EVALUATION OF SIGNIFICANT FACTORS IN ALUMINUM LOST FOAM CASTING USING DOE APPROACH

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical - Advanced Manufacturing Technology)

Mechanical Engineering
Universiti Teknologi Malaysia

DECEMBER 2010

To my parents. Your love and support pass me the biggest strength.

ACKNOWLEDGEMENT

First and foremost I would like to express my gratitude to Allah S.W.T who donates me the strengths and possibility to complete this project report. I would like to express my sincere gratitude to my supervisors, Assoc. Prof. Dr. Mohd Hasbullah Idris200 and Assoc. Prof. Dr. Izman Sudin, for their support during this work. Their constant guidance, motivation, and constructive criticism have provided a good basis for the proposed Master's project.

I would like to thank my friends for their help in various ways throughout the entire duration of this thesis.

Eventually, I would like to give my special thanks to my parents for their constant encouragement, trust and love that I cherish throughout my entire time at academia. I affectionately dedicate this project report to them. Thank you.

Amirreza Shayganpour, Malaysia

ABSTRACT

In the present research, experimental investigation of lost foam casting of LM6-Al-Si cast alloy by using Design of experiments has been conducted. This investigation has as main objectives to determine the factors that significantly affect the process of aluminum lost foam casting of the LA-Si alloy and evaluate the feasible range of factors for producing a sound aluminum lost foam casting. Castings in the shape of step-like with five sections were produced mainly using a foam density of 20 kg/m and dipping time is 20 second. The four parameters were pouring temperature, slurry, vibration time and sand size. The 2-Level full factorial design with 20 experiments run, which are included by 4 center points, were replicated one time for selected responses, silicon spacing, surface finish and Porosity. In the present work, it was shown that slurry, vibration time, pouring temperature and sand size are controlling factors in LFC process of LM6 alloy. DOE full factorial Design is used to study the effects of four process factors on the LFC and their possible interactions separately. The collected data is then converted into graphical form such as normal probability plot, ANOVA, residual plot, main effects plot and interaction plots and these have been analyzed. The result shows that sand size is the most significant factors affecting lost foam casting process, while pouring temprature is the most affective parameter for 24mm thickness in LFC. Moreover, at lowest level of sand size with increasing of slurry, silicon spacing has increased, and at the highest level of vibration time with increasing of slurry, surface has deteriorated and finally at the lowest level of sand size with increasing of Vibration time, porosity has decreased accordingly.

ABSTRAK

Di dalam penyelidikan ini, kaedah rekabentuk eksperimen digunakan untuk kajian proses pengacuanan busa hilang LM6-Al-Si tuangan aloi. Objektif utama penyelidikan ini adalah untuk mengenalpasti faktor-faktor yang penting di mana memberi kesan kepada proses pengacuanan busa hilang aluminum LA-Si aloi dan menilai faktor-faktor yang penting untuk menghasilkan tuangan hilang aluminum. Penuangan untuk bentuk tangga mempunyai lima bahagian dihasilkan menggunakan ketumpatan busa sebanyak 20kg/m dan masa redaman selama 20 saat. Empat parameter yang digunakan adalah suhu tuangan, simen, masa getaran dan saiz pasir. Rekabentuk 2 aras faktorial dengan 20 eksperimen yang mengandungi 4 titik tengah,dengan mengulangi sebanyak sekali digunakan ke atas pilihan respon, termasuk jarak silikon, kemasan permukaan dan rongga. Di dalam kajian ini di dapati simen, masa getaran, suhu tuangan dan saiz pasir merupakan faktor yang mengawal proses penuangan busa hilang LM6 aloi. Rekabentuk eksperimen yang penuh digunakan untuk mengkaji empat faktor yang memberi kesan kepada proses penuangan busa hilang dan kemungkinan interaksi yang berasingan. Data yang terhasil ditukar dan dianalisis kepada bentuk grafik seperti kebarangkalian plot normal, plot kesan utama dan plot interaksi. Keputusan menunjukkan bahawa saiz pasir untuk ketebalan 24mm merupakan parameter yang paling efektif dalam penuangan busa hilang. Pada level yang rendah untuk saiz pasir dengan penambahan simen, saiz silikon bertambah, dan pada masa getaran yang paling tinggi dengan penambahan simen, permukaan akan bertambah buruk dan akhirnya pada saiz pasir yang kecil dengan peningkatan masa getaran, peronggaan akan meningkat

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LIST OF ABBREVIATIONS

LFC	-	Lost Foam Casting
EPS	-	expandable polystyrene
DOE	-	Design Of Experiment
ANOVA	-	Analysis Of Variance
GFN	-	Grain Fineness Number
RSM	-	Response Surface Methodology
PMMA	-	Polymethyl Methacrylate
CTE	-	Coefficient of Thermal Expansion
FMEA	-	Failure mode and Effect Analysis
DTA	-	Differentially Thermal Analysis
QFD	-	Quality Function Deployment
SPC	-	Statistical Process Control

LIST OF SYMBOLS

Al	-	Wavelength
Fe	-	Iron
Cu	-	Copper
Mg	-	Magnesium
Ni	-	Nicel
Zn	-	Zinc
PAC	-	Polyalkylene carbonate
Si	-	Silicon
	-	

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CHAPTER 1

INTRODUCTION

Lost-foam casting (LFC) is a type of evaporative-pattern casting process which uses foam and unbounded sand for its pattern. LFC eliminates the necessity of melting the wax out of the mold by using advantage of the low boiling point of foam. This process is quite applicable and commonly used in the automobile and aerospace industries duo to produce imperfection free casting [1]. Aluminum lost-foam casting process can provide heavy forged steel or cast iron for the lighter and lower fuel automobiles. The properties of Al- Si alloys are controlled by the phases that establish the alloy (Al and Si). In particular, many of the considerations arise due to processing.

