CHARACTERIZATION AND MECHANICAL PROPERTIES OF POROUS CERAMICS WITH DIFFERENT POLYMETHYL METACRYLATE (PMMA) CONTENTS

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR CONDITIONING SYSTEMS) WITH HONOURS

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DECLARATION

I declare that this Bachelor degree project entitled " Characterization and Mechanical Properties of Porous Ceramics with Different PMMA Contents " is the result of my own research except as cited in the references. The title of project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MUHAMAD SYAZWAN ZULHILMI BIN MOHD KASIM

Date : 26 JANUARY 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration And Air Conditioning Systems) with Honours.

Signature	:	
Supervisor Name	:	ASSOC. PROF. TS. DR. UMAR AL-AMANI BIN HAJI AZLAN
Date	:	26 JANUARY 2023

DEDICATION

In the name of Allah, the Entirely Merciful and The Bestower of Mercy and with deep appreciation to the Prophet Muhammad S.A.W. I did the task succefully without any complication faced. I finished this project within the allotted time and to the best of my ability.

To express my gratitude and appreciation to both of my parents which is Noraihan Binti Mohamad, as my mother and my father Mohd Kasim Bin Ismail, for their endless support throughout this process.

ABSTRACT

Porosity refers to the amount of empty space as a percentage inside any ceramic. Based on previous history, ceramics were the best material to be used as a cooling system by past people. Researchers have conducted numerous studies on the properties of ceramic materials. The problem that was being faced while producing ceramics was that the strength was not sufficient to withstand higher pressure than normal. Normally, the production of ceramics in this era is not applicable to all industries. Thus, the purpose of this study is to improve the strength of ceramic, study its properties, and produce ceramic samples with different contents of polymethyl methacrylate. The process starts with the selection of materials. Clay, feldspar, and silica were selected as the main materials in the production of these samples. Different contents of polymethyl methacrylate, starting with 0 %, 3 %, 5 %, and 10 % of the total weight of the mixtures, were being mixed to form a mixture. The mixtures then proceeded with the mixing process with the help of ball millings, and the process took around 3 hours to completed which to ensure that the powder was in a fine powder state. Next, after the mixing process, the mixtures undergo a sieving process. The mixtures were then placed inside the mould, where the pressing process began. After the process of pressing completed, the sintering process began. The following steps are the testing phase. It consists of X-ray diffraction analysis, density and porosity tests, bending tests, and finally a scanning electron microscope. The study's findings demonstrate that the sample's durability will decrease as its porosity rises. The presence of Muscovite occurs during the formation of the sample when this pore-forming agent is present, as shown by the sharp peak on the graph, and phases that cannot be identified due to machine limitations occur during the formation of the low peak. Additionally, SEM images provide visual proof that the addition of pore-forming agents to ceramic samples causes pore enlargement.

ABSTRAK

Keliangan merujuk kepada jumlah ruang kosong sebagai peratusan di dalam mana-mana seramik. Berdasarkan sejarah terdahulu, seramik adalah bahan terbaik untuk digunakan sebagai sistem penyejukan oleh orang terdahulu. Penyelidik telah menjalankan banyak kajian tentang sifat bahan seramik. Masalah yang dihadapi semasa menghasilkan seramik ialah kekuatannya tidak mencukupi untuk menahan tekanan yang lebih tinggi daripada biasa. Biasanya, pengeluaran seramik pada era ini tidak boleh digunakan untuk semua industri. Oleh itu, tujuan kajian ini adalah untuk meningkatkan kekuatan seramik, mengkaji sifatnya, dan menghasilkan sampel seramik dengan kandungan polimetil metakrilat yang berbeza. Proses ini bermula dengan pemilihan bahan. Tanah liat, feldspar, dan silika telah dipilih sebagai bahan utama dalam penghasilan sampel ini. Kandungan polimetil metakrilat yang berbeza, bermula dengan 0 %, 3 %, 5 %, dan 10 % daripada jumlah berat campuran, sedang dicampur untuk membentuk campuran. Campuran kemudiannya diteruskan dengan proses adunan dengan bantuan pengisar bebola, dan proses mengambil masa kira-kira 3 jam untuk disiapkan bagi memastikan serbuk berada dalam keadaan serbuk halus. Seterusnya, selepas proses bancuhan, adunan menjalani proses pengayak. Campuran kemudiannya diletakkan di dalam acuan, di mana proses menekan bermula. Selepas proses menekan selesai, proses pensinteran bermula. Langkah-langkah berikut adalah fasa ujian. Ia terdiri daripada analisis difraksi sinar-X, ujian ketumpatan dan keliangan, ujian lenturan, dan akhirnya mikroskop elektron pengimbasan. Hasil kajian menunjukkan apabila menunjukkan bahawa apabila keliangan meningkat pada sampel, ketahanan sampel akan berkurangan. Semasa pembentukan sampel bersama kontent agen pembentukan liang ini, kehadiran Muscovite berlaku pada puncak tajam yang ditunjukkan oleh graf dan pada puncak yang rendah berlakunya fasa yang tidak dapat diketahui akibat kekangan mesin untuk menetukan bahan apa yang terdapat pada sampel itu. Tambahan pula, imej SEM menggambarkan bukti visual bahawa pembesaran liang berlaku apabila agen pembentukan liang ditambah dalam sampel seramik.

