UNIVERSITI PUTRA MALAYSIA

REDUCING PRODUCTION LEAD TIME THROUGH VALUE STREAM MAPPING APPROACH

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FK 2008 90

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MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

OCTOBER 2008

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

REDUCING PRODUCTION LEAD TIME THROUGH VALUE STREAM MAPPING APPROACH

By

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October 2008

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The plastic injection molding has been widely used in the manufacturing industry due to its advance improvement in producing complex net shaped parts. However, there is still lack of efforts in the concept of early cost estimation on mold and most of the injection molders do not have adequate mechanisms to rapidly estimating the mold cost. This paper addresses the development of a method in estimating the cost of a plastic injection mold at the early stages of design. In this research, an early cost estimation formula for plastic injection mold had been developed from the ten sets of historical data of existing injection molds. This estimation formula had been tested with another four sets of molding part to check for its feasibility study. These all sample sets of injection molds were from a variety of part sizes and complexity designs from a local injection moldmaker. All tested molding parts were selected from the mold type of two-plate with cold runner system. The mold cost formula was derived from the part's envelope volume, number of part dimensions, number of part actuators and part's dimension tolerance as the mold cost independent variables. The strength of the relationships between the mold cost and its independent variables were investigated by using the statistical linear regression analysis. The results of analysis indicated that the number of part dimensions has the highest significant correlation with the mold cost, followed by the part's envelope volume and then the number of part actuators, while the variable of dimension tolerance did not show a significant correlation to the mold cost.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGURANGAN JANGKA MASA PENGHASILAN MELALUI KAEDAH PEMETAAN ALIRAN NILAI

Oleh

YAP AI KIN

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Acuan suntikan plastik telah semakin luas digunakan dalam industri pembuatan. Ini disebabkan perkembangannya yang pesat dalam penghasilan produk yang kompleks dan bentuk bersih. Walau bagaimanapun, konsep anggaran awalan kos pada acuan masih kurang dalam usaha dan kebanyakan pembuat acuan tidak mempunyai mekanism yang sesuai untuk menganggar kos acuan dengan cepat. Kertas ini akan membentangkan satu pembangunan kaedah untuk anggaran kos acuan suntikan plastik pada awalan langkah rekabentuk. Dalam penyelidikan ini, satu formula anggaran awalan kos untuk acuan suntikan plastik telah dibentukkan dari sepuluh set data sejarah kos acuan suntikan yang sedia ada dan formula anggaran ini telah diuji kebolehlaksanaannya dengan empat set produk pengacuan yang lain yang diperolehi daripada pembuat acuan tempatan. Set-set data sampel ini adalah terdiri dari pelbagai jenis saiz produk dan kekompleksan rekabentuk. Produk pengacuan yang telah diuji adalah dipilih dari jenis acuan 2-plat dengan sistem pelari sejuk. Formula kos acuan ini diterbit dari liputan isipadu produk,

bilangan dimensi produk, bilangan penggerak produk dan had-terima dimensi sebagai kos acuan pembolehubah tak bersandar. Kekuatan hubungan antara kos acuan dengan pembolehubah tak bersandarnya dikaji dengan menggunakan analisis regresi lelurus statistik. Keputusan analisa ini menunjukkan bilangan dimensi untuk produk mempunyai korelasi bererti yang paling tinggi dengan kos acuan, diikuti dengan liputan isipadu dan bilangan penggerak, sementara pembolehubah had-terima dimensi tidak menunjukkan korelasi bererti dengan kos acuan.

ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude to the chairman of the supervisory committee, Dr. Tang Sai Hong for his invaluable supervision, guidance and comments throughout the duration of my research project. I would also like to thank the member of the supervisory committee, Associate Professor Dr. Datin Napsiah Ismail for her guidance and patience.

