# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## OPTIMIZATION OF MOULDING COMPOSITION FOR QUALITY IMPROVEMENT OF SAND CASTING

This report is submitted in accordance with the requirement of
Universiti Teknikal Malaysia Melaka (UTeM) for
Bachelor's Degree of Manufacturing Engineering Technology (Product Design)
with Honours

by

**NG SHU JUAN**
**B071210036**
**920426-01-5050**

FACULTY OF ENGINEERING TECHNOLOGY
2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: **OPTIMIZATION OF MOULDING COMPOSITION FOR QUALITY IMPROVEMENT OF SAND CASTING**

SESI PENGAJIAN: **2015/16 Semester 2**

Saya **NG SHU JUAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TERHAD (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TIDAK TERHAD

Disahkan oleh:

Alamat Tetap:

33, JALAN BISTARI 1/7,

TAMAN YAYASAN,

85010 SEGAMAT, JOHOR.

Tarikh: 18TH DECEMBER 2015

Cop Rasmi:

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

# DECLARATION

I hereby, declare that this thesis entitled "Optimization of Moulding Composition for Quality Improvement of Sand Casting" is the result of my own research except as cited in references.

Signature : ……………………………………………

Name : ……………………………………………

Date : ……………………………………………

# APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as one of the requirements for the award of Bachelor's Degree of Manufacturing Engineering Technology (Product Design) with Honours. The following are the members of supervisory committee:

………………………………………………

(Supervisor)

………………………………………………

(Co-Supervisor)

# DEDICATION

To my parents,

Ng Lian Kern and Tay Sew Eng

raising me become who I am today.

# ABSTRAK

Tuangan pasir merupakan proses pembuatan yang digunakan secara luas dalam industri tuangan. Cara tuangan ini adalah sesuai digunakan untuk kebanyakan jenis logam dan pasirnya boleh dikitar semula. Walaubagaimanapun kecacatan dalam hasil tuangan, seperti  lubang hembus, lubang pin, susutan dalaman dan keliangan telah menyebabkan ketidaksempurnaan acuan tuangan pasir. Tujuan projek ini adalah untuk mengoptimumkan komposisi pasir silika, tanah liat, air dan serbuk arang batu dengan cara $2^4$ faktorial eksperimen bagi mengurangkan impak kecacatan produk tuangan. Impak daripada komposisi berlain yang direka pada kebolehtelapan, daya mampatan, daya tegangan dan daya ricih telah dikaji. Analisis yang telah dijalankan dalam perisian Design Expert mengenalpastikan bahawa interaksi antara tanah liat dan air adalah punca utama dalam ketiga-tiga eksperiment berikut. Komposisi spesimen pasir yang optimum, iaitu, 100g pasir silika, 21g tanah liat, 6.5g air dan 6g serbuk arang batu telah dikenalpasti. Nisbah yang dicadangkan bagi jumlah jisim pasir lembap hijau adalah 68: 14: 4: 4. Komposisi ini memberi kebolehtelapan 598.3 GP, daya mampatan sebanyak 26 $kN/m^2$ dan daya ricih sebanyak 20 $kN/m^2$.

# ABSTRACT

Sand casting is a versatile and common used manufacturing process in metal casting industry. This method can be used in almost all types of metal and the sand is recyclable. However the defects in casting product such as blowholes, pinholes, shrinkage and porosity cause imperfection in green sand mould. The aim of this project is to optimize the composition of silica sand, bentonite, water and coal dust in green sand to reduce the defects in the casting products using $2^4$ factorial experiment design method. The effect of composition of green sand on permeability, green compression strength, and shear strength was investigated. Analysis of Design Expert software identified that bentonite and water are the main interaction effect in all the experiments. The optimal settings for green sand composition are 100g silica sand, 21g bentonite, 6.5g water and 6g coal dust, whereby the ratio of their weight contents in a 150g green sand is 68: 14: 4: 4; this composition has an effect of permeability number 598.3 GP, compression strength 26kN/$m^2$ and 20 kN/$m^2$ for shear strength.

# ACKNOWLEDGEMENT

Firstly I would like to express my utmost gratitude and appreciation to my supervisor, Mr. Mohamad Ridzuan, who has guided and encouraged me along this semester. The supervision and supports from him is truly helping the progression of my project. I had been exposed very much in sand casting especially in the role of sand constituent which is very helpful information for the project. Besides I would like to thank my co supervisor, Ms. Rahaini, for her teaching in the design of experiment. This is the most important part for my project whereby the parameter design is all taught by her. With her favour I am able to interpret data analyses from the software.

