Faculty of Manufacturing Engineering

MANUFACTURING PROCESS SELECTION FOR PET BOTTLES USING ANALYTICAL HIERARCHY PROCESS

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MANUFACTURING PROCESS SELECTION FOR PET BOTTLES USING ANALYTICAL HIERARCHY PROCESS

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A thesis submitted
in fulfilment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

Faculty of Manufacturing Engineering

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DECLARATION

I declare that this thesis entitle "Manufacturing Process Selection for PET Bottles Using Analytical Hierarchy Process" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature	:	.....
Name	:	ADIBAH BINTI RAZALI
Date	:	06 SEPTEMBER 2013

DEDICATION

To my beloved mother Ruslah Omar, my supportive twin Arina Razali

and my siblings,

I love u all.

APPROVAL

This thesis is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering). The members of the supervisory committee are as follow:

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NURLISA LOKE BINTI ABDULLAH
PENSYARAH
JABATAN BAHASA
PUSAT BAHASA DAN PEMBANGUNAN INSAN
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ABSTRACT

This thesis discusses on manufacturing process selection of PET bottles using AHP. There are six factors to be considered which are geometry of the design, production characteristics, cost consideration, material, ease of maintenance, as well as availability of equipments and labors. The main objective of this project is to select the most appropriate manufacturing process for PET bottles based on these factors. Therefore, this study emphasizes on the usage of one of multi criteria decision making (MCDM) tools namely AHP. The AHP requires data for all factors to be used in the pairwise comparisons. Data for sub factors are widely available in handbooks. However, direct interviews by distributing questionnaires to experts in the manufacturing process for PET bottles were done to get accurate data on six main factors. From the analysis using AHP, this study reveals that the extrusion blow molding is the most appropriate process for PET bottles with a priority of 28.55%. Injection molding has a priority weight of 21.84% and then followed by blow molding (19.24%), stretch blow molding (17.52%), and lastly is injection blow molding (12.82%). After that, several sets of sensitivity analyses were performed using Expert Choice software to verify whether any small changes to each of the aforementioned factors will affect the results obtained through previous AHP analyses. Further research using different MCDM tools is recommended to enhance knowledge on this area.

ABSTRAK

Tesis ini membincangkan tentang pemilihan proses pembuatan untuk botol PET menggunakan AHP. Terdapat enam faktor yang perlu dipertimbangkan iaitu geometri reka bentuk, ciri-ciri pengeluaran, pertimbangan kos, bahan, kemudahan penyelenggaraan, serta adanya peralatan dan pekerja. Objektif utama kajian ini adalah untuk memilih proses pembuatan yang paling sesuai untuk botol PET berdasarkan faktor-faktor ini. Oleh itu, kajian ini memberi penekanan kepada penggunaan salah satu kaedah membuat keputusan pelbagai criteria kriteria (MCDM) iaitu AHP. AHP memerlukan data untuk semua faktor yang akan digunakan dalam perbandingan berpasangan. Data untuk sub-faktor banyak diperolehi melalui buku. Walau bagaimanapun, temu bual secara langsung dengan mengedarkan soal selidik kepada pakar dalam proses pembuatan untuk botol PET telah dilakukan untuk mendapatkan data yang tepat bagi enam faktor utama. Daripada analisis menggunakan AHP, kajian ini mendedahkan bahawa extrusion blow moulding adalah proses yang paling sesuai untuk botol PET dengan keutamaan 28.55%. Injection moulding mempunyai berat keutamaan 21.84% dan diikuti dengan blow moulding (19.24%), stretch blow moulding (17.52%), dan akhir sekali adalah injection blow moulding (12.82%). Selepas itu, beberapa set analisis sensitiviti telah dilakukan menggunakan perisian Expert Choice untuk mengesahkan sama ada apa-apa perubahan kecil untuk setiap faktor yang disebutkan di atas akan memberi kesan kepada keputusan yang diperolehi melalui analisis AHP sebelumnya. Penyelidikan selanjutnya menggunakan alat-alat MCDM yang berbeza adalah disyorkan untuk meningkatkan pengetahuan dalam bidang ini.

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AHP	-	Analytical Hierarchy Process
ANP	-	Analytic Network Process
APITCO	-	Andhra Pradesh Industrial and Technical Consultancy Organization
AV	-	Availability of equipments and labors
BM	-	Blow moulding
BSDA	-	British Soft Drinks Associations
CC	-	Cost consideration
CES	-	Cambridge Engineering Selector
CI	-	Consistency Index
CR	-	Consistency Ratio
DC	-	Design complexity
EBM	-	Extrusion blow moulding
EC	-	Equipment cost
EM	-	Ease of maintenance
GD	-	Geometry of the design
IBM	-	Injection blow moulding
ILSI	-	International Life Science Institute
IM	-	Injection moulding
LC	-	Labor cost
MAUT	-	Multi Attribute Utility Theory
MAVT	-	Multi Attribute Value Theory
MCDM	-	Multi criteria decision making
MT	-	Material
NAPCOR	-	National Association for PET Container Resources
PC	-	Production characteristics
PET	-	Polyethylene Terephtalate
PQ	-	Production quantity
PT	-	Processing times
RI	-	Random index

SBM	-	Stretch blow moulding
SF	-	Surface finish
SH	-	Shape
SZ	-	Size
TC	-	Tooling cost
TR	-	Tolerance
WG	-	Weight
WT	-	Wall thickness

CHAPTER 1

INTRODUCTION

This chapter explains the project background, problem statement, objectives, scopes and limitations as well as significance of the study.

