UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF RESIN RATIO AND BAKING TEMPERATURE TO THE PROPERTIES OF BIODEGRADABLE RESIN BONDED SAND CASTING MOULD

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

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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

Tuangan pasir adalah proses melebur logam dan dituang ke dalam ruang atau rongga yang dibentuk terlebih dahulu, yang dipanggil acuan, membolehkan logam mengeras dan kemudian dipecahkan acuan tersebut untuk mendapatkan produk tuangan. Pasir mestilah mengandungi pengikat (resin) yang berfungsi untuk memegang dan menghubungkan zarah-zarah pasir supaya acuan pasir cukup kuat apabila logam lebur dituang ke dalamnya. Biasanya, resin tersebut diperbuat daripada bahan tidak biodegradasi yang akan menimbulkan isu-isu seperti reklamasi dan pelupusan pasir tersebut. Tambahan pula, resin yang tidak biodegradasi akan membahayakan alam sekitar. Terdapat dua jenis resin biasa digunakan dalam industri tuangan pasir iaitu resin furan dan fenolik. Dalam kajian ini, kesan nisbah resin yang biodegradasi (PVA dan urea yang diubahsuai) dan suhu pembakar terhadap sifat-sifat pasir akan dikaji. Terdapat tiga eksperimen yang dijalankan dalam kajian ini iaitu ujian kekuatan mampatan, ujian kehilangan pada pencucuhan (LOI), dan kebolehtelapan. Nisbah resin dan suhu pembakar akan menjadi parameter atau faktor-faktor dan nilai kekuatan mampatan, kehilangan pada pencucuhan (LOI), dan kebolehtelapan akan menjadi jawapan atau nilai yang akan di analisa. Terdapat tiga peringkat bagi setiap parameter iaitu 3%, 3.5%, dan 4% bagi nisbah resin dan 150°C, 175°C dan 200°C bagi suhu pebakar. Di akhir experimen ini, maklumat yang dikumpul kemudiannya ditukar ke dalam bentuk grafik iaitu carta bar, plot kesan utama, dan plot interaksi untuk mendapatkan nisbah yang terbaik bagi process tuangan pasir yang terbiodegradasi. Kesimpulannya, cadangan disertakan pada akhir kajian untuk penambahbaikan kerja masa depan.

ABSTRACT

Sand casting is a process of melting the metal and pouring it into a preformed cavity, called mould, allowing the metal to solidify and then breaking up the mould to remove casting. The sand must contain a binder (resin) that works to hold the sand particles together so that the sand mould is strong enough when the molten metal is poured into it. Typically, the resin is made from non-biodegradable materials that have issues on reclamation and disposal of the sand. Furthermore, the resin of non-biodegradable sand mould cause hazard to the environment. There are two types of resin commonly used in sand casting industry which are furan and phenolic resin. In this study, the effect of biodegradable resin (PVA and modified urea) ratio and baking temperature to the properties of resin bonded sand for casting were investigated. There were three experiments conducted during this study which are compressive strength test, loss on ignition (LOI) test, and permeability. The resin ratio and baking temperature as the parameters or factors and the value of compressive strength, loss on ignition (LOI), and permeability as the responses. There were three levels for each of the parameters which are 3%, 3.5%, and 4% for resin ratio and 150°C, 175°C, and 200°C for baking temperature. At the end of the experiment, the collected data was then converted into graphical form which consist of bar chart, main effect plot and interaction plot. As a conclusion, recommendation is included at the end of the study for future work improvement.

DEDICATION

To my family, my friends and to anyone who gives support and help.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

a	-	Cross-sectional area
AFS	-	American Foundry Society
ANOVA	-	Analysis of Variance
ºC	-	Degree Celcius
ºF	-	Degree Fahrenheit
DOE	-	Design of Experiment
g	-	Gram
g/cm³	-	Gram per centimetre cube
Gp	-	Gas permeability
h	-	Height
Kg	-	Kilogram
kg/cm²	-	Kilogram per square centimetre
LOI	-	Loss on Ignition
MID	-	Mid range
ml	-	Mililiter
mm	-	Millimetre
mm Hg	-	Milimeter mercury
mm/min	-	Milimeter per minute
N	-	Newton
No.	-	Number
%	-	Percent
P	-	Permeability number
ρ	-	Pressure
Psi	-	Pounds per square inch
PVA	-	Polyvinyl Alcohol
Ra	-	Roughness average
S.H.S.	-	Super hybrid sensor
SPWG	-	Static Pressure Water Gauge

Std	-	Standard
σ	-	Stress
t	-	Time
W	-	Watt
WMSB	-	Water soluble modified starch binder
V	-	Volume

CHAPTER 1
INTRODUCTION

This chapter reports the general information about the subject field of the process or procedure in resin bonded sand casting with abbreviated introduction to the background of subject field area. The elements which are included in this chapter are problem statement, objective and scope.

