Faculty of Manufacturing Engineering

PROCESS-PROPERTIES EFFECT ON COPPER ALLOY AFTER INVESTMENT CASTING USING ABS MATERIAL AS PATTERN

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Supervisor Name : Professor Madya Dr. Nur Izan Syahriah Binti Hussein

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DEDICATION

To my beloved husband, Mohd Fadhlie Bin Ahmad Bashah, my mother Juwariah Binti Mohamad, my father Mohd Sulaiman Shah Bin Hj Mohd Kassim and all family.

ABSTRACT

This present study is concerned with the investigation of mechanical properties of copper alloy castings produced by investment casting process using Acrylonitrile Butadiene Styrene (ABS) as the pattern material and the Plaster of Paris as the mould material. The studies on the process parameters and the mechanical properties of the copper alloy casting have gained significance. The aim of this research is to investigate the effect of burning temperature, firing time and pouring temperature on surface hardness and dimensional accuracy of the end casts. The sample is using copper alloy as the material which is the combination of elements like copper and zinc. This research used two levels of three parameters which are burning temperature, firing time and pouring temperature of the alloy to investigate their effects on the surface hardness and dimensional accuracy of the end casts. Experiments were conducted as per Full Factorial with Design Expert software. The experimental analysis revealed that the high burning temperature, high firing time and high pouring temperature of the copper alloy can influence the mechanical properties of copper alloy casting due to P-value in ANOVA result for hardness. The results also showed that the high firing time and pouring temperature can influence the dimensional accuracy of the samples. Furthermore, the study emphasized on the improvement of mechanical properties of copper alloy casting which can be achieved by optimizing the correlated processing parameters such as its burning temperature, firing time and pouring temperature of the alloy.

ABSTRAK

Kajian ini adalah berkaitan dengan penyiasatan sifat-sifat mekanik aloi tembaga yang dihasilkan oleh proses 'investment casting' menggunakan 'Acrylonitrile Butadiene Styrene' (ABS) sebagai bahan corak dan 'Plaster of Paris' sebagai bahan acuan. Kajian mengenai parameter proses dan sifat-sifat mekanik pada aloi tembaga telah mendapat kepentingan diantaranya. Tujuan penyelidikan ini adalah untuk menyiasat kesan suhu pembakaran, masa membakar dan suhu ketika dituang pada kekerasan pada permukaan aloi dan ketepatan dimensi pada aloi tersebut. Sampel tersebut menggunakan aloi tembaga sebagai bahan yang merupakan gabungan unsur tembaga dan zink. Penyelidikan ini menggunakan dua peringkat tiga parameter iaitu suhu pembakaran, masa membakar dan suhu mencurah aloi tembaga untuk menyiasat kesannya pada kekerasan permukaan dan ketepatan dimensi sampel tersebut. Eksperimen telah dijalankan mengikut 'Full Factorial' dengan perisian 'Design Expert'. Analisis ujikaji telah mendedahkan bahawa suhu pembakaran yang tinggi, masa pembakaran yang tinggi dan suhu menuang aloi tembaga yang tinggi mempunyai pengaruh sifat mekanikal pemutus aloi tembaga kerana nilai P dalam keputusan ANOVA untuk kekerasan sampel tersebut. Hasilnya juga menunjukkan bahawa masa pembakaran yang tinggi dan suhu mencurah aloi juga mempunyai pengaruh ketepatan dimensi sampel. Kajian ini menegaskan bahawa penambahbaikan sifat-sifat mekanikal pemutus aloi tembaga boleh dicapai dengan mengoptimumkan parameter pemprosesan berkorelasi semasa suhu pembakaran, masa pembakaran dan suhu menuang aloi.

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Finally, I would like to express my deepest gratitude to my beloved husband, my mother, father and my siblings who really understood and support me through this whole completion of my study.