Not forgetting to thank Mr. Khoo from STS Mould-Tech Sdn. Bhd. who has permitted their products to be used as specimens in this research. I am thankful to his assistant, Mr. Jeffrey, who has extended his assistance and precious time in preparing the information data for me in this research as well as for the second mold maker, Sun Tech Sdn. Bhd. for their evaluation samples. Without their collaborations, I would not be able to complete my research.

In addition, I also would like to express my appreciation to my college, especially my superior, Tuan Haji Mesran and all the staffs at KUALA LUMPUR INFRASTRUCTURE UNIVERSITY COLLEGE (KLIUC) for their understanding and encouragement all this while in completing my degree in Master of Science.

I am most grateful to Yayasan Kedah for their support in the form of study loan that has greatly reduced my financial burden so that I can concentrate fully on my studies. Last but not least, I am also indebted to my beloved family and husband, Yong Chin Keong for their patience and concern during the years of my study.

I certify that a Thesis Examination Committee has met on 30th October 2008 to conduct the final examination of Yap Ai Kin on her Master of Science thesis entitled "Reducing Production Lead Time Through Value Stream Mapping Approach" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institution.

(YAP AI KIN)

Date:

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LIST OF ABBREVIATIONS/SYMBOLS

d	Number of dimensions for a single cavity part
a	Number of actuators for a single cavity part
v	Envelope volume for a single cavity part in mm^3
n	Number of cavities
C_{Mold}	Estimated mold cost in RM k
TEV	Total envelope volume for n cavities parts in cm^3
TPD	Total number of dimensions for n cavities parts
TPA	Total number of actuators for n cavities parts
HT	High dimension tolerance
HF	High surface finishing
β	Regression coefficients
ρ	Observed significance level
R	Multiple correlation coefficient
R^2	Multiple determination coefficient
R^2_{adj}	Adjusted R^2
Bhn	Brinell hardness number

CHAPTER 1

INTRODUCTION

1.0 Background of the Study

Nowadays the market trends and demands have changed towards a higher quality, shorter delivery time and lower product cost. An understanding about the elements to make up of a product cost has become more vital due to the competitive nature between global companies. Generally, for most products and designs, cost becomes an important concern in the early stage of development.

To be competitive, it is necessary to keep the initial cost as low as possible, as well as to minimize the time-to-market in order to reach the maximization of profits. Studies have shown that the greatest potential for cost reduction is at the early design stages, where as much as 80% of the cost of a product is decided (Rehman, 1998; Geiger, 1998; Weustink et al., 2000). Consequently, after the design process has been completed, most opportunities of cost reduction have passed. Therefore, it is necessary to understand the cost consequences of decisions during the planning phases of the product development cycle. In these planning phases, many decisions have to be taken into consideration. The engineers often need to consider a design alternative for design-to-cost in order to make cost effective decisions in the product design process as well as to speed up the design process planning and cost estimating activities. In the quotation preparation, cost estimation is a critical activity that directly affects quotation acceptability and profitability (Ni et al., 2007). Generally, this research is intended to develop an approach to estimate cost in the early design stage by defining the economical method in manufacturing a product.

Plastic injection molding has been recognized as an important industrial manufacturing process in conjunction with the extensive usage of a wide range of complex net shaped plastic products, principally from domestic electronics and electrical products to machineries, cars and airplanes. Due to an intense competitive market, the engineers always need to be able to estimate the cost of a mold based on the customer's given part's blueprint or sample with some basic tooling information, for example, number of cavities and mold production cycle life to generate a quotation in a short period of time.

Injection molding is a process in which a polymer is heated to a highly molten state and forced to flow under high pressure into a set of completed tools namely injection mold, where it shapes and then cools the melted plastic that is injected into it. The molded part, called a molding, is then removed from the mold cavity. Injection mold is generally constructed by two main parts that are made of tool steels, that is mold cavities and mold base. The mold cavities are machined out from small blocks of tool steels, hardened and inserted into a standard mold base. For moldmaker companies wishing to maintain the competitive edge in the global markets, it becomes necessary to compromise the priority tooling requirements as minimum cost, shorter lead-time and better quality with customers (Nagahanumaiah et al., 2008; Rahmati and Dickens, 2007).