1.1 Background

In production of metals with variety of geometries or shapes, there are various method or processes to be done in this matter. Metal forming is a process which are characteristics in that the metal being processed is plastically deformed to shape it into a desired geometry (The Library of Manufacturing, 2009). A simple metal geometries can be found like solid sphere (ball bearing), fixed square (machines base), cylindrical (flag pole), and also metals which seems difficult to be formed or complex shapes. For automotive components for example gear box and engine block. All of these component consist of a combination of several geometries that make it too complex to be produced. As a major advantage than any other metal forming processes, metal casting process is more suitable which has the possibility of obtaining part of complex geometries economically.

Casting is a common process in metal manufacturing industries. Casting, the products of the metal founding industry, are manufactured in a single step from liquid metal without intermediate operation of mechanical working such as rolling of forging. This process involves molten metal being poured into a mould which contains cavity of the desired geometry or shape and then allowed to cool and solidify. There are several types of basic metal casting that are available in industries which is sand casting, green sand casting, die casting, plaster mould casting, shell mould casting, slush casting, etc.

In making of the mould, green sand is used due to its low cost than others (Rao, 2009) which contain 90% silica sand, 7% clay and 3% of moisture or water. Green sand is blended or mixed with the developed resin (PVA and modified urea) in resin bonded sand casting. The mixture (sand + resin) will chemically react each other where the resin will polymerized around the sand particles and produce bonding between the sand particles (Sharma, 2007). Phenolic and furan are the common resin which has been used in industry right now. These type of resins does not need any heat or temperature because they will strengthen the sand without baking process (Iyer, 1987).

Cores is the most fragile part of a mould assembly. In order to strengthen the cores, binders were developed in this case. Binder is another most important elements in the sand mould (Paul *et al.* 2007). In the production of foundry moulds and cores, the content may has an organic binders such as cement or clay (Richard, 1986). In this case study, an organic binder is being used which contain PVA and modified urea. Polyvinyl alcohol work to prevent the active ingredient from moisture and oxygen while simultaneously masking their taste and odour (Saxena, 2004).

Heat or temperature is being used as a hardener because the hardener for biodegradable resin was not found. Sand testing is a basic to understand the properties of the resin bonded sand mould. The most important sand testing includes strength, compressive, transverse, permeability, moisture and loss on ignition (LOI). In this case study, compression, transverse, and tensile testing and loss on ignition were applied.

1.2 Problem Statement

Resin bonded sand casting nowadays become one of the most versatile among the sand casting processes. In order to produce or manufacture variety of metal component with complex geometries, many industries using sand casting process. Resin is one of the important elements in sand casting process. Resin is added to a base sand to bond the sand particle together to gain and increase strength and permeability. The parameter setting will effects the condition and characteristic of the sand mould.

In foundry industries, the waste generated after the casting process is called waste foundry sand. Depending on the mould composition and the casting process, waste foundry sand may contain substance that prevent its direct emission to the environment (Liang and Tsay, 2010). This problem is cause by the chemical properties of the sand mixture including the resin itself. Not all types of resin can be disposed to the environment. Modern synthetic resins such as phenolic and furan are made from fossil sources, are not biodegradable and can only be burned under strict precautions due to the release of toxic substances (ScienceDaily, 2011).

In production aspect, the recycling of this waste is limited because its characteristics change significantly after use. Sand castings generate more solid waste than permanent mould due to the sand fines, which cannot be reused. The sand that has been mixed with binders still can be used again (Hussein, 2014). But in terms of cost in order to reclaim the sand before it can be used again, it may be too costly (SIRIM, 2014). Therefore, the biodegradable resin that has been developed from previous study which is PVA and modified urea is being used in this study.

1.3 Objectives

Objectives of this study are:

i) To establish a design of experiment (DOE) in resin bonded sand casting process

ii) To study the effect of resin ratio and baking temperature to the properties of sand mould

iii) To suggest the optimum set of parameters based on targeted propertied of sand mould.

1.4 Scope of Study

This study intensify on resin bonded sand casting procedure by using basic materials such as silica sand, binder (PVA and modified urea), and hardener (heat). All of these materials are mixed together with two types of parameter which is resin ratio and baking temperature and within nine sample. The range of resin used is 3% - 4% of weight of sand used and the value for temperature used is 150°C, 175° and 200°C. Next is, put the sand mixture into the mould that has been prepared with three different patterns for mechanical testing which is tensile, compressive and transverse testing and also loss on ignition (LOI) and after that the mould is place inside the furnace for three different temperature that has been stated. After all the process has been done, data were collected for the value of tensile, compression and transverse testing and loss on ignition (LOI) for further discussion to attain final conclusion.

CHAPTER 2
LITERATURE REVIEW

This chapter will interpret the significant case on resin bonded sand casting based on books, articles and other source of information. This chapter also discuss about the process involve, types of testing, material used and the characteristic of the material.

2.1 Sand casting

Sand casting is one of the process on producing metal components in metal industry. More than 70% of all metal casting are produce by sand casting process (Rao, 2003). This process is done in the foundry. Facilities inside the foundry commonly used to produce components from the cast iron, steel, copper, alloy etc. Sand casting process involve of pouring molten metal or alloy into a sand mould and allowing it to solidify (Ammen, 1979). Moulding materials and equipment are cheap. Sand casting can be divided into three process that is fabrication of pattern, making of the mould and pouring of the molten material (Hussein, 2013). The basic components in the sand casting involve the furnace, silica sand, metal, and pattern. Sand casting is universal and mostly used in metal casting process. The example of products from sand casting process are automotive components, machinery parts, construction machinery, valve body and plumbing fixture (Flood, 2000). There are variety of shapes and geometries can be done through this process even the complex shapes.

The pattern are usually made by metal, plastic and wood (Rao, 2009). Due to easy availability, low cost, and low weight, the pattern made by wood are commonly used in industry and also easy to shape (Rao, 2009).

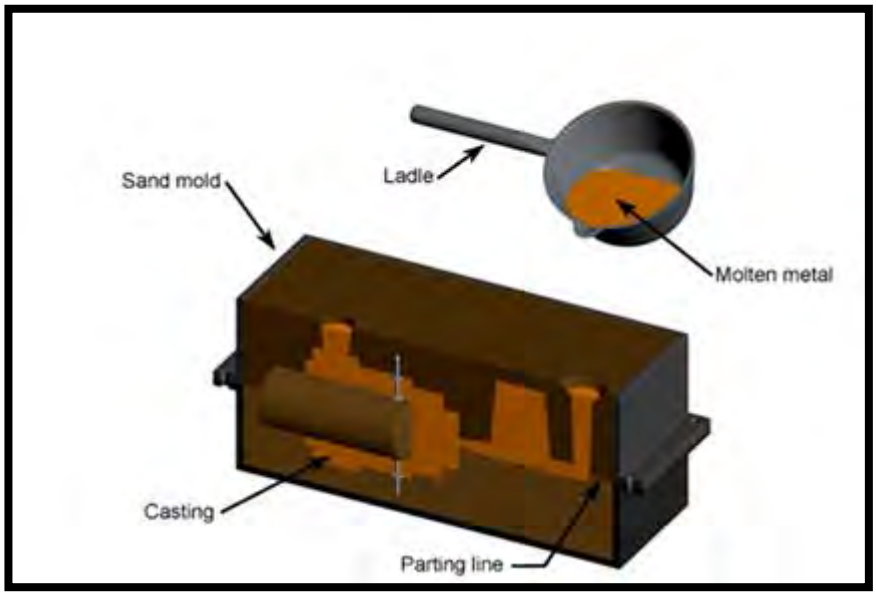

Figure 2.1: Illustration of sand mould pouring process (Custompart.net, 2009)

Figure 2.1 shows that the schematic illustration of sand casting. The metal in being heated until melt then poured into prepared mould. The molten metal will fill up the cavity inside the mould then leave to cold and solidify. After the molten metal inside the cavity is solidify, the sand will be removed to get the casting product. The steps are shown in Figure 2.2.

