UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF BIODEGRADABLE RESIN RATIO ON THE PROPERTIES OF RESIN BONDED SAND FOR 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.)

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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 members of the supervisory committee are as follow:

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ABSTRAK

Penuangan ialah proses pembuatan untuk membentuk bahagian yang kompleks yang menghasilkan bentuk yang hamper siap. Untuk acuan penuangan berikat resin, pasir mestilah mengandungi pengikat (resin) yang bertindak sebagai pengikat pasir bersama. Biasanya, resin deperbuat daripada bahan bukan biodegradasi yang mempunyai masalah pada penambakan dan pelupusan pasir. Lebih dari itu, acuan penuangan berikat resin yang bukan biodegradasi menyebabkan bahaya kepada persekitaran. Untuk kajian ini, kesan nisbah resin biodegradasi (PVA dan urea ubahsuai) pada sifat-sifat acuan pasir berikat resin untuk penuangan akan di analisis. Objectif kajian ini ialah untuk mengkaji kesan perbezaan nisbah dan cadangkan nisbah yang optima untuk resin biodegradasi dan penguat kepada kebolehtelapan dan kandungan kelembapan untuk acuan pasir berikat resin untuk penuangan. Selain itu, proses penuangan dilakukan menggunakan acuan pasir berikat resin yang dimajukan. Reka bentuk factorial penuh dengan tiga tahap dan dua factor digunakan untuk mengkaji tindak balas kandungan kelembapan dan kebolehtelapan dengan interaksi yang boleh. Proses penuangan dilakukan menggunakan nisbah optima untuk memastikan melihat prestasi acuan pasir berikat resin biodegradasi. Kesimpulannya, 3% resin dan suhu 200 ºC ialah nisbah optima untuk acuan pasir berikat resin biodegradasi kerana ianya mencapai nilai piawai setiap tindak balas.

ABSTRACT

Casting is a manufacturing process to form complex parts that produce near net-shape. For resin bonded sand casting mould, the sand must contain some type of binder (resin) that acts to hold the sand particles together. Typically, the resin is made from non-biodegradable materials that have issues on reclamation and disposal of the sand. More than that, the resin of non-biodegradable sand mould cause hazard to the environment. For this study, effect of biodegradable resin (PVA and modified urea) ratio on the properties of resin bonded sand for casting will be analyzes. The objectives of this study are to study the effects of different ratio and suggest the optimum ratio for biodegradable resin and hardener to the permeability and moisture content of resin bonded sand casting mould. Other than that, casting process was performed using the developed resin bonded sand mould. Full factorial design with three levels and two factors was used to study the responses of moisture content and permeability with possible interactions. Casting process was performed using the optimum ratio to ensure and visualize the performance of biodegradable resin bonded sand mould. As a conclusion, 3% of resin and 200 ºC temperature was the optimum ratio for the biodegradable resin bonded sand mould because it achieved the standard value for every response.

DEDICATION

In dedication to my
mother and father
for making me be who I am and supporting me all the way.

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First of all, I am grateful to The Allah S.W.T for the wisdom and perseverance that He has been bestowed upon me during this final year project, and indeed, throughout my life.

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LIST ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

AFS	-	American Foundry Society
ANOVA	-	Analysis of Variance
DOE	-	Design of Experiment
g	-	gram
GP	-	gas permeability
Kg	-	kilogram
kg/cm^2	-	kilogram per square centimetre
MID	-	mid range
mm	-	millimetre
No.	-	Number
P	-	Permeability number
psi	-	pounds per square inch
PVA	-	Polyvinyl Alcohol
R_a	-	roughness average
S.H.S.	-	super hybrid sensor
SPWG	-	Static Pressure Water Gauge
Std	-	standard
µm	-	micrometre
W	-	Watt
WMSB	-	water soluble modified starch binder
%	-	percent
ºC	-	degree Celcius
°F	-	degree Fahrenheit

CHAPTER 1

INTRODUCTION

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

1.1 Background

Sand casting is the most widely used casting process, utilizes expendable sand moulds to form complex metal parts that can be made of almost any type of alloy. In conventional sand casting, the mould is formed around a pattern by ramming sand, mixed with proper bonding agent. After that, molten metal is poured into the mould. The mould will be broken when the molten metal has been solidified.