1.1 Project Background

Due to intense competition between industries for producing products with high quality and low cost, successful companies widely use design of experiments to do market research, product development, manufacturing, and to resolve quality-reliability and customer service issues. Design of Experiment (DOE) is a structured, organized method which is used to determine the relationship between different factors, affecting a process, and the output of that process [2]. This method was first developed in the 1920s and 1930, by Sir Ronald A. Fisher to study the effect of multiple variables simultaneously [3]. DOE plays a significant role in research and development, where solving optimization problems is the most prominent issue in the experimental design. The key to minimizing optimization costs is to conduct as few experiments as possible. DOE requires only a small set of experiments and thus helps to reduce costs. Moreover, design of experiment includes designing a set of ten to twenty experiments, in which all relevant factors are varied systematically and as results they help to identify optimal conditions, the factors that most influence the results, and the existence of interactions and synergies between factors.

DOE using general factorial design approach can economically satisfy the needs of problem solving and product/process design optimization projects. This design allows for simultaneous study of several factors effects on a process and also can vary the levels of the factors concurrently rather than one at a time. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time and cost required for experimental investigations. However, intense competition between industries for producing products with higher quality and lower cost expense has convinced them to move further ahead in the use of statistics for product and process improvement. Designed experiments, for example, are rapidly becoming a way of industrial life in among Japanese companies.

1.2 Study Motivations

Despite of different existing methods in designing phase, designers still have challenges to ensure whether their design operate within specific limitation or not. In another perspective, choosing the proper parameter setting is the considerably important issue for gaining the best result in experiments. Moreover, running experiments for each effective variable in the system clearly is not practical due to various difficulties such as low speed, time consuming, and high cost of the implementation. Therefore, an appropriate setting of design factors could lead to robust design in manufacturing field.

Although in most related works merely one significant factor has been evaluated, one variable cannot lead to find the accurate and proper response for the system. On the other hand, choosing one variable is unable to disclose the impact and interaction of different parameters on the system. In this project we are aimed to choose more than one significant variables in order to attain more proper outcome in our work.

1.3 Study Objectives

This project concentrated on the evaluation of significant factors in lost foam casting experiment to reduce the number of unnecessary experiments and offer the robust design by factorial design. Particularly, this research aimed to achieve the following objectives:

1. Determined the factors that significantly affected the process of aluminum lost foam casting.
2. Evaluated and verified the feasible range of factors for producing sound aluminum lost foam casting.

1.4 Scope of Work

In this study, using experimental design for aluminum lost-foam casting is a strategy to gather empirical knowledge based on the analysis of experimental data and not on theoretical models. Scopes of this project are:

i. Lost-foam casting of Al-Si (LM6) alloy was investigated in this project.
ii. DOE factorial design method was aimed to use.
iii. This experiment is limited to study only four most significant factors in the LFC process.
iv. The responses evaluated were silicon spacing, surface finish and porosity.

1.5 Significance of Findings

The principle goal of using design of experiment in our study was However, The significant contribution of this methodology is to eliminate the need for running uneccessary experiments in the lost foam cating process. Since running experiments for every effective parameter in this process is not appropriately practical, this methodology by using design of experiment could reduce the number of experiments and find the best setting for process parameters Moreover, the interaction between three significant factors has been studied in this experiment that led to expose the impact of different parameters and attain more effecitve outcome in aluminium lost foam casting.

1.6 Dissertation Organization

This dissertation is organized as follows.

Chapter 2 reviews the characteristics of aluminium lost foam casting and design of experience approach. It begins with the discussion on different available techniques for design of experience, and then, it explores the process parameters that are influence more effectively in lost foam casting process. Finally, it describes the current related works for aluminum lost foam casting and DOE method along with justification for choosing the effective parameters for further investigation in LFC process.

Chapter 3 defines the major topics in this chapter with emphasizes on the concepts and ideas in designing the experience. It starts with describing the project background and the system design. Then it continues with the explanation on the technology and algorithm for each sub-module in the proposed signature generation module.

Chapter 4 deals with different steps for running the LFC process and also great details for using DOE software has been covered in this chapter.

Chapter 5 discusses the result of our experiment. This chapter also involves different plots obtained from DOE software in which all the significant factors along with their interaction has been depicted in different types of plot. The critical parts of the results are observed and discussed towards the end of the chapter.

Chapter 6 summarizes the result and overall discussion as well as conclusion of this study. suggestions for future work are at the end of the chapter.