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	-	Degree celcius
μ	-	micrometres
Mm	-	Millimetres
PMMA	-	Polymethyl methacrylate
PFA	-	Pore-forming agent
%	-	Percentage
XRD	-	X-ray Diffraction
SEM	-	Scanning Electron Micrsocope
CIP	-	Cold Isostatic Presssing
HIP	-	Hot Isostatic Pressing

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CHAPTER 1

INTRODUCTION

1.1 Background

The establishment of ceramic is very crucial for the human survival. According to history that have been studied, it shows that the usage of ceramic as a replacement for cooling system. Many studies have been made by researchers to achieve a perfect balance between strength and the porosity of the ceramic material.

Two major challenges for today's ceramics industry are the growing concern for the strength is not sufficient enough to withstand greater pressure and the growing need for ceramics improvement. On the other hand, as urbanization progress and building area gradually increases and the demand for ceramic will be skyrocket. Buildings make up nearly 30 % of total world energy use in 2020, according to data released by the International Energy Agency (IEA), which contributes to huge carbon emissions and has an adverse impact on the environment, such as global warming. As a result, energy efficiency and strength are both equally important. (Tang *et al.*, 2022).

Silicon Nitride (Si_3N_4) or ceramic can be interpreted as one of the best cooling materials that can be use. Because of its superior properties, such as high decomposition temperature, high strength at room and elevated temperatures, low coefficient of friction and resistance to environments, as well as excellent oxidation. Silicon nitride ceramics are frequently referred to as an ideal engineering material. Furthermore, silicon nitride has excellent dielectric characteristics and is a popular material among others. However, for practical applications, it is critical to produce (Si_3N_4) with a low dielectric constant and low dielectric loss. (Xia, Zeng and Jiang, 2011).

1.2 Problem Statement

According to the findings of various studies, achieving a balance between the mechanical and physical properties of ceramic materials is an extremely challenging task from a theoretical standpoint. Porosity, density, strength, and elasticity are all characteristics of the ceramic that fall under this category. It has already been established that porosity can have an effect on the strength of the ceramic, which can be tested using a variety of methods that have already been put into use.

One of the most common ways of producing porous ceramics with controlled microstructure is the use of pore-forming agents (porosity and pore size). These pore-forming agents are burnt out during the heating process to the final firing temperature of the ceramics, leaving void pores in the ceramic. Among the various pore-forming agents, those of biological origin, particularly starch, have taken centre stage. They are cheap, non-toxic, and environmentally friendly, with something like a defect-free burnout temperature range of 300°C to 600°C (Tang *et al.*, 2022).

PMMA, also known as polymethyl methacrylate, is an amorphous, high-strength polymer that possesses excellent dimensional stability as well as outdoor weatherability. PMMA is one of the most researched polymers because it has such interesting properties. The dielectric loss that can be achieved with composites based on PMMA is significantly lower than that of other materials, and the material's relatively low price makes it the material of choice. Polymers, which are long chain molecules that are multiples of simpler chemical units (monomers), have received attention as capacitor materials due to their flexibility, low cost, and ease of processing. Monomers can be thought of as the fundamental building blocks of polymers.