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LIST OF SYMBOLS

°	-	degree celcius
mm	-	millimeter
HRB	-	Rockwell Scale

LIST OF ABBEREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
FDM	-	Fused Deposition Modeling
DOE	-	Design of Experiment
RP	-	Rapid Prototyping

CHAPTER 1

INTRODUCTION

1.1 Background of study

In the recent past, authors studied the effect on mechanical properties of metal cast with different processes such as green casting and investment casting. In between of the two different process of metal cast, investment casting process offers good quality castings rendering good surface finish and other desirable mechanical properties (Yadav *et al.* 2011). This present study will focus on investment casting process that is the most economical ways of producing complicated shaped part from metal. Investment casting process is the only method available when parts have undercuts, thin walls or inaccessible configurations. In the traditional investment casting process creates wax patterns utilizing a process similar to plastic injection moulding (Gouldsen, 1998). From that traditional investment casting process, the wax injected into aluminium tools to produce the pattern. But present study use alternative material that is Acrylonitrile Butadiene Styrene (ABS) to replace wax in traditional investment casting process without major modification in the process.

With the advantages of investment casting process known for its ability to produce components of excellent surface finish, dimensional accuracy, and complex shape, this technology applies to copper alloy as end cast. This research aim to investigate the various parameter by burning temperature, firing time and pouring temperature to carry out to study their effects on the harndness and dimensional accuracy by using ABS as patterns.

1.2 Problem Statement

Investment casting is one of the most economical ways to produce complex shaped parts from metal. The difficulties of copper casting process in many cases direct our attention to the investment casting method, especially in special casts technology for power engineering (Rzadkosz *et al.* 2015). The reason why investment casting was chosen by many industrial because of it can produce the intricate details and high dimensional accuracy (Yadav *et al.* 2011). In addition, the mechanical properties of the other method such as sand casting also show dissimilarities (Gebelin *et al.* 2003).

According to the previous study, the parameter of the casting process influences the mechanical properties of the end casts. In this research, ABS will be chosen as the pattern replace from conventional wax patterns that has a limitation of hardness at low temperature. It is supported by (Harun *et al.* 2009) which is the surface finish of ABS parts is proved to be far better than rapid prototyping wax.

Therefore, an experimental investigation is conducted in order to determine the effect of hardness and dimensional accuracy on copper alloy as a material for investment casting process using ABS patterns. This research will produce different results for each cast with the two level of parameters in burning temperature, firing time and pouring temperature.

1.3 Research Objectives

The objectives of this research are:

i. To investigate the effect of using ABS as pattern in an investment casting of copper alloy.

ii. To study the effect of investment casting process parameters to mechanical properties of copper alloy with ABS as a pattern.

iii. To suggest the optimum set of parameters for investment casting of copper alloy with ABS pattern.

1.4 Research Scope

The material used for the pattern is ABS because of it has been proven that ABS parts better than rapid prototyping wax. ABS is the one cleaner materials to process through a burn-out cycle. It is proved from the testing by the characterize the amount of residual ash produces during the burn-out cycle (Gouldsen, 1998). The experimental type of the research by controlling the variable parameter in order to find the mechanical properties behaviour result. In order to have the optimize parameter during investment casting process, the hardness testing and dimensional accuracy for part length over casting conducted. Scope of study also represent by a K-Chart and can be reffered to Appendix A

1.5 Importance of Study

From all of the assumptions, products that fabricated is identical. This thought used to be critical to the performance of the products during application in the industries. From this research, it has been potential occurrence of the differences in mechanical properties because of the variants of the parameter. As all of the research result, industries can produce products higher accurate according to this analysis by depends what of the minimum requirement they needed. Therefore, a better quality product can be produced to avoid the wrong orientation and arrangement of the parameters.

1.6 Research Activity

In this research, investment casting used to investigate each cast produced. Each cast compared for mechanical properties by using ABS as a pattern. Hardness testing and dimensional accuracy of the casts included in this research. Research activity or planning cited in Gantt chart as in Appendix B

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The basic knowledge of the investment casting will be provided in this chapter, which consists of the rapid prototyping pattern process using ABS. In this chapter also describes the mechanical properties of copper alloy that apply in this process. Besides that, theoretical and previous research on investigating on dimensional accuracy is also included in this chapter.