1.1 Problem Statements

Even though the concepts of early cost estimation in the product design phase have been recognized in the last two decades of the 20^{th} century, there are still lack of efficiency due to the traditional cost estimation system do not have adequate mechanism to provide engineers with a rapid cost feedback on a proposed new product. The traditional cost estimation approaches are primarily based on cost similarity have limited capabilities for accurate estimation of mold cost (Nagahanumaiah et al., 2008). Most customers will have the behavior to seek for alternative designs in estimating the cost of project until their satisfactions are achieved. This can cause lots of inconveniency to the engineers because the redesigning process is very costly and time consuming. Normally, engineers will base on their experiences to estimate the cost of project in order to meet the customer requirements.

Many researches had been studied on the cost of injection mold in the past. However, the researches made are insufficient for practical use and needs improvement. The research from Dixon and Poli (1995), which estimates the relative tooling cost of an injection molded part by referring relatively to a tooling cost for a simple reference part, has encountered many difficulties particularly the lack of information and the rough design descriptions found in the look-up table for the attributes of part's complexity. Whereas Boothroyd et al. (1994) used the total estimated manufacturing times for a finished mold multiplying with an average mold shop hourly rate to get the estimated tooling cost. The manufacturing time is difficult to be defined accurately in the early design stage due to the different types and advance levels of machine used. Even though Fagade and Kazmer's (2000) have come out with a better empirical approach to estimate a tooling cost, however, their empirical formulas derived from multiple regression analysis in late 20th century may not suitable to apply in today's local market due to the increasing global price of steel and different resource regions.

The accuracy of the cost estimation is crucial to a company. Any of underestimation and overestimation may bring loss to the company if awarded or lost in the bidding for the job. Presently, the cost estimation is carried out mainly based on experience or historical cost data, which compares the part to one made in the past, making due allowance for the differences that could lead to inaccurate and inconsistent estimation (Fuh et al., 2004). Obviously, a quick and systematic early cost estimation tool is needed for both mold quotation and design engineers so that they can easily make faster and more accurate cost estimation relatively to their design-decisions. An updated mold data is needed to be re-collected to suit the present local market as well.

1.2 Objectives

The objectives of this research are:

i) To develop a mathematical model at the early stages of plastic injection mold tooling design based on the analysis of historical mold designs and cost data from a local injection moldmaker company.

ii) To identify the main cost factors for a plastic injection mold and their relative importance relationships in the mold cost by using regression analysis.

1.3 Scope of Study

The scope of this thesis is confined to the establishment of a linear cost estimation function for a two-plate mold with cold runner systems of local plastic injection mold with a maximum of two cavities. The way to carry out this study is to build an empirical model relative to the dependent (criterion) and independent (predictor) variables based on 10 sets of existing finish mold costs and designs. These 10 sets of data are collected from a wide range of plastic part sizes and complexity from a designated local moldmaker. Multiple linear regression analysis is the best statistical technique to be used in manipulating the empirical model. A well known computer software program, known as SPSS is used in fitting the multiple regression model as well as defining the parameter quantities that reflects the importance of information about the regression models.

1.4 Overview of the Thesis

The layout of this thesis is divided into five chapters. The first chapter is the introductory section of the research with its descriptions on the problem statements and the research objective. In addition, the scope of thesis also is well explained. The second chapter cites the relevant literature reviews from previous researchers as well as the theories and the hypotheses tested in the research.

Chapter three is to describe the methodology used for this research. This includes the initial stage of the research design and planning, the data preparatory stage and data analysis with using SPSS. The data preparatory stage consists of the selection of research sample, data collection from hardcopy of drawings and lastly the data recording into a proper table. After all data has been keyed into the SPSS program, the statistical regression analysis is performed with undertaking a few hypothesis tests to examine the feasibility of the research results.

