UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

THE EFFECTS OF GLASS WASTE AND GROG ON PHYSICAL AND MECHANICAL PROPERTIES IN PORCELAIN BY POWDER PRESSING METHOD

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Master of Manufacturing Engineering (Industrial Engineering)

2014

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A thesis submitted

in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

DECLARATION

I declare that this thesis entitled "The Effects of Glass Waste and Grog On Physical and Mechanical Properties in Porcelain By Powder Pressing Method" 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.

Signature : .....

Name : Abu Bakar bin Aramjat

Date : 12th August 2014

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 of Master of Manufacturing Engineering (Industrial Engineering).

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DEDICATION

This thesis is dedicated to my beloved wife Norhaslinda binti Md Nor and my sons (Muhammad Akief Azfar, Muhammad Hadif Hafiy and Muhammad Hafidh Shafiy). They have been a source of motivation and strength during moments of despair and discouragement, support has been shown in incredible ways recently.

ABSTRACT

This research aims to study and investigate the effects of glass waste and grog on physical and mechanical properties in porcelain by using pressing method. Soda lime silicate glass is used as fluxing agent and fired ceramic (grog) act as filler in porcelain body fabrication. Firstly, the recycle glass waste (glass window) and fired glazed tiles were crushed by using disc crusher until they passed through a sieve of less than 53μm. The glass powder and grog was than mixed with based porcelain body (50% kaolin, 25% feldsapr and 25% silica) with different percentage (5%glass-20% grog, 10%glass-15% grog, 15%glass-10% grog and 20%glass-5% grog). Then, green ceramic article is formed using uniaxial dry pressing method. All waste materials were analysed on their thermal behavior, chemical composition and mineralogical phase. In this study, the sintering temperature are varied at 1150°C, 1200°C, 1250°C, and 1280°C. The microstructure and phase present in sinterd products is analyzed using optic microscope, scanning electron microscope (SEM) and x-ray diffraction (XRD).The physical properties are determined using apparent porosity, bulk density and water absorption test. Mechanical analysis is carried out using modulus of rupture to determine its mechanical properties. The results shown that the sintering temperature of porcelain decrease with the decreasing in percentage glass waste in composition. Hence, it will decrease the water absorption and porosity of the porcelain. The physical-mechanical properties of porcelain will be affected by the sintering temperature, where physical-mechanical properties will be decreasing when the temperature reach at the optimum value (1200°C). The best formulation composition is G5T20 (5% glass waste and 20% grog) and the optimum firing at 1200°C. Through the study, the enhancement of fabricated porcelain could be applied to the structural (such as floor and wall tile) applications through the advantage of mechanical and physical properties by high performance of strength, low water absorption, low porosity and high bulk density.

ABSTRAK

Kajian ini bertujuan untuk mengkaji dan menganalisis kesan campuran sisa kaca dan 'sisa jasad bakar ubin ke atas sifat-sifat fizikal dan mekanikal di dalam jasad porselin dengan menggunakan kaedah penekanan serbuk. Kaca soda-kapur-silikat digunakan sebagai fluk dan sisa jasad bakar ubin bertindak sebagai pengisi dalam fabrikasi jasad porselin. Sebagai permulaan, sisa kaca (kaca tingkap) dan jasad bakar ubin dihancurkan dengan menggunakan pengisar dan ditapis mengunakan penapis 100μm. Serbuk sisa kaca dan sisa jasad bakar ubin dicampurkan di dalam formulasi jasad porselin (porselin tradisional sebagai jasad piawaian) dengan peratusan yang berbeza (5%kaca-20% sisa ubin,, 10%kaca-15%sisa ubin, 15%kaca-15%sisa ubin dan 20%kaca-5%sisa ubin). Kemudian, jasad anum dibentuk dengan menggunakan kaedah penekanan serbuk. Semua bahan sisa iaitu sisa kaca dan sisa jasad bakar ubin dianalisis ke atas sifat terma, komposisi kimia dan fasa mineralogi. Dalam kajian ini, suhu pensinteran diubah pada 1150°C, 1200°C, 1250°C dan 1280°C. Mikrostruktur dan fasa dalam produk bakar dianalisis menggunakan mikroskop optik , mikroskop elektron imbasan (SEM) dan pembelauan sinar-X (XRD). Sifat fizikal ditentukan berdasarkan keliangan, ketumpatan dan ujian penyerapan air. Manakala, analisis mekanikal dijalankan menggunakan modulus kepatahan untuk menentukan kekuatan sampel. Keputusan di dalam kajian ini menunjukkan bahawa suhu pensinteran porselin berkurangan dengan peningkatan peratusan sisa kaca di dalam komposisi jasad porselin. Oleh itu, ia akan mengurangkan penyerapan air dan keliangan porselin. Sifat fizikal mekanikal porselin dipengaruhi oleh suhu pensinteran, di mana sifat-sifat fizikal mekanikal akan berkurangan apabila suhu mencapai pada nilai optimum iaitu suhu 1200°C. Komposisi formulasi yang terbaik adalah sampel G5T20 (5% sisa kaca dan 20% sisa jasad bakar ubin), manakala suhu pembakaran yang optimum ialah pada suhu 1200°C. Melalui kajian ini, penggunaan campuran sisa kaca dan jasad bakar ubin mampu menghasilkan produk seramik untuk kegunaan di dalam bidang struktur seperti ubin lantai dan dinding, berdasarkan prestasi sifat mekanikal dan fizikal yang dipamerkan.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Muhammad Zaimi bin Zainal Abidin from the Faculty of Manufacturing Engineering Universiti Teknikal Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this report.