2.2 Investment Casting

Investment casting, often known as precision casting process, is used to produce parts with controlled dimensional tolerances. This process is well understood and practiced by thousands of investment casting foundries across the world. Commonly, investment casting used the wax model that the wax model method, based on melting the wax before the mould is cast (Rzadkosz *et al.* 2015).

In other cases, it is the only method available when these techniques capable of providing an economical means of mass production components with complex features. Although the large used of applications in many industries, the conventional Investment casting process practice in modern foundries has its drawbacks. High tooling costs and lengthy lead times are associated with the fabrication of metal moulds required for producing the sacrificial wax patterns used in investment casting (Harun *et al.* 2009). On

the other hand, Investment casting is known for its quality castings rendering good surface finish and other desirable mechanical properties (Yadav *et al.* 2011).

In addition, the basic steps involved in the production of investment casting, using a ceramic shell, which are shown in figure 2.1. Though their presentation covers only the basic steps and overview of the investment casting, it helps a beginner very much. As per their presentation, in the investment casting technique, a pattern of the desired shape, usually made of wax, is formed by injecting molten wax into a metallic die. Then the pattern or a cluster of such patterns are gated together to a central wax sprue. The sprued pattern is invested with ceramic or refractory slurry, which is then solidified to build a shell around the wax pattern.

The pattern wax is then removed from the shell by melting or combustion, leaving a hollow void within the shell, which exactly matches the shape of the assembly. Prior to casting, the shells are fired in an oven where intense heat burns out any remaining wax residue. The resulting refractory shell, hardened by heating, is filled with molten metal. After the molten metal is solidified, the shell is broken and the gates are cut off from the solidified casting to obtain the near net shape component. The authors not only attempted to furnish basic steps involved in this process but also explained different applications of the process, along with its advantages and limitations (Pattnaik *et al.* 2012).

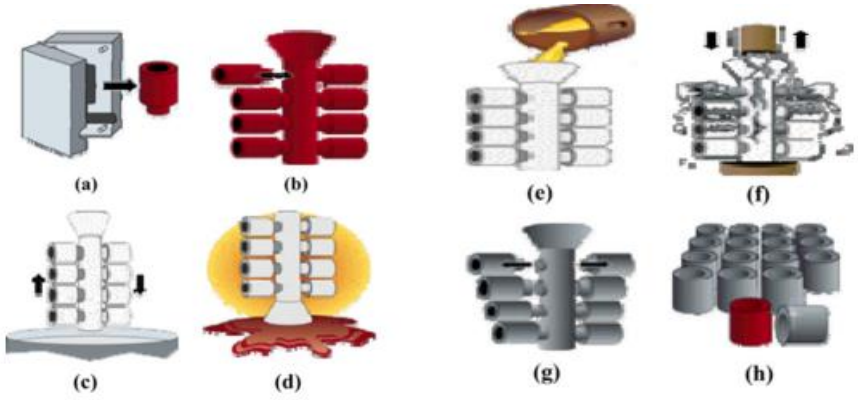

Figure 2.1 : Basic steps involved in ceramic shell investment casting: (a) pattern production, (b) pattern assembly, (c) investment, (d) dewaxing, (e) casting, (f) knock-out, (g) cutoff, and (h) finishing and inspection (Kalpakjian and Schmid, 2008)

The investment casting process became one those alternatives and the process can fulfill an urgent demand for producing finished components, used in the machining tool industry and also offered the solution for producing many complex shaped components with accurate dimensions and fine details. This process has continued to expand not only due to the advantages it offers as a casting process, but also in manufacturing variety of products. The review different investigations of important stages of investment casting process from previous authors, they highlight its applications and advantages also limitation of the process. Even the authors deal with different methods and development for making wax patterns, followed by different techniques developed for making ceramic shells for different alloys, it can be used in this paper also (Pattnaik *et al.* 2012).

Based on the previous investigations by (Pattnaik *et al.* 2012), it was found that an investment casting sprue wax can be converted into low-cost pattern wax having better properties than high-cost commercial one by blending and mixing economically non-hazardous chemicals. They found also that the wax which was dewaxed in a microwave oven showed negligible physical-chemical changes compared to the autoclave. Because of