UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF PHENOLIC RESIN AND HARDENER PERCENTAGE ON MECHANICAL PROPERTIES AND LOSS ON IGNITION RESIN BONDED SAND CASTING

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

by

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I hereby, declared this report entitled "The Effect of Phenolic Resin and Hardener Percentage on Mechanical Properties and Loss on Ignition Resin Bonded Sand Casting" is the results of my own research except as cited in references.

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APPROVAL

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

……

(Dr. Nur Izan Syahriah Bt. Hussein)

ABSTRAK

Diterangkan di sini adalah kaedah pembuatan logam berhampiran bentuk-bersih iaitu resin terikat proses tuangan pasir yang menggunakan fenolik sebagai resin pengikat. Kajian ini adalah untuk menentukan faktor-faktor yang memberi kesan signifikan kepada sifat acuan pasir iaitu resin dan pengeras seterusnya menilai lingkungan faktor yang boleh dilaksanakan untuk menghasilkan acuan pasir fenolik. Reka bentuk faktoran penuh dengan 9 eksperimen tiga peringkat telah dijalankan bagi menilai kekuatan mampatan, kekuatan tegangan, kekuatan melintang dan kerugian atas pembakaran (LOI). Reka bentuk faktorial penuh telah digunakan untuk mengkaji kesan dua faktor keatas resin fenolik pasir acuan terikat dan interaksi yang mungkin antara dua faktor tersebut. Data yang dikumpul kemudiannya ditukarkan kedalam bentuk grafik iaitu carta bar, plot kesan utama dan interaksi plot. Seterusnya, plot ini dianalisis. Daripada keputusan yang diperolehi berdasarkan empat respon, sampel dari nisbah 9 adalah yang optimum. Ini adalah kerana nisbah ini mencapai nilai piawaian untuk setiap respon yang dikaji. Parameter nisbah yang paling sesuai adalah dari 9 nisbah yang mengandungi 3% daripada resin dan 20% daripada pengeras.

ABSTRACT

Describe herein a method of manufacturing a metalic to a near net-shape which is resin bonded sand casting process that use phenolic as a resin binder. This study was to determine the factors that significantly affect the sand mould properties which was resin and hardener and evaluate the feasible range of factors for producing a phenolic sand mould. The three-level full factorial design with 9 experiments run was performed for responses that were compressive strength, tensile strength, transverse strength and loss on ignition (LOI). DOE full factorial design was used to study the effect of two factors on the phenolic resin bonded sand mould and their possible interactions. The collected data was then converted into graphical form that were bar chart, main effects plot and interaction plots and these plots were analyzed. From the result obtained based on the four of responses, the sample from ratio 9 was the optimum. This was because this ratio achieved the standard value for every responses studied. The most suitable ratio parameter was from ratio 9 that contain 3% of resin and 20% of hardener.

DEDICATION

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

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First, I would like to express my gratitude to Allah S.W.T who give me the strengths and possibility to complete this project report.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AFS	-	American Foundry Society
AFS GFN	-	Grain Fineness Number sand
DOE	-	Design of Experiments
F	-	Fahrenheit
g	-	gram
LOI	-	Loss on Ignition
kg/cm^2	-	Kilogram over centimeter square
Ra	-	Surface roughness
SIRIM	-	Institut Piawaian dan Penyelidikan Perindustrian Malaysia
SiO_2	-	Silica sand
SO_2	-	Sulfur dioxide
°C	-	Degree celsius
%	-	Percent
µm	-	micrometer

CHAPTER 1
INTRODUCTION

This chapter describes the general information about the study on the process of resin bonded sand casting with a brief introduction to the background of the research area. It also include a brief review on the items of previous research in the area also the exact purpose of the research. The problem statement, objectives and scope also included in this chapter.

1.1 Background

By far sand casting is the most versatile of the various method and techniques of forming metals which include forging, punching, rolling, stamping, extrusion and many others. Sand casting affords the designer the greatest freedom and latitude of any forming methods with an unlimited choice of metals and alloys and can be readily sand cast singly or by the millions (Ammen, 1979). In conventional sand casting, the mould is formed around a pattern by ramming sand, mixed with the proper bonding agent, onto the pattern. Molten metal is poured into the mould, and after bit has solidified the mould is broken to remove the casting (Davis, 1993). The quality of castings in a sand mould are influenced significantly by its properties, such as compression strength, permeability, mould hardness and others which depend on input parameters like sand grain size and shape, binder, water and others (Mahesh et al., 2008).

Binders were developed to strengthen the cores, which are the most fragile part of a mould assembly. Inorganic binders, such as clay or cement, are

materials that have long been used in the production of foundry moulds and cores (James and Richard, 1986). Phenolic sand casting or phenolic ester system is a new no bake binder technology introduces recently to the metal casting industry (Iyer *et al*., 1987). The system is based on the alkaline phenolic resin in conjunction with an organic ester that act as a co-reactant (Iyer *et al*., 1987). Alkaline phenolic resin have been widely adopted since the introduction of Alphaset in 1981 as a cold setting binder for mould and coremaking and later BetaSet cold box process (Stevenson, 1987).