I would also like to express my greatest gratitude to KKTM Masjid Tanah programme coordinator, Dr.Nur Izan Syahriah Binti Hussein from the Faculty of Manufacturing Engineering Universiti Teknikal Melaka (UTeM) for her effort and guidance.

Special thanks to MARA for giving full scholarship throughout this project. To Kolej Kemahiran Tinggi MARA Masjid Tanah Director, Mrs. Noresah Bt. Lani, Academic Deputy Director, Mr. Rahim Bin Selamat, Ceramic Processing Head Department, Mr. Khairul Anuar Bin Mohd. Jais and all KKTM Masjid Tanah staff for giving fully support during this study.

Particularly. I would also special thanks to Mr. Hairul Hisham, the technicians from material laboratory Faculty of Manufacturing Engineering for his assistance and efforts in XRD and particle size analysis works.

Special thanks to all my beloved, wife, sons and peers for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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L_o	-	Dry length
L_1	-	Fired length
WA	-	Water absorption
Ms	-	Soak weight
M_f	-	Fired weight
W_1	-	Dry weight
W_2	-	Suspension weight
W_3	-	Wet weight
F	-	Force
b	-	Width
h	-	Thickness
D,d	-	Diameter
BD	-	Bulk Density
MOR	-	Modulus of Rupture
UTM	-	Universal Testing Machine
XRD	-	X-Ray Diffraction
XRF	-	X-Ray Fluorescence
SEM	-	Scanning Electron Microscope
CTE	-	Coefficient of Thermal Expansion

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Recycled materials have now become a part of the processing stream, taking the place of virgin materials in manufacturing. Manufacturing with recycled materials can reduce cost conserves raw materials and reduces energy consumption. Porcelain is a triaxial whiteware that is composed mainly of quartz, feldspar and kaolin. Feldspar is the most expensive raw material and therefore its replacement would represent a significant reduction in final costs. Feldspar is a fluxing agent used to reduce the firing temperature. This fluxing agent can be replaced by using inexpensive material such as the glass waste (Youssef et. al., 1998, Matteucci et. al., 2002) and granite waste (Vieira et. al., 2004). The glass waste component in municipal waste is usually made up of window glass, bottles, broken glassware, light bulbs and other items. Chemical composition of glass waste (soda-lime glass) is composed of alkaline silicate which can react as fluxing agent to reduce the firing temperature. Fired glazed tile will be replacing the quartz partially. The function of fired glazed tile in ceramic body as filler, where usually exhibited by quartz or silica. This work is based on this fact and investigates the use of milled powder obtained from recycled soda–lime glass as a fluxing agent and grog (fired glazed tiles) act as filler for porcelain. Reformulation of the new porcelain body incorporated with waste material were prepared and processed under the same experimental conditions so as to make the data more comparable.

There are various types of forming techniques of ceramic products such as wet pressing, powder pressing and slip casting. In this study uniaxial pressing is chosen as a method for compaction and shaping of the powder materials into a green compact body. Subsequently, green compact body then has been dried and fired in a furnace to develop the desired microstructure and properties. This stage is also called sintering which involve the shrinkage and densification. The performance of the final product will be analysed in terms of its microstructures, phase's present and physical-mechanical properties. In this study, Scanning electron microscope (SEM) and x-ray diffraction (XRD) analysis are used to analyse the microstructure and phases present in the samples produced. Physical analysis and mechanical testing are also conducted in order to analyse the properties of the samples.