The utmost appreciation also goes to family. With their love and encouragement, I am tough to go through the obstacles come to me. Last but not least I would like to thanks all my friends especially who has helped me in every possible way to complete this project. I would like to express my appreciation to technician in foundry laboratory, Mr Syafiq, who had helped me in the laboratory session. I would like to thanks to the Universiti Tun Hussein Onn Malaysia (UTHM) which has allowed me to conduct my experiments in the foundry lab.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVATIONS, SYMBOLS AND NOMENCLATURES

| | | |
|---|---|---|
| $SiO_2$ | - | Silicon Dioxide |
| AFS | - | American Foundry Society |
| Ca | - | Carbon |
| Na | - | Sodium |
| $CO_2$ | - | Carbon Dioxide |
| USSM | - | Universal Sand Strength Machine |
| ANOVA | - | Analysis of Variance |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Sand casting is the most widely used casting process until today as the low cost of raw materials, wide variety of castings in size and compositions and its moulding sand is recyclable. This is one of the most adaptable processes in manufacturing because it can be used for most high melting temperature metals and alloys such as non-ferrous and ferrous metal. Sand casting is a process of making a mould in sand mixture and then pouring liquid metal into sand cavity, allowing it to solidify and then breaking away the sand mould to remove the cast product. The sand composition that is used in casting is known as green sand which is the combination of silica sand, coal powder, clay powder (bentonite) and water. The sand mould plays an important role in sand casting process and helps to remove the gases in moulded part during the process. Therefore a maximum permeability must be achieved and hence helps to remove gases in mould through the sand grains. Permeability is the measure of the flow capacity of a porous media to emit gases from an object. In this project, Design Expert will be the main media to evaluate the efficiency of the flow capacity of the sand mould. This software helps to locate the ideal process for top performance and discover the optimal product formulations and the vital factors in the process.

## 1.2 Problem Statement

From the combination of silica sand, coal powder, clay powder (bentonite) and water, each of them plays an important role respectively to reduce and control defects in castings. Defects may occur when any one of the component is out of the optimum value. First of all, the common defect is blowhole, which is happened when the gas is trapped in the metal during solidification. Besides the permeability will be decreasing as the grain size is decreasing. In another words, finer sands will decrease the permeability value. Water helps to hold the clay together and hence produce the strength of sand mould. The value is depending on the proportion of clay, it is a compulsory to achieve an optimum value of water to avoid the clay becomes too soft and loses the bonding.

## 1.3 Objectives

i. To evaluate the performance of green sand specimens with different composition on permeability, compression strength and shear strength.
ii. To investigate the optimum value of bentonite with respect to the amount of water.
iii. To establish the mathematical model for permeability, green compression strength and shear strength.
iv. To optimize the best composition of green sand to minimize the occurrence of defects.

## 1.4 Scope

i. Ratio of water to clay is started at 1:3.
ii. Green compression strength is to achieve 30-160 kPa.
iii. Green shear strength is to achieve 10-50 kPa.
iv. Design expert software is used to analyze the effectiveness of new composition of green sand.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Green Sand

Green sand is a combination of silica sand, clay powder, coal dust and water. It is also known as tempered sand. Due to the moisture content in the sand, it is known as green sand whereby the word "green" is representing the mould, which is tempered with water, is not dried or baked (Walton et al, 1981). A typical green sand mixture contains about 85% silica sand, 9% clay, 3% water and 3% organic additives (Seidu & Kutelu, 2014). However natural sand contains silica sand, clay substances and water, they can be founded easily from natural resources like deserts, seas, lakes or rivers. Another typical composition of green sand is made up of 50 to 60% of natural sand from rivers, 12 to 15% of clay, 5 to 15% coal dust and 4 to 6% water.

The sand will undergo a "mulling" process whereby the clay acts as a binder in the sand, which will produce a suitable composition for sand moulding process. This sand mixture is first compressed around the pattern at specific pressures and temperatures to ensure it will maintain its shape of the casting process required. The sand is compact around the pattern, which is following the desired casting. In general, the moulding pressure is about 7 to 40 $kg/cm^2$ and the mould is required to have a hardness of at least 90 (Matsui, 1980). Moulding sands are required to possess properties that able to be tempered and formed into certain desired shapes. The green sand must be able to withstand a temperature from the pouring metal to avoid fusion takes place. Small and medium sized castings of ferrous and nonferrous metals are made in this sand as it is the least expensive foundry sand and takes less time in making the mould ready for casting (Kaushish, 2010).