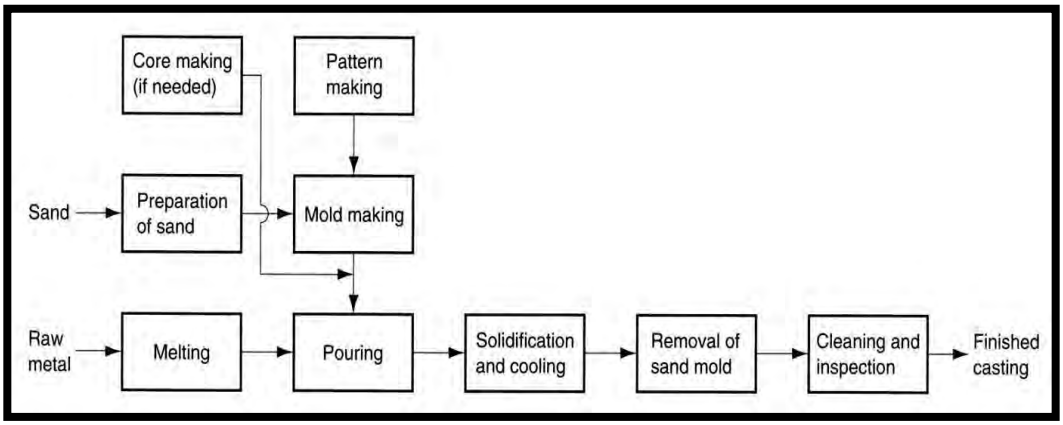

Figure 2.2: Steps in production of casting product (Wang, 1995)

2.2 Resin bonded sand casting

Resin bonded sand casting is also known as chemically sand bonded and require no bake process. This type of sand casting is same like the ordinary sand casting but require resin as a binders. Binders give chain or bond, strength and cohesion to the sand during mould ramming to ease the shaping process and retain it shape under pressure, temperature and erosion of liquid metal during pouring process (Hussein, 2013). The common resins used in sand casting industry are phenolic and furan. Curing of the binder begins immediately after the combination of all the components are done (James and Richard, 1986). Binders can be used in two styles which is first, is a self-hardening mixture. The reaction of the hardener to the mixture of sand and binder will immediately react. The second style is the mixture of sand, binder and hardening chemicals are rammed into a core box (Brown, 2000). (Nigbo Ruican machinery Company, 2010) stated that, resin bonded sand casting has better dimensional accuracy of a cast product rather than green sand casting product.

2.2.1 Sand

Sand is described as granular particle resulting from the come from disintegration or crushing of rocks such as olivine, chromite, zircon and silica. In sand casting industry, silica sand (SiO^2) is the most commonly used because of good refractory materials up to 1650°C (Chakrabarti, 2005). Sand with high silica content are essential to attain good refractory properties of moulding or core sand mixture and this is especially important for steel casting. Naturally bonded sand are sometimes used in nonferrous foundries a good sand with four sieve distribution gives far better results for green sand production rather than one which has a widely dispersed grading or peaks on one or two sieve.

Table 2.1: Sintering Point of Respective Sands

Sand	**Sintering Point (°C)**
High silica sand (>99% quartz)	1450
Medium purity silica sand (96% quartz)	1250
Sea sand	1200
Natural clay bonded sands	1050-1150

Based on Table 2.1, these sand contain a percentage of indigenous clay and are normally delivered in the damp condition. Sand with low sintering point normally produce poor surface finish on iron and steel casting.

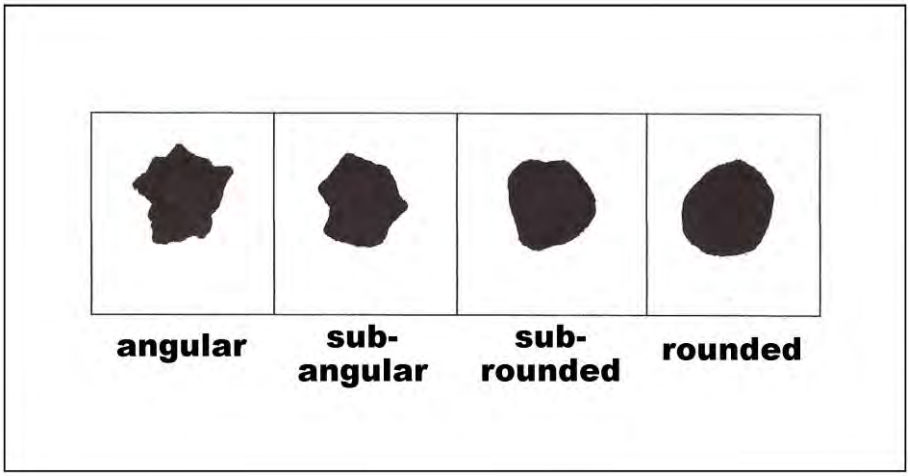

Figure 2.3: Different types of sand grain

Based on Figure 2.3, rounded grain give good permeability, compact easily and maximum flow ability and this will give advantages in mechanized core production. The least amount of binder and compact to a high density required for rounded grain. The increase of sand angularity, the increase of binder required to maintain a desired tensile strength value (Chakrabarti, 2005). A moulding sand is supposed to pass possess properties for its efficient functions. The properties are depend upon, cohesiveness, resistance to high temperature, permeability, grain size distribution, types of binders, moisture and additive.