1.2 Problem Statements

Nowadays, many industries using sand casting process to produce a wide variety of metal components with complex geometries. Quality of products is very important for determining the efficiency of a process performed. The parameters setting play an important role for the mould characteristic. Amount of resin and hardener included will also influence the quality of the mould and resulting products. There are variations range of parameters involved in resin bonded sand casting process.

The mould has to have the optimum hardness that is mould hardness number–80 (Guharaja *et al*., 2006) so that it takes a definite shape with accurate dimensions. Proper mould properties will give castings a better surface finish in range 5-25μm of surface roughness, R_a (Kalpakjian and Schmid, 2006), more accurate dimensions and reduced penetration, drops and swells. Excessive hardness, meanwhile can cause cracks, scabs, blows, pinholes and penetration (Granlund, 1999). In industry, it has no recorded understanding regarding mixing all the material at different ratios. The easiest way to do the set-up on the parameter is based on the operator or technician's experience, or trial and error method (SIRIM, 2012). This trial and error method is unacceptable because it is time consuming and not cost effective. Then, using a more systematic method, design of experiment can be used to evaluate how the parameters of resin bonded affect the sand casting process.

1.3 Objective

i. To study the ratio parameter of phenolic resin and ester hardener to get the significant condition for casting mould.

ii. To develop a design of experiment in resin bonded sand casting process.

iii. To analyze the casting mould properties of different ratio parameter specimens in term of compressive strength, tensile strength, transverse strength, and loss on ignition (LOI).

1.4 Scopes

This study focus on resin bonded sand casting process that uses silica sand, phenolic resin as a binder, and ester as a hardener. Parameters selected that will affect the quality of the mould is the percentage of resin and hardener. The range of resin that used is 2% - 3% while the range of a hardener is 20% - 30%. In this study the design of experiment that applied is full factorial method. After the process, a detail study was conducted on the mould based on characteristics of compressive strength, tensile strength, transverse strength, and loss on ignition (LOI). At the end of the experiment, all data was collected and further discussion was made to obtain a final conclusion. The effect of the resin binder on the cast product is not included in this study.

1.5 Outlines of Study

For this study, six chapters are included in this report. PSM I will cover chapter 1, 2, and 3, while for PSM II will cover chapters 4 and 5.

Chapter 1 includes a brief introduction to the background of the research area. It also include a brief review on the items of previous research in the area also the exact purpose of the research.

Chapter 2 is literature review that includes to analyse the relevant literature relevant to the research purpose. Then, report and evaluate information that have been read in relation to stated research question and purpose. At the end of literature review, the research are put in clear setting, briefly reformulate the problem and the dimensions of study.

Chapter 3 in methodology that describes the data precisely that have been selected. It will include all the information about the relevant details.

Chapter 4 consists results and discussions for mechanical properties that is a decision have to make according to the nature and purpose of dissertation and the nature of the analysis. It will be evaluated according to the framework that have been used.

Chapter 5 consists results and discussions for loss on ignition properties that is a decision have to make according to the nature and purpose of dissertation and the nature of the analysis. It will be evaluated according to the framework that have been used.

Chapter 6 includes the conclusion of the study that summarise the main findings that have been discussed in detail and conclusion that have reached.

Chapter Summary

In this chapter, the information about the purpose of the study on resin bonded sand casting have been discussed that included the problem statement, objectives and scope. Further information will discussed in great details in next chapter.

CHAPTER 2
LITERATURE REVIEW

This chapter describe about the articles, books and other sources for example dissertation, conference proceedings and so on that relevant to a particular issue that is on significant condition on resin bonded sand casting proce ss by using DOE method. The purpose to have this literature review is to offer an overview of significant literature published on the related topic.

2.1 Foundry

The foundry industry use a variety of procedures for casting metal parts. These include such processes as permanent mould casting, centrifugal casting, evaporative pattern casting, and sand casting. In sand casting, moulds and cores are used. Cores are required for hollow castings and must be removed after the metal has solidified (James and Richard, 1986).

Sand casting is the most widely used casting process, utilizes expendable sand moulds to form complex metal parts that can be made of nearly any alloy. Because the sand mould must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand casting process involves the use of a furnace, metal, pattern, and sand mould. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mould, which is formed by the pattern. The sand mould separates along a parting line and the solidified casting can be removed (Kalpakjian and Schmid, 2006).

Sand casting is used to produce a wide variety of metal components with complex geometries. These parts can vary greatly in size and weight, ranging from a couple ounces to several tons. Some smaller sand cast parts include components as gears, pulleys, crankshafts, connecting rods, and propellers. Larger applications include housings for large equipment and heavy machine bases. Sand casting is also common in producing automobile components, such as engine blocks, engine manifolds, cylinder heads, and transmission cases (Kalpakjian and Schmid, 2006).