The quality of sand casting is influenced by its properties such as compression strength, shear strength, permeability, moisture content and others, which are depends on the composition ratio of the sand mould. The relations of these properties with the input parameters such as grain size, type of binder, and others. For this reason, in sand casting, the sand must contain some type of binder that acts to hold the sand particles together. By using a systematic method, a proper design of experiment can be used to evaluate how the parameter of resin ratio and hardener will effect on the strength of sand casting mould. Binders were developed to improve strength of the cores, which are the most fragile part of a mould assembly. Inorganic

binders, such as clay or cement, are the materials that had been used in the production of foundry moulds and cores.

Combination of PVA and modified urea as a resin is a new biodegradable binder that to be used in the study. Effect of resin ratio on the properties of resin bonded sand for casting mould will be studied by using the PVA and modified urea resin, heat as hardener and also silica sand.

1.2 Problem Statement

Sand casting has been developed over many years with various size and shapes depends on the application such as engine block, automotive components, crankshaft, power strains and many others. Therefore, sand casting dominates above 90% of the other type of casting process (Shi and Wang, 2010).

Resin bonded sand is often referred as "no bake" sand, because it will harden at room temperature without heat. Resin bonded sand is created by bonding polymeric resin with silica sand. Nowadays, resin bonded sand casting use alkaline resins as the binder. Typically, the resins are made from non-biodegradable materials that have issues on reclamation and disposal of the sand. More than that, the resin of non-biodegradable sand mould cause hazard to the environment (plants and animals). Hussein et al. (2013) had been identified a new biodegradable resin bonded sand casting which is a combination of Polyvinyl Alcohol (PVA) with modified urea.

For this study, effect of biodegradable resin (PVA and modified urea) ratio on the properties of resin bonded sand for casting will be analyzes. Properties of resin bonded sand will be test by using several tests such as permeability test and moisture content. Moisture content study had been done by Abdullah (2013). Composition of moulding sand will affects the mould properties and thus the quality of the finished castings.

1.3 Objectives

The objectives of this study are:

(i) To study the effects of different ratio for the biodegradable resin and hardener to the properties of resin bonded sand casting mould that are permeability and moisture content.

(ii) To suggest the optimum ratio of biodegradable resin and hardener for the resin bonded sand casting mould.

(iii) To perform casting process using the developed resin bonded sand mould.

1.4 Scope

The research investigates on the resin bonded sand casting that uses silica sand as the base, PVA and modified urea as binder, and heat as the hardener. Parameters selected that will affect the quality of the sand mould are the percentage of resin and hardener. Range of resin that will be used is 2% - 3% while the values of the hardener are 150℃, 175℃, and 200℃. Design of experiment that will be used for this study is full factorial method. After the process, a detail study will be performed on the mould based on the characteristics of permeability and moisture content. During all the tests, the data required will be collected and further discussion is to be made obtain an accurate result or conclusion.

Chapter Summary

This chapter discussed the information about the purpose of the study on the biodegradable resin bonded sand casting that included the problem statement, objective and scope of the research area. Further information will be discussed in the following chapter.

CHAPTER 2

LITERATURE REVIEW

This chapter describes 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 process. The purpose to have this literature review is to offer an overview of significant literature published on the related topic.

2.1 Sand Casting

Casting is a process of pouring molten metal or alloy into a mould and allowing it to solidify. The most common productive method of the casting process is sand casting. Sand casting also known as sand moulded casting is a metal casting process that use sand as the mould material. Sand casting dominates above 90% of the other type of casting process. Sand casting has been developed over many years with various size and shapes depends on the application such as engine block, automotive components, crankshaft, power strains and many others.

The conventional sand casting produces products with low accuracy and poor surface quality. Moreover, it used to produce a lot of metal materials waste and also increase processing cost and even result low efficiency and poor economic. For a long time, foundry workers improved the casting dimension accuracy and surface quality to reduce the processing workload of the follow-up processes (Shi and Wang, 2010).

Nowadays, automated process-control system and advanced machinery have replaced the traditional method of casting. There are two trends that give major impact on the casting industry. The first is automation and mechanization of the casting process which led to the changes of labour and equipment. The second major trend increased the demand of casting with high quality and close dimensional tolerances (Kalpakjian and Schmid, 2010).

2.1.1 Principle

Basically, there are three general steps of sand casting which are fabrication of pattern, making the mould, and pouring of the raw materials. The Figure 2.1 below show the production steps in a typical sand casting operation.