1.3 Research Objective

- To fabricate ceramic samples with different content of Polymetyhl Methacrylate.
- To study the mechanical and physical properties of the ceramic samples

1.4 Scope of Research

The study will look at the preparation of powder, the fabrication of ceramics, the properties of the powder or ceramic, and the performance of ceramics. All of this research will be carried out in order to create porous ceramics with the strength are kept constant for use in applications and buildings.

The raw materials for ceramic production can be obtained in the form of a powder of varying types. The investigation of powder is one of the processes that are being carried out in order to guarantee that the appropriate material is being used in this experiment. This is the most important step, as it will determine whether or not the entire experiment was successful, or whether it was unsuccessful.

In order to properly evaluate the results of this experiment, a series of tests such as an x-ray diffraction analysis (XRD), a scanning electron machine (SEM), a three-point bending test, and a density and porosity test. In order to determine which parameter or method will yield the best results, it is necessary to conduct all of the tests described above. The outcome can serve as a point of reference for further development of the ceramic samples.The most significant stage of this experiment is to study the performance of ceramics. This step is very crucial as it will determine the mechanical and physical properties of the ceramic samples and the t that it can withstand.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the next part of this chapter, more exposure about the earlier research that has been done on the subject of structured ceramics as well as the findings that have been discovered as a consequence of this study. This discussion will take place in the following portion of this article. This chapter provides an overview of the evolution of ceramics as well as the structural components that goes into the creation of ceramics. The structural components of ceramics will be the primary topic of the discussion throughout this chapter. Furthermore, exploration the necessity of examining earlier research and identifying how to grasp the subject that has grown over the course of time. Specifically, to deepen the understanding of the subject that has evolved over the course or past several decades. This is an action that has to be done in order to obtain a comprehensive knowledge of a subject that is being discussed. In an effort to bring about the changes that are desired in the ceramic, it is of the highest necessity to follow these methods to the latter. This will make it possible to make the appropriate adjustments, which will ultimately result in the enhancements that were intended.

2.2 History of Ceramics

The term "ceramics" originates from the Greek word "keramikos," which can be translated directly into English as "pottery." According to the findings of research that was carried out by scientists towards the Palaeolithic period, the first form of functional art to emerge was not body painting but rather ceramics. Ceramics can be traced back thousands of years, making it one of the most historically significant fields due to the fact that it is one of the oldest businesses operating on this planet. The beginning of human civilization can be traced back to the time when people learned that clay could be obtained in large quantities and, eventually, figured out how to shape it into objects by combining it with water and then heating it.

The art of making ceramics is thought to have originated in East Asia and then spread westward to the Middle East and Mediterranean over the course of a thousand years, according to the findings of archaeological excavations. It is quite possible that the relatively cold climate conditions that prevailed at the time in China were the primary factor in the development of pottery in China. These climate conditions prevailed at the time in China. Because it was necessary to prepare food in harsh environments, high-temperature-resistant cookware was developed as a result of the demand for this kind of cookware.

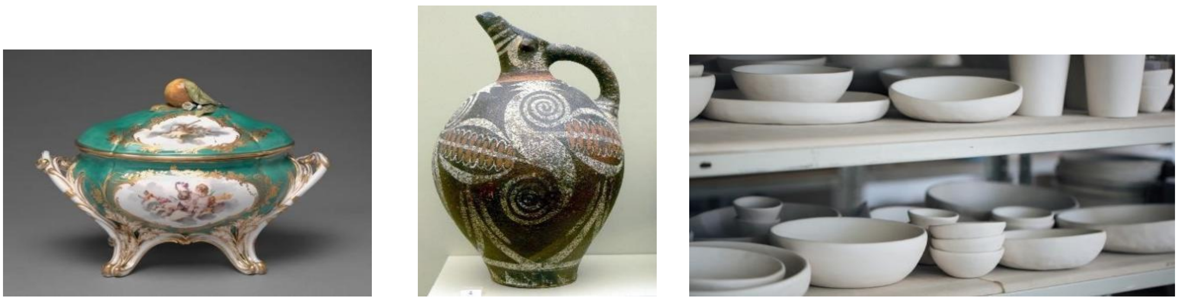

Figure 2.1: Example of ceramic use in pottery

2.3 General Properties

Ceramics are metal ions' oxides, carbides, nitrides, & borides. It contains more inorganic and non-metallic components rather than organic ones. Ceramics are important to humans in many aspects of their day-to-day lives. The advancement of ceramics is one factor that helps bring about a decrease in demand in industries. Refractivity is the general property of ceramics that is considered to be the most important. The materials are resilient enough to withstand significant stress in both typical and exceptional circumstances.