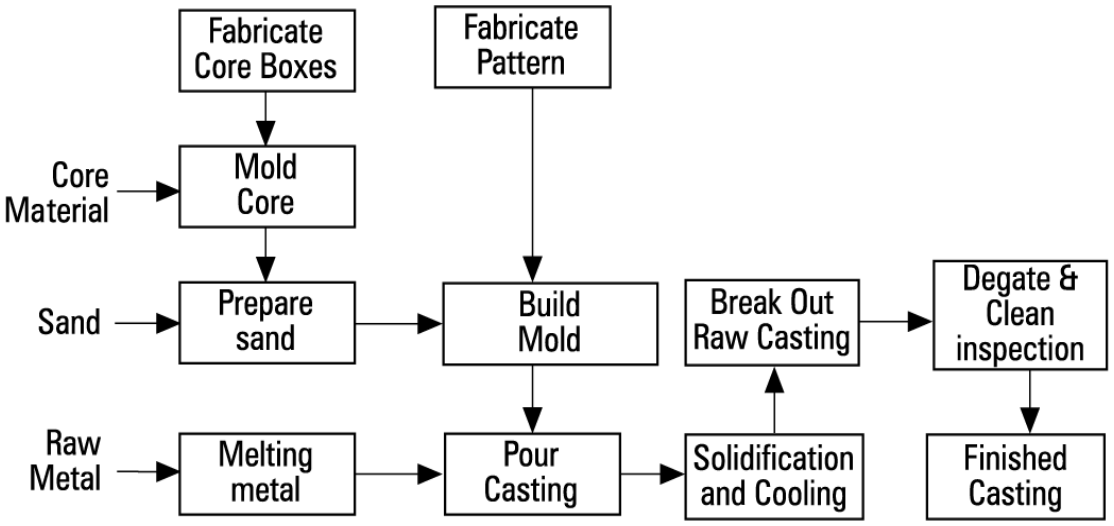

Figure 2.1: The steps in the production sequence in sand casting (Wang, 1995).

2.2 Resin Binder Process

Resin bonded sand casting is the same as sand casting but it is use a resin as a binder in the process. It is also known as chemically bonded sand and no bake process. A wide variety of chemical binders is available for making sand moulds and cores (Brown, 2000). Binders can be used in two way which is a self-hardening mixtures. Sand, binder and a hardening chemical are mixed together, the binder and the hardener start to react immediately. Second is with trigged hardening which is the sand and binder are mixed and blown or rammed into a core box (Brown, 2000). Binders were developed to strengthen the cores, which are the most fragile part of a

mould assembly. Curing of the binder system begins immediately after all components are combined (James and Richard, 1986).

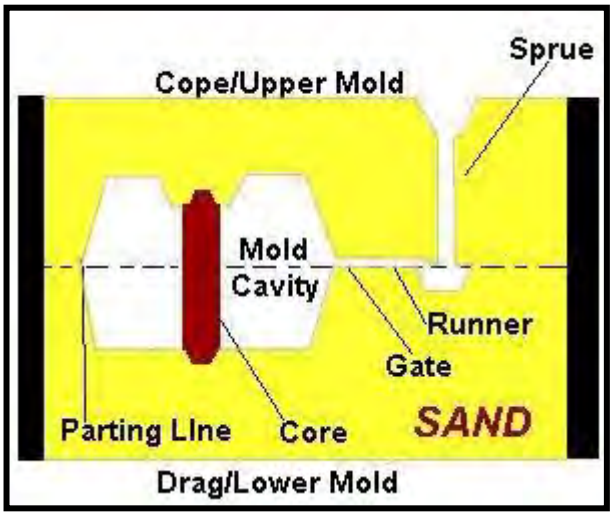

Figure 2.2: Sand is again packed tightly around a wood or metal pattern, but the sand is bonded with a self-setting organic binder. The bonded sand has higher strength and improved dimensional control, compared to green sand (American Foundry Society, 2005).

2.2.1 Binder System Development

In the 1940s, sand cores were made with oven-baked, oil-bonded sand. The moulding processes during this era consisted of green sand for smaller castings and skin-dried green sand or "dry sand" (oven-baked pitch and clay-bonded moulds) for larger castings. The oil sand process was used to construct "core moulds" by fastening sections of cores together in ways that would form moulds. These core moulds produced castings with better dimensional properties than those made in clay-bonded sands.

Following World War II, drastic changes occurred in the core and mould making processes used for casting aluminium. Heat-cured "shell resin" sand systems which produced hollow, shell-like cores and carbon dioxide gas-hardened silicate systems which made the more conventional solid cores were introduced during the 1950s. In the decades that followed, heat-cured hotbox binders, no-bake systems which