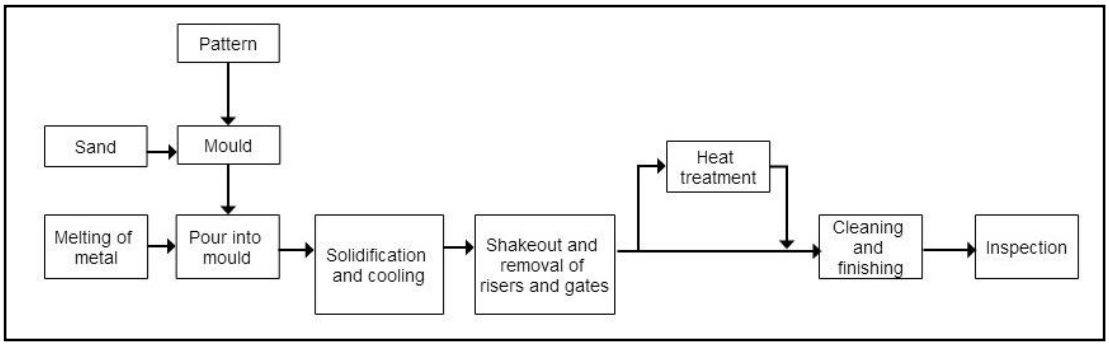

Figure 2.1: Outline of production steps in a typical sand casting operation

After solidification, the casting's products are shaken out of its mould. Then, vibration (shaker) or sand blasting method is used to remove the oxide layer from the casting. The castings are also cleaned by blasting with steel shot or grit (shot blasting). Gates sand risers on the casting can be remove by sawing, shearing, abrasive wheels, oxyfuel-gas cutting, carbon-arc cutting, torches or trimmed in dies. For further cleaning purpose to remove surface oxide from the castings, electrochemical or pickling with chemicals method may be used. After further cleaning process, castings may be heat treated to improve certain properties necessitated for its intended purpose. Finishing operations such as straightening, machining or forging are to obtain final dimensions. Final step is inspection which is important to ensure that castings meet all the requirements needed operation (Kalpakjian and Schmid, 2010).

2.1.2 Composition

A sand mould normally consists of 90% sand, 7% clay, and 3% water. These materials are refractory, means that they are capable to withstand high temperature of molten metal. The mould need to broken up in order to remove the casting after the casting has been solidified (Kalpakjian and Schmid, 2010).

Organic and inorganic bonding agents can be used in place of clay. Sometime, additives (catalysts or hardeners) are combined with the mixture of sand and binder to enhance properties such as the strength of the mould (Ammen, 2000).

2.1.2.1 Sand

Sand is defined as granular particles resulting from the disintegration or crushing of rocks. Good sand must be readily mouldable and able to produce defect-free castings. Moreover, moulding sand is ordinarily quite inexpensive (Ammen, 2000). The most commonly used sands in the foundry industry are silica, olivine, zircon and chromate.

Silica sand is the most commonly used in the industry because consists of mineral quartz which makes it as a good refractory material up to 1650 °C. For green sand production, a good base sand with four sieve distribution gives far better results than which has a widely dispersed grading on one or two sieves. Naturally bonded sands exhibit greater variability in their properties compare to synthetic sands (Chakrabarti, 2005).

2.1.2.2 Clay

Clay plays the role to improve the bonding strength of moulding sand so that after ramming, the mould does not lose its shape. Nevertheless, the permeability of the mould is reduced when the quantity of the clay is increased. Clay consists of two materials which are fine silt and true clay. Actually true clay provides the necessary bonding while fine silt has no bonding power.

The most common type of bonding clay used with silica sands is bentonite in which to increase the bonding power and impart plasticity. Furthermore, bentonite functions to oppose erosion of moulds and its volumetric contraction helps in compensating the expansion of silica grains (Jain, 2009). Features of resin-bonded sand casting mould is clearly illustrate in Figure 2.2.

2.1.3 Mould

Sand moulds are characterized by the types of sand that comprise them and by the method to produce them. Fundamentally, a mould is produced by shaping a refractory material to form a cavity of desired shape such that molten metal can pour into the cavity. The mould cavity need to retain its shape until the metal has solidified and the casting is removed.

The mould must be meet several requirements:

- Strong enough to sustain the weight of the molten metal
- High permeability to permit any gases formed within the mould to escape into the air
- Resistance to erosive action of molten metal during until the casting is solid
- Collapsible enough to permit the metal to contract without undue restraint during solidification
- Able to cleanly strip away from the casting after the casting has sufficiently cooled
- Economical, since large amounts of refractory material are used