1.1 Project Background

Murthy et al. (2008) defines a new product development goes through a multi-stage process which involves interaction between creativity and management of the process and the varying needs of potential consumers for the new product. The high cost investment and unpredictable results of this process has substantial impacts to the profits generated for a manufacturing business. It has been mentioned that 25% of the sales are represented by products which are five years old and below.

The new product development programmes often fail due to project related or technical problems. Project related which refers to the cost and time often exceed the constraints imposed to the products whereby these products are failed to be introduced to the market before competitors do. There are also cases in which the new products are successfully introduced in the market but ultimately failed due to commercial factors such as poor sales, lower revenue, and others (Murthy et al., 2008). They reported that insufficient market analysis, product problems or defects, and high costs are the key factors that lead to products failure.

Problems or defects presented with the products are directly related to manufacturing process involved. Products with defects need to be reworked or even worse, they need to be discarded for not meeting specifications because these problems will increase the manufacturing costs and time prior to the marketing of these products. All of these problems can cause losses in the manufacturing business. Therefore, there is a need to conduct manufacturing process selections as early as possible in the new product development. Besides, they also need to adopt concurrent engineering during whereby different stages run simultaneously. This will help in reducing product development time and time to market.

In this study, plastic bottles are selected to illustrate this concern. Seven types of plastics are used to make bottles; namely polyethylene terephthalate (PET), high density polyethylene (HDPE), vinyl or polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), and other mixed resins. However, out of these seven materials, PET is typically used to produce bottles (Gotro, 2011). This project will concentrate particularly on PET bottles.

Manufacturing process selection in this study is an activity which can be influenced by many factors. There are geometry of the design, production characteristics, cost considerations, material, ease of maintenance, as well as the availability of equipments and labours. As the selection is governed by many factors, it is not an easy task to be performed. Hence, multi criteria decision making tools are applied in manufacturing processes selections.

This project utilizes AHP, one of the useful tools to select the best alternative process of PET bottles manufacturing process. AHP was developed by Thomas L. Saaty in 1980s and now it has become as one of the most frequently used tools for multi criteria decision making process. It simplifies the complex decision making process and thus reduces the time needed for manufacturing process selection. Analysis using AHP is better than using another tool as it models the problem in the form of a hierarchy structure which represents a relationship between each element to an overall goal. Therefore, it helps decision makers to find alternative solutions that best suit their objectives.

1.2 Problem Statement

The rapid growth of manufacturing industries from time to time is causing intense competition between them (Swift and Booker, 2003). Manufacturing businesses are competing with each other to provide higher quality products and cheaper manufacturing cost per unit. Besides, customers' demands for some products which keep rising have urged manufacturers to seek alternatives that can reduce the time to manufacture products. This situation has become a great challenge for new products (Swift and Booker, 2003).

Both quality and cost are essential to be taken into consideration from the beginning of the development process of the product. The quality of any product is characterized by its conformity with respect to design specifications and requirements. According to Booker and Swift (2001), the cost of quality is estimated to be 20% of companies' total turnover. Products' failure during manufacturing or usage by customers is the dominant portion out of aforementioned percentage. Failure of products may result from rework and scrap which will reflect company's losses.

As products' quality is closely related to manufacturing, the selection of manufacturing process is a crucial activity to be carried out at the early stage of product

development (Esawi and Ashby, 2000). According to Hollins and Pugh (1990), the conceptual design stage is one of the early stages in the product development process. The success of a new product introduction is highly depending on the steps or activities performed at this stage.

However, Krishnakumar (2003) mentions that manufacturing process selection is one of the most often performed processes during a detail design stage instead of during the conceptual design stage. This process is not appropriate to be performed during detail design stage due to constraints imposed to products. Redesigning the products will increase the time and costs in manufacturing. Therefore, the most appropriate process needs to be identified as early as possible to maintain a lower manufacturing costs (Ashby, 1999). Anyhow, it is hard to be realized due to many factors influencing the selection.

Until now, various methods and techniques have been developed for manufacturing process selection. One of the famous methods was introduced by Ashby (2004) consists of four steps; translating, screening, ranking, and documenting. These steps are adopted in the manufacturing process selection until the best process is identified. This approach also used concurrently with the Cambridge Engineering Selector (CES) software. Swift and Booker (2003) have developed Process Information Maps (PRIMAs) software which is similar to CES.

However, these methods do not distinguish the strengths and weaknesses each of these processes. Multi criteria decision making (MCDM) tools can be employed to reduce this problem. MCDM tools are categorized into two; the first one accepts qualitative inputs and it performs based on the decision maker's own judgment while the second one is for both qualitative and quantitative inputs (Tam et al., 2007). One of the tools in the first category, Analytical Hierarchy Process (AHP) is suitable to be used in this study as own preferences are used. Currently, there is no study discusses about the manufacturing

process selection using AHP. Thus, this project intends to apply AHP in the manufacturing process selection which can be beneficial to manufacturing engineers to determine the most appropriate manufacturing process for PET bottles.

1.3 Objectives

The main goal of this project is to perform manufacturing process selection for PET bottles using Analytical Hierarchy Process (AHP). In order to achieve this aim, this study is conducted based on these specific objectives:

i. To identify the factors and sub-factors that influence the selection.

ii. To conduct sensitivity analysis to verify decisions.

1.4 Scope and Limitations

This study is carried out within the following limits:

i. Utilization of AHP for solving multi criteria manufacturing process selection.

ii. Selection process in this project is specifically demonstrated for PET bottles.

iii. Sensitivity analyses are performed using Expert Choice software.