### 2.1.1 Silica Sand

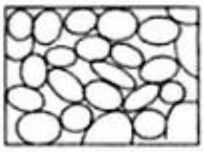
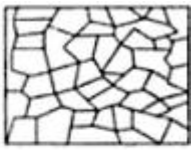
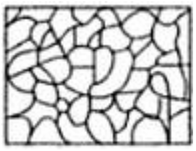
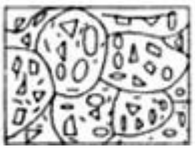
Silica sand is used primarily because it is readily available and inexpensive. Silica sands (silicon dioxide, $SiO_2$) are very refractory and usually contain a small amount of organic component. The silicon oxide is characterized by having very high softening temperature and thus having high thermal stability. The grains of silica sand will not melt and fuse together easily, they will not split into smaller particles when they contact with molten metal (Johnson, 1984).

However silica sand is not suitable to be used singly for moulding purpose because it lacks of binding properties. Therefore silica sand must be composed with bentonite and other constituents to achieve the binding property. The grain size of silica sand determines the permeability and refractoriness of green sand, the finer the silica sand, the poorer the permeability and refractoriness of the green sand. Silica sand of AFS grain size 50-60 is usually used in green sand composition. The size of sand grains varies considerably over a wide range from 50 microns to 3360 microns and accordingly the sand are classified as fine, medium or coarse grained (Kaushish, 2010). The shape of sand grains can be categorized into angular, round, sub-angular or compounded. Table 2.1 shows a brief of each type of grains shape. The best foundry sands have grains shapes which are rounded with medium to high sphericity.

Table 2.1 Properties of non-silica sands (compared with silica) (Brown, 1994)

| Property | Silica | Zircon | Chromite | Olivine |
|---|---|---|---|---|
| AFS grain size no. | 60 | 102 | 74 | 65 |
| Grain shape | Rounded | Rounded | Angular | Angular |
| Specific gravity | 2.65 | 4.66 | 4.52 | 3.3 |
| Bulk density($kg/m^3$) | 1490 | 2770 | 2670 | 1700 |
| ($lb/ft^3$) | 93 | 173 | 167 | 106 |
| Thermal expansion 20-1200°C | 1.9% Non-linear | 0.45% | 0.6% | 1.1% |
| Application | General | Refractoriness Chill | Resistance to penetration Chill | Steel |

Table 2.2 Classification of grain shape of sand

| Grain shape | Characteristics |
|---|---|
|  Round | • Poor strength to mould<br>• High permeability |
|  Angular | • Better strength<br>• Reduced permeability |
|  Sub-angular | • Less permeable than rounded grains |
|  Compounded | • Hard lumps<br>• Undesirable for moulding sand |