All outputs generated from the SPSS analysis will be clearly defined in an orderly fashion in chapter 4 with appropriate plots and tables. The finding of the outcomes are interpreted and discussed to validate the objective stated in this study. Chapter 5 is about the conclusions reviewed and the important observations gained from this research study. Recommendations to improve the research's gaps are also proposed for future researches.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The acknowledgement of the importance of early cost estimation for a product is slowly being recognized in most fields to compete in the basis of cost leadership marketplace for producing high-functioning and low-cost designs.

However, all too often, the industrial past practice in product cost estimation is to wait for a complete cost analysis in a detail phase derived from the various cost components such as material cost, machining cost, labor cost, administration and engineering cost. If the product cost was proven to be excessive, they will try to wring the excess cost out of the manufacturing process or to substitute a less expensive material, which is usually at the expense of quality. Therefore, a fairly accurate estimation cost in the early design stage is essential not only for saving product cost but also to improve productivity and product quality if changes to the product were made in the early stage.

2.1 Principal Types of Injection Mold

There are two main types of injection mold, that is, a cold runner injection mold which can be divided to two plate and three plate designs, and a hot runner injection mold which is also known as the runnerless mold. A runner is the channel in the mold that conveys the melted plastic from the barrel of the injection molding machine to the part. The significant difference between these two types of mold is the presence of a runner system (sprue and runner) with molded part in the cold runner mold. A cold runner mold type is very simple and much cheaper than a hot runner system. This is because of the cold runner mold requires less maintenance and less skill to set up and operate.

2.1.1 Cold Runner Molds

The two plate is the simplest type of mold. It is called a two plate mold because there is one parting plane and the mold splits into two halves, one half reams on the injection side containing the plastic part, runner system, cavity cooling system while the moving half containing core cooling system and ejector pins, mounted with the machine clamp as shown in Figure 2.1. A simple part with large gate is usually molded in a two plate mold. Sometimes it is also needed for a low activity and less expensive mold that is less than 10,000 per year. A disadvantage of the two plate mold is that the molded parts remain attached to the runner systems. Thus, a post molding operation is needed to exert in order to trim off the runner system.

A three plate mold differs from a two plate in that it has two parting planes, and the mold splits into three sections every time the part is ejected. Since the mold has two parting planes, the runner system can be located on one, and the part on the other. Generally, the three plate mold separates the molded part from its runner system automatically when the mold opens as shown in Figure 2.2. Three plate molds are used because of their flexibility in gating location. It is normally used for multi-cavity molding parts.

