Faculty of Manufacturing Engineering

AN INVESTIGATION OF SODIUM SILICATE ADDED MALACCAN RED CLAY FOR SLIP CASTING PROCESS

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AN INVESTIGATION OF SODIUM SILICATE ADDED MALACCAN RED CLAY FOR SLIP CASTING PROCESS

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DECLARATION

I declare that this thesis entitled "An Investigation of Sodium Silicate Added Malaccan Red Clay for Slip Casting Process" is the result of my own research except as cited in the references. The thesis has not been accept for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award Master of Manufacturing Engineering (Industrial Engineering).

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DEDICATION

This thesis is dedicated to my beloved mother, father, wife and son. They have been a source of motivation and strength during moments of despair and discouragement, support has been shown in incredible ways recently.

ABSTRACT

The development of local pottery industries in any area is dependent on the availability of a high quality local clay resource. This study explores the possibility of using Malacca-originated clay to replace Sayong clay in producing ceramic pottery using slip casting technique. Red clay from Kampung Sungai Petai, Malacca (Malaccan red clay) is selected as a raw material due to close vicinity of the resource to KKTM Malacca. The Malaccan red clay was characterized in term of mineralogy and chemical composition by using X-Ray Diffraction machine and Energy Dispersive X-Ray Fluorescence machine. The optimization of the dispersant dosage (Sodium silicate, Na_2SiO_3) varying from 0.20% wt. to 0.40% wt of total raw material powder was determined by the agglomeration measurement size and sedimentation test. Then the study is continued with the determining optimum solid loading. Slurry with solids loadings of 60%, 65%, 70%, 75% and 80% by weight was determined by viscosity and the casting rate measurement. After that, test bar was cast by using slurry with the optimum dispersant dosage and the optimum solid loading. The test bar was fired at temperatures of 1100, 1150, 1200, 1250, 1300 and 1350°C and then underwent physical analyses according to the specific ASTM standard. Optimum sintering temperature on test samples was determined by water absorption and firing shrinkage measurement. Optimum dispersant dosage was 0.30 wt %. Optimum solid loading was determined at 75% wt indicated by viscosity reading below and near to 1 Pa.s and the highest casting rate value with good cosmetic appearance. Optimum sintering temperature is at 1250°C identified by its maximum linear shrinkage. Malaccan red clay contains high percentage of hematite (Fe_2O_3), and red colour comes from iron inside the mineral so it should categorize in red clay classification. Apart from hematite phase, characteristic peaks of quartz, mullite, kaolinite and montmorillonite were identified. Occurrences of kaolinite and montmorillonite act as a body of the ceramic products, however quartz and mullite as a filler and little fluxing agent exist such as elements of K_2O and Na_2O. By all ingredients, so definitely this clay can be made as an independent raw material for producing ceramic products without added others filler and fluxing agents. Malaccan red clay also has ability to disperse well after added with sodium silicate and has low enough viscosity with high solids loading which are very important criteria in slip casting process. It also has a reasonable matured temperature and suitable for the manufacture of terra cotta products. With all of the investigation, sodium silicate added Malaccan red clay is suitable for slip casting process.

ABSTRAK

Pembangunan industri seramik tempatan di sesuatu kawasan bergantung kepada kewujudan sumber tanah liat tempatan yang baik. Kajian ini dijalankan adalah untuk mencari kemungkinan menggunakan tanah liat tempatan bagi menggantikan tanah liat Sayong untuk menghasilkan produk seramik menggunakan teknik tuangan slip. Tanah liat merah dari Kampung Sungai Petai, Melaka (tanah liat merah Melaka) telah dipilih sebagai bahan mentah kerana sumbernya yang dekat dengan KKTM Melaka. Tanah liat merah Melaka dicirikan dari segi komposisi mineralogi dan kimia dengan menggunakan mesin XRD dan XRF. Pengoptimuman dos agen penyuraian (Natrium silikat, Na_2SiO_3) dengan dos dari 0.20% kepada 0.60% dari berat keseluruhan serbuk bahan mentah telah ditentukan. Kajian ini diteruskan dengan penentuan nilai optimum muatan pepejal. Lima muatan pepejal berbeza mengikut berat jumlah buburan ditetapkan iaitu 60%, 65%, 70%, 75% dan 80% telah ditentukan menerusi pengukuran kelikatan dan kadar tuangan. Selepas itu, bar ujian dibentuk dengan menggunakan buburan dengan nilai optimum dos agen penyuraian dan nilai muatan pepejal yang optimum. Bar ujian bakar pada 1100, 1150, 1200, 1250, 1300 dan 1350°C dan seterusnya menjalani analisis fizikal mengikut piawaian ASTM. Suhu optimum pembakaran pada sampel ujian ditentukan oleh nilai pengecutan pembakaran dan nilai penyerapan air. Nilai optimum dos agen penyuraian adalah 0.30 wt %. Optimum muatan pepejal iaitu 75% dari berat serbuk telah ditentukan dengan nilai kelikatan yang rendah dan menghampiri 1 Pa.s dan kadar tuangan yang cepat dengan kosmetik yang baik. Suhu optimum pembakaran pada sampel ujian iaitu 1250°C telah ditentukan oleh nilai pengecutan pembakaran maksimum. Tanah liat merah Melaka mengandungi nilai peratusan hematite (Fe_2O_3) yang tinggi dan warna merahnya adalah dari kandungan mineral ferum yang terkandung. Selain dari fasa hematite, puncak pencirian quartz, mullite, kaolinite and montmorillonite juga ditemui. Kewujudan kaolinite and montmorillonite bertindak sebagai jasad kepada produk seramik manakala quartz dan mullite bertindak sebagai pengisi dan sedikit agen flux wujud seperti elemen K_2O dan Na_2O. Dengan kajian ini, terbukti bahawa tanah liat merah Melaka sesuai dijadikan bahan mentah tunggal untuk menghasilkan produk seramik tanpa menambah pengisi dan agen flux yang lain. Tanah liat merah Melaka juga mempunyai kebolehan untuk menyurai dengan baik selepas ditambah sodium silikat dan mempunyai kelikatan yang rendah dengan nilai muatan pepejal yang tinggi dan merupakan kriteria yang sangat penting untuk proses tuangan slip. Ia juga mempunyai suhu pembakaran yang sesuai untuk pembuatan produk terra cotta. Dengan kajian ini, tanah liat merah Melaka yang ditambah sodium silikat sesuai untuk proses tuangan slip.

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LIST OF ABBREVIATIONS

KKTMMT	-	Kolej Kemahiran Tinggi MARA Masjid Tanah
Na_2SiO_3	-	Sodium Silicate
CaSiO3	-	Calcium Silicate
Ca_2CO_3	-	Calcium Carbonate
Na_2CO_3	-	Sodium Carbonate
Si_2O	-	Silica
Al_2O_3	-	Alumina / Aluminium Oxide
Q	-	Quartz
M	-	Montmorillonite
PAA	-	Polyacrylic Acid
%	-	Percentage
wt.	-	Weight
pH	-	Measure of the acidity
mPa.s		Mili Pascal second
°C		Degree celcius
µm		Micron meter

CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the factors which influence price of the product is a raw material. For ceramic products, especially pottery, the main raw material is clay. For that reason, Kolej Kemahiran Tinggi MARA Masjid Tanah, Melaka (KKTMMT) try to find cheap local clay to reduce the production cost. KKTMMT now was buying imported raw material from supplier.

Besides KKTMMT, ceramics souvenir industry in Malacca also will gain benefits from the new local raw materials resources. Malacca generates income through tourism industry. The souvenirs industry especially small medium industry should take this opportunity to produced more products and increase their profits by using raw materials with the lowest cost. As state by Bordeepong (2012), the development of local ceramic industries in any area is dependent on the availability of a local good clay resource.

However, in Malaysia, there is very few researchers study the ability of using local clay in producing ceramic products. Usually, local clay is evaluated as a low quality raw material because of having lots of impurities that can reduce the physical and mechanical properties such as water absorption, firing shrinkage and strength of the final products. But, there is no prove due to the limited study on determine the characterization and chemical compositions of the local clay as many researcher done for their country like Bordeepong et al. (2012), Vieira et al. (2008) and Kamseu et al. (2007).

1.2 Problem Statement

This project is to study the possibility of using local clay from Kampung Sungai Petai, Alor Gajah, Melaka (Malaccan red clay) in producing souvenirs products through slip casting process. This clay was selected because there is a small company known as Bendang Studio located at this area which was using this clay to produced souvenir ceramic products like broaches, fridge magnets, pendants, small vases or container for wedding gift.

However, Bendang Studio was never done a proper study on the characteristics and chemical compositions of the Malacan red clay and this limits the range of their products. As examples, they only produce a small ceramic souvenir products and not confidence in producing large ones such as vase which required a good green strength to support mass. Besides that, they never study on the optimizing of the slurry properties and this will results to the inconsistency for each batch of the final products that they have produced and also can contribute to the increasing of the cost due to the rejects parts, excessive usages of the materials and long processing time.

The abundant of local resources are not optimum utilized because of presence high impurities contents. There is one well known clay that is used in Malaysia for ceramics pottery from Kampung Sayong, Kuala Kangsar, Perak and was used in traditionally local products which are known as *'Labu Sayong'*. But for KKTMMT, Kampung Sayong, Kuala Kangsar, Perak is far enough and includes extra cost for transportation. Luckily there is a small medium industry located in Kampung Sungai Petai, Alor Gajah Melaka named as Bendang Studio claimed that they are use local clay near their studio. They use the local clay to produced small souvenir ceramic products like broaches, fridge magnets and pendants. Because of their location is about 20 km from KKTMMT, it is possible to get cheaper raw material from new supplier.

The most important factor in producing ceramics products is a type of clay. There are two common clay names as ball clay and kaolin. Usually, the impurities in the clay will influent the properties of the ceramics products. So the need to analysis the chemical contents of the clay was very crucial. Besides that, selected of the process also will be influence by clay properties. As example, slip casting will involve with rheology and never tolerated with the flocculated clay particles which can increase the viscosity. Type of clay and its impurities also will contribute to the final properties of the products.

So, by this research in investigating the possibility of the local clay from Kampung Sungai Petai, Alor Gajah, Melaka (Malaccan red clay) for utilizing in producing ceramic products is made possible, hope the KKTMMT and ceramic industries nearby Malacca will get the benefit by having a new and cheaper raw material in producing ceramic products.

1.3 Aims and Objectives

The objectives of this research are:

i. Determination of optimum dispersant dosage need for the Malaccan red clay suspensions for slip casting process.

ii. Determination of optimum solid loading of Malaccan red clay in slip casting slurry.

iii. Identification of optimum firing temperature of the Malaccan red clay.

1.4 Scope of Study

Research to verify the characterization and chemical composition of the local clay have to organize. This is important in understanding the character and it ability in producing products through slip casting technique. The properties to be study include water absorption and linear shrinkage which influence by temperature because it will affect the quality of the finish products. Other properties to be considered in a slurry stage are viscosity and specific gravity which influence by solid loading and amount of deflocculant. The viscosity and specific gravity is the important parameters because it affects the forming process by slip casting.

The study will be focused on the usage of local clay (Malaccan red clay) in slip casting technique as a forming method of ceramic products before sintered between 900°C and 1150°C because of the vitrification of the clay usually happened within this range (Boch and Niepce, 2007). The material characterization is determined in terms of mineralogical composition and the chemical composition. Mineralogical composition of the clays will be determined by using the X-ray diffraction analyses. However, for chemical contents, the clay will be analysed by using X-Ray Fluorescence analysis.

Then, the optimization of the dispersant dosage is organized. The dispersant use is sodium silicate. The dosage is varying from 0.20% to 0.40% by weight of raw material powder because of at this range the particle size of the clay is at minimum value due to dispersant effect (Niyomrath, 2013). The optimum dosage of dispersant will be determined by the particles size and sedimentation height of the slurry.

In determining optimum solid loading, five different solid loading by weight of the total slurry is set which are 40%, 45%, 50%, 55% and 60% in order to minimize the usage of distilled water and to maximize the specific gravity of the suspensions (Boch and Niepce,

2007). The optimum of solid loading will be discovering by the value of viscosity and the casting rate.

After that, test bar will be cast by using slurry with the optimum dispersant dosage and the optimum solid loading. The test bar samples will be undergoing the sintering stage, where some physical properties are study. The optimum firing temperature on test samples will be determined by water absorption and shrinkage.

1.5 Activity Planning

Refer to the Gantt chart below :

No.	Activities Description	Status	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
1.	Literature Review	Plan						
		Actual						
2.	Material Preparation	Plan						
		Actual						
3.	Material Characterization	Plan						
		Actual						
4.	Optimization of Dispersant Dosage	Plan						
		Actual						
5.	Optimization of Solid Loading	Plan						
		Actual						
6.	Optimization of Firing Temperature	Plan						
		Actual						
7.	Data Collection and Analysis	Plan						
		Actual						
8.	Report Writing	Plan						
		Actual						

Figure 1.5 : Research Milestones

Legends:

Plan Actual Final Report Submission Medical Leave

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Galos (2011) and also Sousa and Holanda (2005) was state that the advantageous properties of ceramic products are distinctly related to mineral composition of raw materials used, as well as to process of ceramic batch preparation and its firing. So, this research will cover some of distinctly influences of the ceramic products. Start with the process of forming, slip casting is chosen because it is one of the ceramic forming processes that require the most affordable cost and can be used to produce products with complex shapes (Sun et al., 2009). Therefore, most of the traditional industry owners use this method to produce product such as vases, souvenirs, mugs and decorative products. The materials needed for this method is slurry and plaster mould. Clay and water are the basic ingredients to produce the slurry. One of the important additives should not be forgotten in slurry preparation is dispersant which acts to prevent the clay particles flocculated. As state by Kasabov et al. (1995) cited in Eygi and Atesok (2008), mineralogical and chemical contents of raw materials, their proportion in the recipe, particle shape and size distribution, amount and quality of water, pH and electrolyte determine the final density of a slip and its casting behaviour.

2.2 Clays

Clay actually is a rock that resulting from disintegration of pre-existing crystalline rocks such as granites, or from a formation inside sedimentary basins. Clays are the main raw materials used in the fabrication of diversified ceramic products. Due to inherently complex

physical, chemical and mineralogical characteristics, clays usually have unique properties. The characteristics and quality of the clay are important for the best technical performance of the local products (Viera et al., 2008).

In ceramics purpose, clays can be divided into two types of deposits which are primary clays and secondary clays (Boch and Niepce, 2007). Primary clays are found on the site of formation and usually coarse and mixed with residual of original rocks such as quartz, mica and feldspar. Example of primary clays is kaolin. It has an important function and contribution to plasticity and workability in green state and provides the main oxides which react with the fluxing agents during firing (Marquez et al., 2008 and Andreola et al., 2009). However, secondary clay deposits have been moved by erosion and water from their primary location and this make them much finer and more homogenous. Ball clays is an example of secondary clays which is finer than kaolin and are often referred to as plastic clays as they provide a greater plasticity in the ceramic body (Bordeepong et al., 2012). However, Galos (2011), claimed that ball clays assure good moulding properties of ceramic batch and high mechanical strength of raw tile after drying

2.2.1 Classification of Clay

Besides the clays can be divided into two types of deposits, Boch and Niepce (2007), was claimed that the clays also can be classified in term of aptitude towards manipulation and behaviour during firing. There are four classes which are vitrifying plastic clays, refractory plastic clay, refractory clays and red clays.

Vitrifying plastic clays generally coloured and has high plasticity. They are made up of very fine particles, organic matter, iron and titanium oxides, illite and micaceous and feldspathic impurities. It also characterized by high free silica contents. Ball clay is an