INVESTIGATION OF MACHINING COST MODELLING BASED ON PRODUCT DRAWING

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

by

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I hereby, declared this report entitled “Investigation of Machining Cost Modelling Based on Product Drawing” is the result of my own research except as cited in reference.

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Date : 26/6/2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons). The member of supervisory committee are as follow:

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(ASSOCIATED PROFESSOR DR. MD. NIZAM BIN ABDUL RAHMAN)

ABSTRAK

Perkembangan semasa teknologi ICT di era ini membolehkan paradigma pembuatan baru dikenali sebagai *Cloud Manufacturing* (CM). Fleksibel dan dinamik adalah aspek penting untuk masa depan dalam proses pembuatan untuk memenuhi tuntutan pelanggan, contohnya dalam siri pengeluaran yang besar. CM membolehkan pembuatan sebagai perkhidmatan agar pemilik produk dapat memenuhi permintaan pelanggan menggunakan sumber modal yang ada di serata dunia tanpa membuat pelaburan modal. Salah satu elemen penting dalam CM adalah keupayaan untuk dipadankan antara keperluan pemilik produk dan keupayaan penyedia sumber fizikal serta-merta. Ini termasuk harga dan sebut harga. Keupayaan untuk memberikan sebut harga berdasarkan lukisan dan spesifikasi produk masih merupakan jurang dalam CM. Tiada parameter piawai dalam model anggaran harga pemesinan. Kajian ini bertujuan untuk membina model pemesinan mengikut faktor penting yang perlu dipertimbangkan berdasarkan lukisan produk. Model ini dihasilkan berdasarkan kesusasteraan yang ada dalam bidang pengetahuan ini. Model yang ini telah disahkan menggunakan kajian kes bagi suatu produk yang akan dibuat menggunakan CNC Makino F5 3-axis. Kos pemesinan produk dikira dan dibandingkan dengan petikan yang diperolehi daripada pembekal perkhidmatan pemesinan. Satu sampel Ujian T telah dilakukan untuk membandingkan kos yang dikira menggunakan model yang dicadangkan untuk petikan harga pemesinan. Model kos pemesinan yang dihasilkan terdiri daripada beberapa komponen kos. Komponen kos ini adalah penggunaan elektrik, penggunaan penyejuk, penggunaan minyak pelincir, penggunaan alat, kos mesin dan kos buruh. Produk untuk kajian kes ini dimodelkan menggunakan Perisian Catia V5. Waktu pemesinan dianggarkan menggunakan simulasi CAM. Berdasarkan model yang dicadangkan, kos pemesinan adalah RM87.15. Kos yang dikira ini dibandingkan dengan tujuh petikan yang diterima daripada penyedia perkhidmatan pemesinan dengan menggunakan satu kaedah Ujian t-sampel. Nilai ujian ialah 0.181. Ini menunjukkan bahawa, kos yang dikira secara statistik adalah dalam lingkungan petikan yang diterima dengan 95% selang keyakinan.

ABSTRACT

Current developments of ICT technologies in this era enables a new manufacturing paradigm known as Cloud Manufacturing (CM). Flexible and dynamic are the important aspects for the future in manufacturing processes in order to cater to customer demands, for example in a large series of production or mass customization. CM enables manufacturing as a service concept so that product owner can fulfil customer demand using available capital resources around the world without having to make a capital investment. One of the important elements to enable CM is the ability to match between product owner requirement and physical resource provider's capabilities instantaneously. This, include the pricing and quotation. Ability to provide instantaneous quotation based on product drawing and specification is still a gap in CM environment. There is also no standard parameters or factors set to be considered in the machining cost estimation model. This study aims to establish a machining cost model according to the important factors that should be considered which based on the product drawing. The model was developed based on the available literature in this body of knowledge. The proposed model was validated using a case-study of a product to be fabricated using CNC Makino F5 3-axis vertical machining centre. The machining cost of the product was calculated and compared to the quotations obtained from the machining service providers. One sample t-Test was performed to compare the cost calculated using the proposed models to the machining cost quotations. The developed machining cost model consists of few cost components. These cost components are electrical consumption, coolant usage, lubricant oil usage, tools usage, machine cost and labour cost. The product for this case study was modelled using Catia V5 Software. The machining time was estimated using CAM simulation. Based on the proposed model the machining cost is RM87.15. This calculated cost was compared to the seven quotations received from machining service providers using one sample t-Test method. The p-value of the test is 0.181. This implied that, statistically the calculated cost is within the range of quotations received with 95% CI.

DEDICATION

Only

my beloved father, Pahorudin Bin Hj Latif

my appreciated mother, Jamaliah Binti Sallehuddin

my adored brothers and sisters, Awi, Adib, Asri, Asrul, Norizan, Norliah and Anuar

For giving me moral support, money, cooperation,

encouragement and also understandings.

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LIST OF ABBREVIATIONS

ABC	-	Activity-based Costing
ACO	-	Ant Colony Optimization
ATC	-	Automatic Tool Changer
BO’s	-	Business Orders
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CM	-	Cloud Manufacturing
CMM	-	Coordinate Measuring Machine
CI	-	Confidence Interval
COM	-	Cost of Machining
ICT	-	Information and Communication Technology
NC	-	Numerical Control
NPD	-	New Product Development
PRPs	-	Physical Resource Provider
RPM	-	Revolution per Minute
TDABC	-	Time-driven activity-based costing
TNB	-	TENAGA NASIONAL BERHAD
UFT	-	Unified Feature Technology

CHAPTER 1
INTRODUCTION

Chapter 1 provides a concise introduction of the study. The introduction begins with a background of the study that explains briefly on the information related to the context of the study. Next, a problem statement is presented to explain the current problem that being subjected by this study. Then, the objectives and scope are state. Finally, at the end of this chapter, the significance of this study is explained.

1.1 Background of Study

Manufacturing paradigm emerged over time, driven by current developments in this era, including new ICT technologies and new theories. The manufacturing processes in the future need to be more flexible and dynamic in order to map customer demands, for example in large series of production or mass customization. Therefore, a proper action need to be take into account so that the demands can be met and improve the productivity. The product that have been made and created is produced by various manufacturing companies. Indirectly, this companies will not only involve in part sequential and long-term supply chain but also involve in extensive networks that require agile collaboration between partners.

In cloud manufacturing, emerging technologies like Internet of Things, cloud computing and service-oriented technologies are joined together for complex problems solving in manufacturing application (Siderska, J., and Jadaan, K. S. 2018). Mainly, the objective of cloud manufacturing is to offer manufacturing as a service. In order to accomplish manufacturing as a service, matching process between users and the physical

resource providers need to be automated. This is because, its need to be done instantaneously. Therefore, the gaps identified is for instantaneous quotation based on drawing and specification of the product.

According to Li *et al*. (2011) stated that cloud manufacturing as a new networked manufacturing paradigm that organizes manufacturing resources over networks (manufacturing clouds) according to consumer's needs and requirements to provide a variety of on-demand manufacturing services via networks such as Internet and cloud manufacturing act as a service platforms. In this service platform (cloud manufacturing), it will gain and gathers all the information and data from the user and physicals resource provider which is the owner of manufacturing resources via the network connection. Next, the process of meet up the requirements of the user to the potential availability of the PRPs to run the process that need to be done for fabrication of product.

In order for cloud manufacturing to be run successfully, there are several requirements for ideal cloud manufacturing environments. Firstly, there are three main groups of people in this CM which are user/customer, cloud-based application provider and physical resources providers. The role of application provider is to interpret the product engineering requirements from the customer. Then, determine the production planning and process sequencing of product fabrication. Finally, match and locate the required resources among the physical resource provider. The PRP's are the groups of the manufacturing owners whose know-how and experience to utilize those resources efficiently and effectively. They also provide relevant capability and capacity information in real time. Eventually, physical part will be manufactured as per user requirement and ship it to user.

Cavalieri et al. identifies (as cited in Dai and Balabani, 2006) that there are three ways on estimating cost of product which are analogy based, parametric and engineering approaches. Each of these approach have its own advantages and disadvantages. All these approach are considered as classical approaches for cost estimation activity. Unfortunately, each of these approach is matched to different stage that involved in NPD process, given there is a dissimilar degree of analyticity and also the amount needed of input data.

1.2 Problem Statement

Michele Germani *et al*. (2011) found that features based of the 3D CAD models have useful data to do cost estimation but, many researches on feature recognition and extraction, there is still no cost estimation software system can give reliable result. There is no system that able to come out with a good estimation of machining cost from the product drawing or at early design stage of the product. Besides, there is also no standard features or parameters set to be included in order to develop costing model for machining operation. Most of the research on manufacturing cost actually focussing on the development of cost of the product only, it does not look into the high volume manufacturing of the product. Due to that, a machining cost modelling need to be develop to ease cost estimation of product at early stage.

1.3 Objective

The objectives of this report are:

i) To identify the important parameters to be included in machining cost model.
ii) To develop machining cost model for given product drawing.

1.4 Scope

This study focus on the development of machining cost model in CNC milling operation. This modelling will be based on the parameters that is involved in machining operation but does not include the material cost. The material of product used for this model is Aluminium 6061 T6 Standard which commonly used in industry. Basically, there are two types of techniques that can be apply for the costing model which are qualitative and quantitative techniques. In this study, a quantitative technique is used to create the machining cost model. The study involves statistical analysis in order to validate the proposed machining cost modelling to the actual cost quoted by manufacturing industries using one sample t-Test method.

1.5 Important of Study

This study will bring multiple impacts, especially to the industry company. The costing model that been developed can be an alternative to interpret the given product drawing from the customer into the estimation of the machining cost of the product. On the other hand, the presence of machining cost model will help to control the cost, bidding for successful jobs and retain a competitive position in the marketplace.

1.6 Organization of Report

Chapter 1 comprises a brief introduction of the on-going research that is being done in Universiti Teknikal Malaysia Melaka (UTeM) about the Investigation of Machining Cost Modelling Based on Product Drawing. The problem statement of the research is stated in order to definite the objectives of the current study. The scope of the study covers the research work done to encounter these objectives.

Chapter 2 is about literature review. It consists of important information on the estimation of product and machining cost in the manufacturing industry. The published studies on cost estimation for product and machining offered a powerful and helpful reference for researchers to conduct the study. Furthermore, it also consists of reviews of methodologies and approaches that strengthen the persuasiveness of researcher to validate the research.

Chapter 3 is about methodology. This chapter focuses on the method of how to create the model for the machining cost operation. Parameters that need to be considered during the development of the model will be introduced in this chapter. On the other hand, the comparison between the types applied for costing approach is analysed. Hence, the machining cost model is develop and the drawing of a product is drawn using Catia V5 software.

Chapter 4 is the discussion and result. In this particular chapter, the result gained by using the model proposed in the methodology is discussed. The result with respect to the objectives that been set are described on how the objectives are accomplished.

Chapter 5 is the conclusion for the entire project. The conclusion, recommendations for future study, sustainability and complexity element throughout the project are discussed in the end of this chapter.

CHAPTER 2
LITERATURE REVIEW

In this chapter, a review of previous studies related to this area has been done. A summary of information research from journals, articles, books and related website is gathered and presented. It is used to support the discussion on the current issue, research objectives, and the methodology used.

2.1 Costing Requirement in Cloud Manufacturing Environment

Generally, the cloud manufacturing act as a platform to assists in achieving the variety of manufacturing resources. Besides, it also provide the multi-grained resource sharing. Cloud manufacturing environment able to help in developing a machining cost model for various manufacturing processes in a CM environment, the standardization on physical requirement provider (PRP's) and input variables are required. A specific common variables need to be identified in order to get the specific values of the variables. Therefore, the users and PRP's able to analyse and specified these values and it will be the inputs to the costing model.

Wei Peng et al. (2017) found that the participation of the user in the CMfg system services closely related to service prices. As a result of enhancement of the service resources, it involved highly price-sensitive. A model called game-theory based framework is applied for dynamic problem in pricing for manufacturing supply chain that consist of service provider, broker agent and service demander.

Wei and Liu (2015) provided assistance here by introduced the allocation of the resource in CM environment so that optimal dynamic resource service provision can be achieved. A modified ant colony optimization (ACO) algorithm is used to allocate the resources.

Basically, there are three step involves in whole process of allocation of the resources in the CM. The first step is identification of the scope of manufacturing resources. The second step is proceed with the primary selection in a subjective way whereby an indicator system is created according to the user ratings on the resources in terms of cost, time, reliability and so on. The last step is by further the optimal allocation of the resources for the cloud manufacturing.

2.2 Product Cost Estimation

Product costing is one of the crucial element that needs to be analysed at the early stage in the manufacturing industry. There is a research result that shows approximately over 70% of the production cost of a product is been decided during the conceptual design stage but only 6% of the total development comes from the design phase. Thus, in optimising of the product costs, the design cost is one of the important steps to be done. Generally, cost estimating can be classified into the parametric approach, intuitive, analogical models, and analytical models. According to Shehab and Abdalla (2002), an analytical approach is the most accurate way for cost estimating.

Wei and Egbelu (2000) study (as cited in Shehab and Abdalla, 2002) found that development of a framework of AND/OR tree is to represent an alternative process for estimating the lowest manufacturing cost of the product. In this framework, it only focused on the processing and material handling costs rather than others direct product cost, for example, labour cost, setup cost and also material cost.

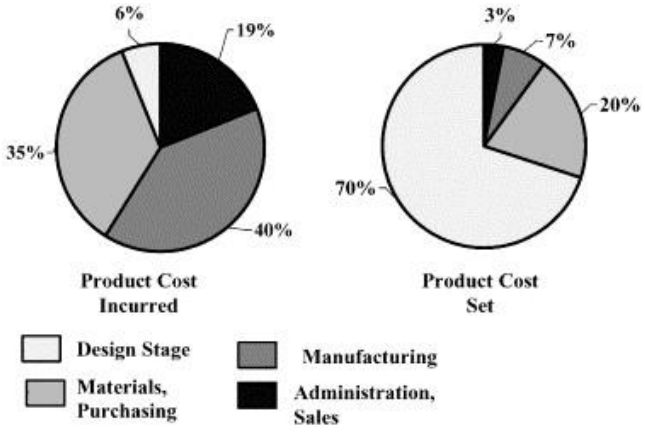

Figure 2.1: Product cost incurred and product cost set in the different phase (Shehab and Abdalla, 2001).

Product cost can be described by developing a methodology of manufacturing cost modelling during the design phase of the product lifecycle (Rehman and Guenov, 1998). This system involves advanced artificial intelligence architecture which is linking the knowledge of design and manufacturing. For example, the blackboard framework, that is used for problem-solving. Unfortunately, this model is not able to provide an accurate manufacturing cost because the manufacturing cost estimates without including the process planning.

Cavalieri et al. (2004) found that there are three approaches to cost estimation techniques which are analogy-based approach, parametric approach and engineering approach. According to Dai and Balabani (2006), product cost estimation can be categorized into qualitative and quantitative technique. The qualitative technique can be divided into intuitive and analogical technique, while the quantitative technique is divided into parametric and analytic technique.

In qualitative cost estimation techniques, comparison based analysis between the existing products and new product is done in order to identify the similarities with the new product. The similarities that have been identified will assist to include the past data from existing product into the new product. Thus, the requirement to obtain the cost estimation will greatly reduce from scratch. Besides, to get a reliable cost estimation of a new product, a knowledge of previous experience estimator will estimate the cost of the product based on

a similar past design case. Generally, qualitative techniques able to provide a rough estimate of cost in design conceptualization stage.

In the quantitative techniques detailed analysis of product design, features of a product and related manufacturing processes to fabricate the product is taken into consideration in order to obtain the cost estimation of the product (Dai & Balabani, 2006). Therefore, the quantitative-based technique is more accurate than qualitative techniques since qualitative is only rely on the knowledge of past experience estimator and also using historical cost data of previous product that have similarities.

Gayretli and Abdalla (1999) have developed their rule-based algorithm in order to choose and optimized the feasible processes to predict the cost based on the features of part and processing time. Standard formula to calculate process time is presented as below:

$$\text{Process Time} = \frac{\text{Form Feature Volume}}{\text{Material Removal Rate}} \qquad \text{Equation 2.1}$$

The process time will be further used to calculate a lot time, which is based on a form feature quantity. Thus, the total process cost is calculated as follow:

$$\text{Total Process Cost} = \text{Lot time} \times \text{PHC} \qquad \text{Equation 2.2}$$

Where PHC is the productive hour cost by a cost estimation database. Finally, the total cost is calculated as below equation 2.3:

$$\text{Total Cost} = \text{Material Cost} + \sum[\ (\text{Lot Time} \times \text{PHC}) + \text{Tool Cost} + \text{Setup Cost}]$$

Equation 2.3

The proposed cost estimation system allowed to select a combination of feasible processes when it is possible. Therefore, the calculation of the product cost and processing time are based on the user input constraint.

On the other hand, the new product cost development is one of the critical issues to be solved by companies especially in manufacturing sector. The main challenge to developed product cost estimation is the making of the right plan development, security of resources, climate and preparing a launch system. The importance of choosing the right technique in predicting the costs of the innovation process will lead to the market lose or success of the company (Chwastyk and Ko, 2014). Thus, details and information about the future cost implementation of the new product are significant. Therefore, it is crucial to designate the appropriate techniques of cost estimation.

The planning stage is one of the most difficult part to assess the future cost of the product. According to Chwastyk and Ko (2014), two types of techniques can be used, which are intuitive technique or analogical technique. Intuitive technique require sufficient knowledge and experience to evaluate subjectively of the information to estimate the cost of the product. Most of the time, this technique is applicable to experts people in that particular field. For the analogical methods, historical data of past design is required to do cost estimation according to the basis of similarity on the previously executed process. Regression analysis is usually been used.

Another important stage in product cost estimation is design stage. The upcoming utility characteristic of the product is determined in this stage. The parametric techniques are used to estimate the cost by determined all these features as it can be cost drivers to the estimation of product cost. The basis process involves in the new product development (NPD) before proceed to the next task is the estimation of the cost. Figure 2.2 shows that the idea of cost estimating process and the estimation technique used in NPD. Each of the level involved is the basis of assessment of the correctness in the process and detection of any deviation in order to correct it immediately according to the decision making.

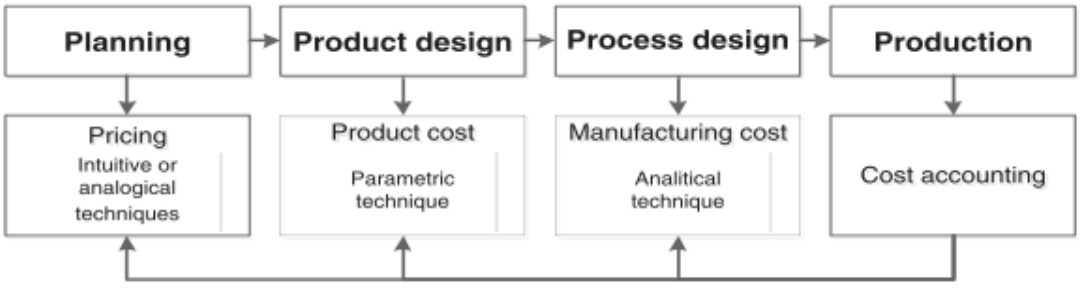

Figure 2.2: The costs estimation of New Product Development (Chwastyk and Ko, 2014).