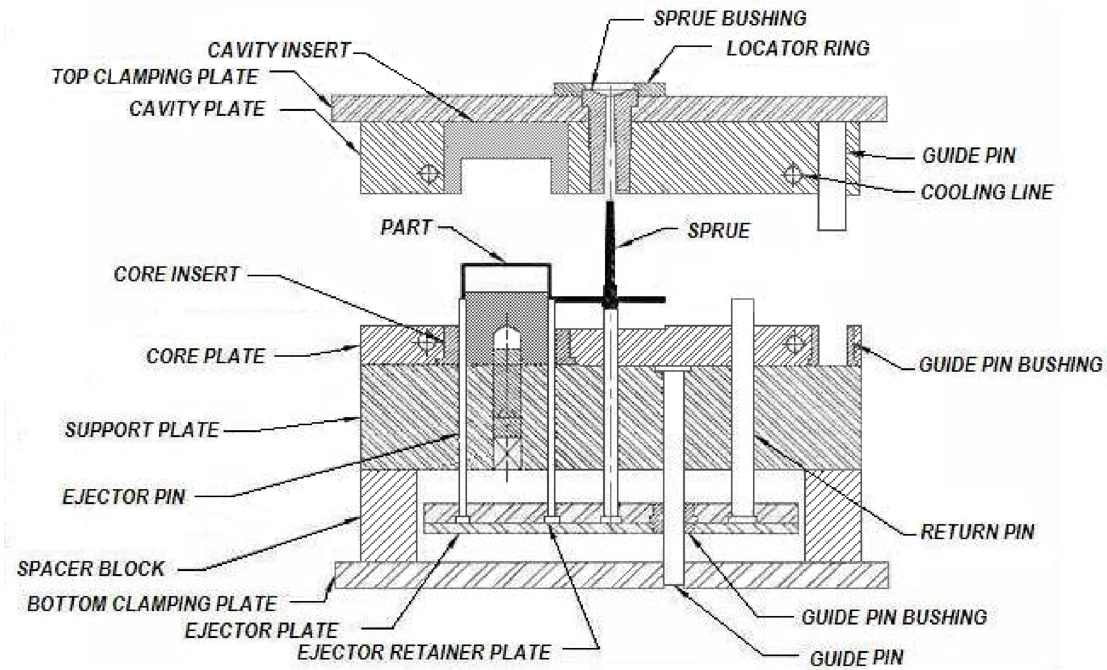

Figure 2.1: A Two Plate Cold Runner Mold (KenPlas Industry Ltd.)

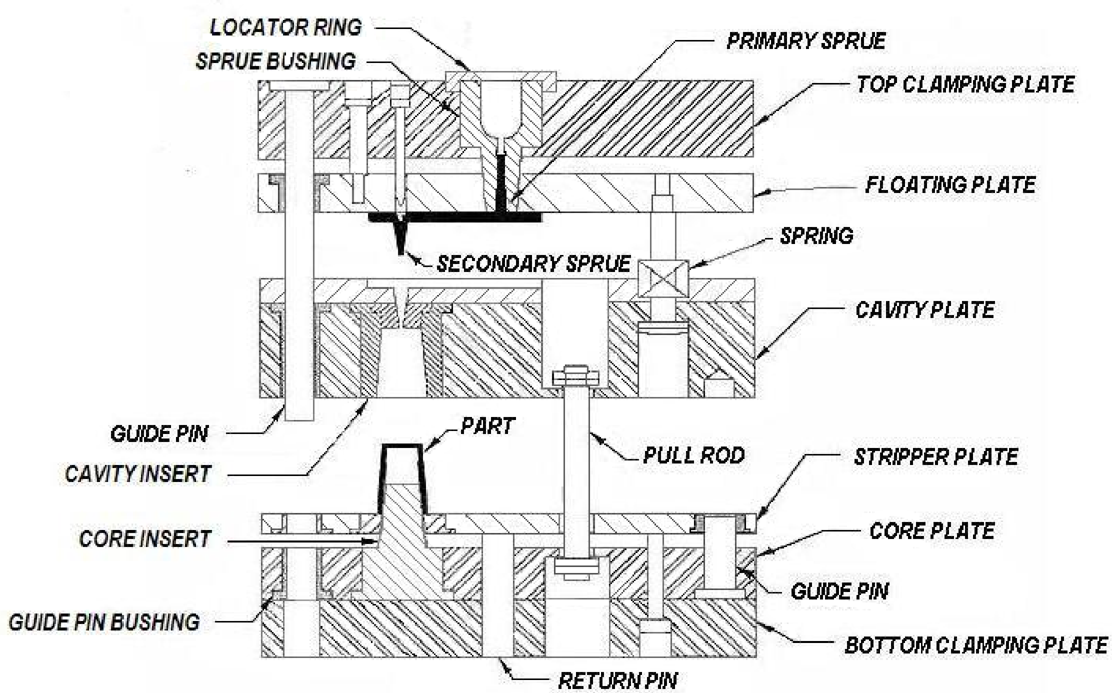

Figure 2.2: A Three Plate Cold Runner Mold (KenPlas Industry Ltd.)