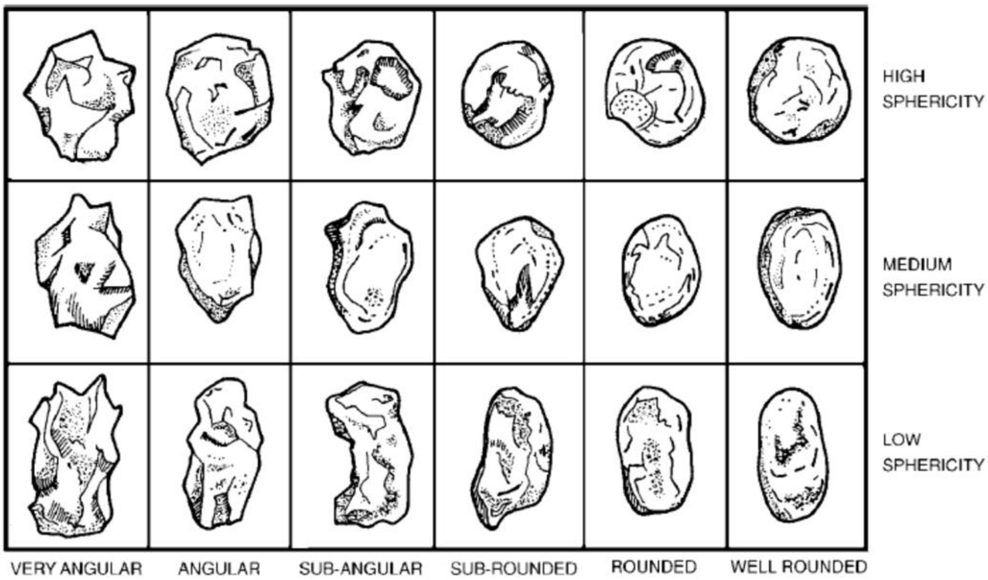



Figure 2.1 Classification of grain shapes (Altan, 2001)

### 2.1.2 Clay powder (Bentonite)

Bentonite acts as a binder in green sand, it gives cohesiveness and strength to the sand to maintain the shape of mould cavity after the pattern is removed. Generally bentonite fits the water molecules between the layers which cause the inner structural water. By increasing the weight percentage of clay, it will increase the strength, hardness and toughness of sand but flow ability and permeability of sand are also reduced. However the moisture content of green sand is extremely decisive on nearly all physical properties in foundry. Figure 2.2 shows how the influence of bentonite content in green sand is to its strength.

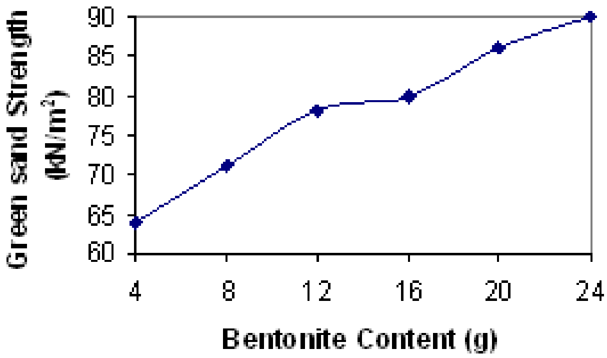



Figure 2.2 Influence of bentonite content in green sand strength (Aramide, 2011)

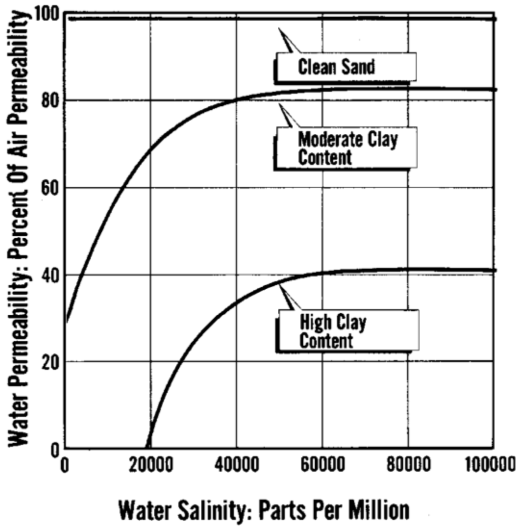



Figure 2.3 Variation in water permeability with salinity and clay content (CoreLab, 1983)

There are two types of bentonite, Calcium (Ca-type) and Sodium (Na-type) bentonite. Na-type bentonite able to expand to a greater size of 10 to 20 times its original by absorbing moisture and then swelling, therefore it has a greater state of disaggregation, and hence larger surface area of the particles in mould sand is developed. Besides, Na-type bentonite has a higher fire resistance that prevents cutting and erosion of mould when molten metal passes over it. However, Na-type is slow in hydration speed. It is dispersed in the moulding sand in heterogeneous suspended state and it takes a long time to obtain a uniform green strength. Therefore, the sand must not be too soft. Ca-type bentonites have higher property as bonding agents in moulding sand. Among the mineral binders, considering the small amount of bentonite to implement optimum strength, Ca-type bentonite has higher green compression strength and permeability.

By mixing both calcium and sodium bentonites, a favourable strength of green sand throughout all phases of casting process can be achieved and the mixture is kept to be compatible with the other components of green sand (Clem, 2010). Table 2.3 shows the sand characteristics with respect of weight content of bentonite types in the green sand. Wet tensile strength and hot properties of bentonite will affect the sand erosion, inclusion and expansion of scabs. When the hot property is increased, the energy required to remove sand from solidified cast part is higher, thus increasing the potential for broken and cracked castings.