function.

Design parameter: Design parameters (DPs) are the key physical variable (or other equivalent terms in the case of software design, etc.) in the physical domain that characterize the design that satisfies the specified FRs.

Process variable: Process variables (PVs) are the key variables (or other equivalent term in the case of software design, etc.) in the process domain that characterize the process that can generate the specified DPs.

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The design would consists of four domains. There are the customer domain, the functional domain, the physical domain and the process domain. The domain structure is illustrated schematically in Figure 2.1.

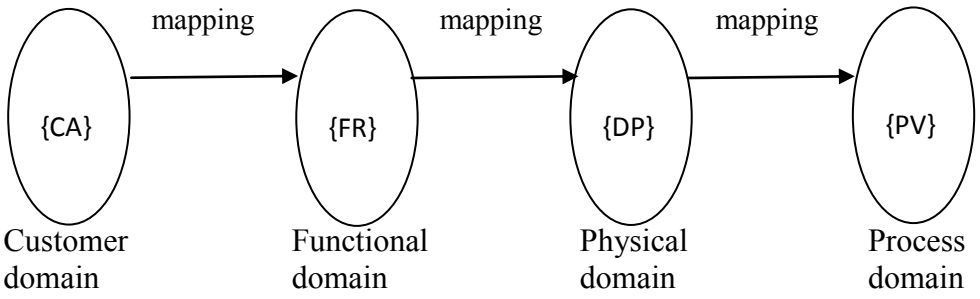

Figure 2.1: Four domain of the design world. The {x} are the characteristic vectors of each domain. The process flow from domain on the left to the domain on the right. the process is iterative means that designer can go back to the left domain based on the idea generated in right domain (Suh, 2001)

2.1.1 Types of AD

Axioms are widely used principles which are the fundamentalconcepts of this process. The first design axiom is knownas the Independence Axiom and the second axiom is known as theInformation Axiom. They are stated as follows (Suh, 1990).

1. **Axiom 1. The Independence Axiom**: Maintain the independence of functional requirements.
2. **Axiom 2. The Information Axiom**: Minimize the information content.

2.1.1.1 Independence Axiom

The Independence Axiom claims that the independence of functional requirements (FRs) must always be maintained, where FRs are defined as the minimal set of independent requirements that characterizes the design goals. Mathematically, the relationship between the FRs and design parameter(DPs) are stated as (O. Kulak, 2010):

$$\{FR\} = |A|\{DP\} \quad \text{.....(2)}$$

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2.1.1.2 Information Axiom

The Information Axiom expressed that among those designs that satisfythe Independence Axiom, the design that has the lowest information content is the best design. Information is defined interms of the information content, I_i, that is related in its uncomplicated form to the probability of satisfying the given FRs. Information content, I_i for a given FR_i is stated as follows (O. Kulak, 2010):

$$I_i = \log_2 \left(\frac{1}{p_i}\right) \text{.....(3)}$$

2.1.2 Application

There are many application that has been applied in system design, product design, software design, manufacturing system design, decision making and theoretical development and other studies.

2.1.2.1 System Design

Heo and Lee (2007) analyzed the design procedure of crisis core cooling systems in nuclear power plants simply by using independence axiom. In the previous study, the independence axiom was applied being a judge in order to improve nuclear safety. In designing the safety features of nuclear power plants, the axiom was applied to state the various responsibilities of the design strategies like independency or redundancy. Within the research, two existing emergency core cooling systems, OPR1000 (Optimized Power Reactor 1000MWe) and APR1400 (Advanced Power Reactor 14000MWe) were investigated based on the independence axiom with respect towards the defined FRs and DPs. Subsequently, the better design was decided in accordance with the independence and redundancy.

Helander (2007) proposed a way, known as design equations, for system analysis based axiomatic design. The objective of the paper was to recognize sources of couplings and propose new design guidelines that uncouple the design for human factors design. In the research, the two axioms of axiomatic design principles were used. The independence axiom was used to reduce couplings as well as complexity

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in human machine interaction. The information axiom was used to human factor design in order to consider the variability of human attributes. As the case studies, a refrigerator, hand tools and also a driver's compartment were taken towards account through the independence axiom even though the information axiom was illustrated by an adjustable workstation.

Bang and Heo (2009) introduced a new design of coolant nano-fluids since a coolant of the thermal fluid system establish on independence axiom. The design of nano-fluid system was coupled referable to the attributes of the thermal-fluid system. Within the system, the independence axiom was used to extinguish the amount of coupling of the system as it was seen that the design parameters affected each other.

2.1.2.2 Product Design

Lee and Shin (2008) produce a product design technique based on the independence axiom in order to build the design of water jet nozzle for washing TFT as well as LCD screens. Some FRs had been determined in order to limit the cleaning impact and the decoupled design was produced between FRs as well as DPs founded on the independence axiom. In the research, it was mentioned that axiomatic design with the design of experiments was efficient since it did not require any mathematical formulation of design problem.

Ferrer, Rios, and Ciur (2009) proposed a two-phase technique according to axiomatic design methodology to create a connection between design and manufacturing information. In the first stage, the independence axiom was used to evaluate and validate the design parameters which satisfied FRs and design constrains. In the second stage, the important manufacturing process detail was defined and formalized. The manufacturing detail was displayed by the concepts of process property and also process execution variable. In the second stage, manufacturing process selection was apply as well as also then, process factors and execution factors were stated and formalized. The suggested method had been utilized to a linking rod design, an internal combustion engine part.

Tang, Zhang, and Dai (2009) study the drawbacks of axiomatic design as well as design structure matrix (DSM), which were two popular design approach and

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