Ceramics have a density that falls somewhere in the middle of that of metals and polymers. Crystalline substances tend to have a higher density than their non-crystalline counterparts. Ceramics are characterized by the importance placed on the particle size. It is available in two different granularities, fine and coarse. The presence of fine particles in a particular ceramic causes the volume to increase because there is less void space, which ultimately results in a high density that is able to withstand heat capacity. When the surface condition is harsh, there is more empty space, which can lead to a reduction in the material's resistance to heat.

Ceramics are typically brittle or ductile. Because of their high brittleness and low ductility, ceramics have a low thermal shock resistance (TSR), which has constrained their application as structural materials, especially in extreme situations (Liu et al., 2022). Meanwhile, in ductile condition, it occurs a necking situation before the material breaks. This is a combination of elastic and plastic deformation.

Ceramics is a material that expand when heat is present. Ceramics are frequently used because of their exceptional resilience in harsh chemical and thermal environments

(Arnold, n.d.). Because of several reasons, thermal expansion varies. Internal porosity, grain boundaries, and contaminants are among the factors which can manipulate the heat conductivity by altering these variables.

2.4 General Applications

Numerous industries are currently making extensive use of applications made of ceramics, which can be broken down into many subcategories. In the production of a wide variety of engine components, such as valves, crankshaft housings, and any and all pump components, the automotive industry makes extensive use of it (including water and fuel). It has a high thermal capacity, which may help to boost efficiency, reduced wear, and lower noise emission; all of these factors combine to make it a leading choice in this segment of the industry's product offerings.

In the field of electronics, it is frequently used in the production of capacitors and insulators, which are ceramics that serve as heat-sinks to bring the high temperature of electronics that are being manufactured down to a more manageable level. In addition to that, it is utilised in a variety of other applications as well.

Ceramics find a wide variety of uses in the aerospace industry, including the manufacturing of engines, air frames, nose cones, and tiles for space shuttles. It prevents the shuttles and rockets from being damaged by acting as a barrier between them and the intense heat that is produced during launch and even in space.

Ceramic is put to use in the construction of residential buildings in a variety of ways, one of which is the production of tiles made out of ceramic. The walls and the floors are both covered in tiles to complete the look. Customers are presented with a various range of options from which to choose in order to satisfy the particular requirements that they have articulated. Utilizing ceramic tiles has a variety of benefits, some of which include the fact that the house will have a more comfortable temperature as a direct result of the use of the tiles, the fact that the tiles are more cost-effective than other materials, and the fact that they are not easily damaged.

2.5 Bi-Layer Ceramic Structure

Bi-layered ceramic structures are widely used in a variety of applications, they are composed of a dense layer on a dense substrate, a porous layer on a dense substrate, or a dense layer on a porous substrate. (Chen et al., 2017). The process of creating bi-layered ceramic tiles, that are comprised of two layers with various densities–dense and porous–and varying thicknesses. The new production process consists of a double pressing action that ensures the formation of a flawless interface bonding between layers and is quick and straightforward to use in the industrial setting. (Novais et al., 2015).

Advantages of using bi-layered ceramic are that the conductivity of thermal increases which it can withstand a higher temperature compared with a single layer of ceramic. Furthermore, with the increasing of thermal conductivity, the porosity of bi-layered also increase which can help with thermal absorption.

The disadvantage of using bi-layered ceramic is that the ceramic core supports and strengthens the restoration in the bi-layered, all-ceramic repair. The core, on the other hand, may influence the shade of the final repair. Nonetheless, because bi-layered all-ceramic restorations are prone to delamination and fracture, the veneer-core bond strength is regarded one of the weakest links. When aesthetics is the primary consideration, the bi-layered, all-ceramic restoration is typically chosen.