1.2 Problem Statement

Currently eco-material or sustainable manufacturing a major focus in the manufacturing industry. Demand and marketability of eco-friendly products is a key aspect of research in the use of waste materials. Recyclable waste material will reduce the environmental impact, through lowering the amount of residues or treating those that are inevitably generated during production processes. High costs associated with raw material extraction, as well as the damage that the extraction causes to the environment, are also important reasons to motivate the use of industrial process residues. Glass waste and tiles were one of the waste materials be produced either in the field of building, constructions and consumer domestic. Recycling glass has big environmental pay offs. It saves raw materials, lessens demand for energy, and cuts CO_2 emissions. Reject tiles and unsold tile is one reason dumping tile at the landfill. Therefore, if these waste glass and tiles are used in ceramic products, the pollution of environmental can be decreased. Many studies have

been made to use the glass waste (cullet) as a raw material such as in the production of glass container, bricks (Dondi et. al., 2009) and tiles (Luz, et. al., 2007, and Matteuci, et. al., 2002) as a fluxing agent. However, the use of waste glass as an alternative raw material for fluxing agent may have an impact on the end product properties, such as strength, density and water absorption. In the porcelain a necessary phase in mullite phase, because the phase mullite be the major factor in determining the strength of porcelain bodies. Studied by Mahmoud et. al., (2006) found that the increasing of mullite phase in hard porcelain lead to increasing density, hardness, bending strength and decreasing the porosity. Lee et. al., (2001) said various types of mullite is strongly dependent on the extent of mixing of the body raw materials. From Yaseen et. al., (2000) primary mullite forms from decomposition of pure clay (primary mullite forms at 1000 ^{o}C) and secondary (granular type-II and elongated type-III) mullite by reactions of clay and feldspar and clay, quartz and feldspar (forms at > 1200^{o}C). Secondary mullite phase is the major contributor to the quality of the properties of porcelain (hardness, bending strength). Loryuenyong et. al., (2012) found that the secondary mullite (mullite needles) gives high mechanical strength and thermal shock resistance to porcelain body. Support by Dondi et. al., (1995) that a higher mullite content contributes to a higher mechanical strength. Alumina shortage in glass waste can inhibit the formation of mullite phases, thus fired tile scrap added to the sample to provide Al_2O_3 element. Additional fired tiles scrap into the porcelain bodies will helpfully assist the formation of mullite phase, and thus increase the technological properties of porcelain. The purpose of the present study was to investigate the effect of the additional of glass waste and fired tile scrap on mullite phase formation and evolution of physical and mechanical properties of porcelain.

1.3 Research Questions

In this present research, the answer to this question was investigated.

i. Can the mixture of waste glass and scrap of glazed tile be used in porcelain body?

ii. Can the glass waste and scrap of glazed tiles as a raw material in porcelain a better behaviour sintering?

1.4 Aim and Objectives

The objective of this research is:

i. To prepare the new formulation of porcelain using waste materials (such as glass waste and fired tiles)

ii. To characterize the physical-mechanical properties of porcelain with different percentage of waste material at different firing temperature.

iii. To analyse the microstructure of porcelain due to different percentages of waste material.

1.5 Scope of Study

This study focuses on physical and mechanical properties behaviour of porcelain bodies mixture with glass waste and grog (fired ceramic tiles scrap). The fabrication process is by uniaxial powder pressing method. The study starts by preparing recycle glass and scrap fired tiles as raw materials to be used in fabrication of porcelain samples. The glass waste powders were prepared by crushing plate glass (window glass) made from the disc crusher and milling until they passed through a sieve of less than 100 μm to obtain fine particles .Reformulation porcelain added waste mixed in ball mill and screened

through a sieve 63μm. The powder was prepared by mixing 8-10% water, before preparing a sample pressed done. All the raw materials will be analysed using XRF and XRD to identify their chemical composition and mineralogical phase. Particle size of waste material also will be analysed. Fired product will be characterized through physical and mechanical testing such as flexural test, water absorption, porosity, linear firing shrinkage and bulk density. The result will be supported by various analysis techniques such as optic microscope, SEM, XRF and XRD. All experimental activities such as sample preparation, testing and analyze planned on Gantt Chart (Appendix A). The effect of glass waste and grog in different percentage in porcelain will be studied. In this study glass waste is used is clear window glass. Grog will be used in this study is fired glazed wall ceramic tile.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The use of recyclable materials is the latest move to reduce the effects of pollution to the environment. Waste materials selection should be based on the main functions of each raw material used in the formulation of porcelain body. Every raw material waste must undergo the characterization process early to ensure that the material does not cause harmful effects such as the release of toxic gases or significantly reduce the quality or nature of porcelain main body as strength, water absorption, shrinkage, bulk density and others.

2.2 Waste

From National Solid Waste Management Department according Act 167 define of solid waste includes any scrap material or other unwanted surplus substance or rejected products srising from the application of any process; any substance required to be disposed of as being broken, worn out, contaminated or otherwise spoiled; or any other material that according to this Act or any other written law is required by the authority to be disposed of, but does not include scheduled wastes as prescribed under the Environmental Quality Act 1974 (Act 127), sewage as defined in the Water Services Industry Act 2006 (Act 655) or radioactive waste as defined in the Atomic Energy Licensing Act 1984 (Act 304). Based on information from National Solid Waste Management Department, composition of solid waste in Malaysia in 2005 as below: