UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DETERMINATION OF DIMENSIONAL ACCURACY OF A PART BY SILICONE RUBBER MOLD USING TAGUCHI METHOD

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Manufacturing Engineering Technology (Product Design) with Honours.

by

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Determination of Dimensional Accuracy of A Part By Silicone Rubber Mold Using Taguchi Method**

SESI PENGAJIAN: **2017/18 Semester 7**

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APPROVAL

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

……

(Project Supervisor)

ABSTRAK

Teknologi Perkakas Cepat adalah salah satu teknologi dalam Pengilangan Rapid. Tooling cepat adalah proses yang menggunakan model fungsional dari data CAD untuk menghasilkan bahagian dalam masa yang kurang dan pada kos yang lebih rendah. Proses pemutus vakum adalah salah satu kaedah dalam Teknologi Alat Rapid. Bahagian yang dihasilkan oleh pemutus vakum mempunyai ketepatannya bervariasi dengan perubahan parameter proses mesin seperti suhu resin, masa tekanan vakum, suhu acuan dan beberapa yang lain. Untuk mencapai ketepatan optimum bahagian yang dihasilkan, kaedah Taguchi digunakan. Ini adalah kaedah yang mudah dipermudahkan untuk reka bentuk eksperimen menggunakan kaedah array ortogonal. Dalam projek ini, pelbagai orthogonal L'9 digunakan dengan 3 parameter iaitu suhu resin, suhu acuan dan masa tekanan vakum. Eksperimen itu adalah persediaan dengan melibatkan proses membuat corak, acuan getah silikon dan menuang dalam ruang vakum. Kemudian 9 sampel telah menjalani proses pengukuran oleh Measuring Machine Coordinate (CMM). Oleh itu, hasil pengukuran 9 sampel perlu dibandingkan dengan data CAD untuk mendapatkan ketepatan ketepatan. Selain itu, hasil pengukuran dianalisis dengan menggunakan kaedah Taguchi untuk menentukan keadaan parameter optimum. Hasilnya menunjukkan bahawa peratusan ketepatan bagi setiap sampel diperolehi. Di samping itu, keadaan parameter yang dioptimumkan adalah untuk suhu resin, suhu acuan dan masa tekanan vakum masing-masing adalah 30 ° C, 60 ° C dan 5 min. Hasil perbandingan antara parameter lalai dan menunjukkan optimum bahawa nilai pengecutan bahagian itu meningkat 0.176 mm. Oleh itu, parameter yang dioptimumkan diperoleh dan matlamat dicapai.

ABSTRACT

Rapid Tooling Technology is one of technology in Rapid Manufacturing. Rapid Tooling is the process that used functional model from CAD data to produce a parts in less time and at a lower cost. Vacuum casting process is a one of the method in Rapid Tooling Technology. The part produced by vacuum casting has it accuracy varies with the changes of the process parameters of the machine such as resin temperature, vacuum pressure time, mould temperature and some others. In order to achieve the optimum accuracy of the produced part, the Taguchi method was applied. It is a simplified yet powerful method for experimental design using the orthogonal array method. In this project, an orthogonal array of L'9 is used with 3 parameters which are, resin temperature, mould temperature and vacuum pressure time. The experiment was setup by involving the process of pattern making, silicone rubber mold and pouring in vacuum chamber. Then 9 sample have undergone process of measuring by Coordinate Measuring Machine (CMM). Thus, result of measurement of 9 samples have to be compared to CAD data to get the percentage of accuracy. Besides that, the measurement result is analysed using Taguchi method to determine the optimum parameter condition. The result shows that the percentage of accuracy for every sample is obtained. Besides that, the optimized parameter condition is for resin temperature, mould temperature and vacuum pressure time are 30°C, 60°C and 5 min respectively. The comparison result between default parameter and optimum shows that the shrinkage value of the part is improved by 0.176 mm. Hence, the optimize parameter is obtained and the objective is achieved.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Dearest siblings

Honorable supervisor and lecturers

Supportive friends and mates

ACKNOWLEDGEMENTS

I would like to use this opportunity to express my gratitude to everyone who supported me throughout the completion of the report for Final Year Project. I am thankful for their guidance, criticism and also advice during the project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

SLS	-	Selective Laser Sintering
FDM	-	Fused Deposition Modelling
SLA	-	Stereolithography
CNC	-	Computer Numerical Control
DOE	-	Design of Experiment
ABS	-	Acrylonitrile Butadiene Styrene
PP	-	Polypropylene
PE	-	Polyethylene
Polycarb	-	Polycarbonate
PLC	-	Programmable Logic Controller
OA	-	Orthogonal Array
S/N Ratio	-	Signal-to-Noise Ratio
ANOVA	-	Analysis of Variance
3D-CAD	-	3 Dimensional Computer-aided Design
STL	-	Standard Triangle Language
RP	-	Rapid Prototyping
CMM	-	Coordinate Measuring Machine

CHAPTER 1
INTRODUCTION

1.0 Background

Vacuum casting is the most importance of the prototype production process. It is typically apply approach in rapid prototyping industry, frequently utilize for producing up to 40 pieces of functional prototypes made from different range of polymers. Initially, the process begins with creating an accurate and highly finished master model by using rapid prototyping technologies such as Selective Laser Sintering (SLS), Fused Deposition Modelling (FDM), Stereolithography (SLA), Computer Numerical Control (CNC) or existing part. This model is well-positioned inside a mold box and liquid silicone rubber is poured over the master. After silicone is completely cured, the mould is separated in as split line established and master model is getting rid, leaving precisely formed cavities. This grant rapid production of great quality parts in a short lead-time. The advantage of using vacuum casting is that the mould are evenly filled and the resin degassed. Significantly better model properties result. Today a vast number of commercial plastic materials can be used as vacuum casting material and the resulting models are comparable with the later injection cast mass production parts, at least with regarding to certain selected properties depend on the vacuum casting material and the complexity of the mould.

The term of Design of Experiment (DOE) are a powerful statistical technique to improve the quality of the parts and DOE also been introduced by R.A Fisher in England in the year 1920's. Fisher's idea was to study the effect of several variables together. In his early applications, Fisher wanted to find out how much rain, water, fertilizer, sunshine, etc. are needed to produce the best crop.

By using a Design of experiment process, mostly the entire the possibilities need to be done before an optimal performance can be completed. The number of tests can increases rapidly. Roy (2001) stated to reduce the number of such tedious and costly tests while still be able to maintain an insight into the overall effects of the input factors on the output, Taguchi approach based on the DOE should be considered. In this method, only a few tests that consistently choose certain combinations of values of control factors are needed. Prasad *et al.* (2005) stated this approach not only saves considerable time and cost but also leads to a more fully developed process by providing systematic, simple and efficient methodology for the optimization of the near optimum design parameters with only a few well defined experimental sets. Taguchi showed that DOE could be used not only to improve quality, but also to qualify the improvements made in terms of saving money. He also make the method easy and friendly to be apply. For laying out experiments, he created the number of special orthogonal arrays, each of which is used for a number of experimental situations. By introducing a new way to analyze the experiment results, he can determine the best design solution and quality.

There are not many researches about silicone rubber molding or dimensional accuracy of wax pattern. Horacek and Lubos (1996) studied the influence of injection parameters on the dimensional stability of wax patterns produced by injection molding process. They found the correlation between numerous injection parameters and their dependency on other parameters in their studied. Yarlagadda and Hock (2003) compared accuracy of wax patterns created by hard tool (polyurethane mold) and soft tool (RTV mold). They found the injection pressure and holding time only have a slight effect on the accuracy of wax patterns and the only parameter that has an effect on the dimensional accuracy is the injection temperature. The purpose of this project is to discuss the optimal parameters of dimensional accuracy in vacuum casting silicone rubber mold. All analysis experiments are using the Minitab Software. The parameter selection or the factors for this studied are resin temperature, vacuum pressure time, and mold temperature to achieve better dimensional accuracy of the product. The material used is Resin AXSON PX 223.

1.1 Problem Statement

Mold shrinkage is the phenomenon where the volume of the molten plastic filled inside the cavity of a mold is shrinking at the time as being cooled and solidifying. Thus, it is important to determine the right parameters of the Vacuum casting machine in order to produce a part which can fulfil the desire specifications. There are basically few parameters which are important and will influence the specifications of the produced part, and these parameters are resin temperature (°C), vacuum pressure time and mold temperature (°C). The combinations of different setting of the parameters will definitely produce parts with different specifications, thus the study of the suitable combination of parameters is necessary for optimum output produced.

1.2 Objectives

The objective of this project is to determine the optimal process parameter for resin temperature (°C), vacuum pressure time and mold temperature (°C). Besides that, to evaluate the shrinkage of a part.

1.3 Scopes of the Study

The scope for this project is specifically design the part by using SOLIDWORKS and make a pattern out of it using the PROJET 1000 3D printer. For the material required to produce the part model is Axson PX223. This project will be conducted in vacuum casting KLM-1000A Machine. The result data will be tabulated and analyzed using Minitab software.

1.4 Significant of Study

Silicone rubber mold is a useful alternative of metallic mold to produce patterns for casting. The finding of this study will have benefits to the reduction in production lead-time and cost for silicone rubber mold.

1.5 Project Planning

The Gantt charts is used as tool for planning and scheduling operations involving experimental research. On the other hand, charts is easy to construct and understand. The Gantt chart for this project is shown in Table 1.1.

Table 1.1: Gantt chart for Project Planning

PROJECT PLANNING																																								
List down the main activity for the project proposal. State the time frame needed for each activity.																																								
	2017																												2017/2018											
Project Activity																																								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Identifying the problem	**BP Briefing**							**Mid Term Break**							**Study Week**				**Final Semester Examination**					**Semester Break**						**Mid Term Break**							**Study Week**	**Final Semester Examination**		
Find objective of the project																																								
Collect the information																																								
Find work scope of the project																																								
Project proposal																																								
Design a pattern																																								
Make a part																																								
Measure the part and collect data																																								
Analyze data and result																																								
Conclusion and recommendation																																								
Documentation update																																								

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Literature review is a significant process of evaluate and research information of the studies. The sources of literature review are obtained from the journals, books, and electronics resources. All of the information in based on historical data, manufacturing method and past studies that related to this studied.

2.1 Vacuum Casting

According to Radu and Fratila (2012), vacuum casting is a modern technique that allows the manufacturing of pieces in small batches and individual fabrication at minimum price and shorter time. This technique aids to build intricate prototype parts with similar form details and surface quality of the duplicate master model.

Gebhardt (2003) added that vacuum casting is able to offer an excellent quality of ingot without blow-holes, flaws or any other defect. Others state that vacuum casting is soft tooling method that replaces conventional method such as investment casting. Vacuum casting representing a method in which silicone molds are fabricated based on prototype and the mold is employed to form several similar parts. Prototype that is generated by this method is closely perfect production quality.

Denoual et al. (2004) describe that vacuum casting process composed of silicon female mould with an original part, followed by resin casting under vacuum to produce

the duplicated parts. Jijociya et al. (2013) enlisted vacuum casting system into two which embodies of vacuum chamber and heat chambers. Vacuum chamber enable for producing silicon rubber moulds and resin free of air bubbles formed during mixing. This system is significant in casting of resins, waxes and other plastics in silicon mould which formed in the initial step from rapid prototyping models. Vacuum chamber is equipped in driver which taking charges all processes such as pumping out air from chamber, mixing resin component, and unloading ready resin to mould.

Chua et al. (2010) regards vacuum casting as one of the most flexible form of rapid prototyping and tooling for consumer products. Besides it is simpler to be applied and inexpensive tools and materials, vacuum casting increases the potential of silicone rubber mould in the batch production of functional prototype.

Chabra and Singh (2011) describe that vacuum casting is a method that provides sublime properties to other casting methods which form limited run of parts. It is a method that offers good surface finish, void-free interior structure, and clarity or desired colour as well as close tolerance to a predetermined size.

Eyers and Dotchev (2010) stated the close dimensional tolerance and void-free interior structure induce similar physical properties that can be expected from injection moulded thermoplastic shapes. Eyers and Dotchev (2010) also claim that this technology offers higher consistency and faster processing at about thirty to forty minutes.

2.1.1 Vacuum Casting Process

In term of process, vacuum casting is a casting process for elastomer using a vacuum to draw the liquid material into the mold, which is one of the rapid prototype technology. This process is used when air entrapment is a problem, there are intricate details or undercuts, or if the material is fiber or wire reinforced, it is usually for small volume production.