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Manufacture of porcelain from natural materials

A research Submitted to the College of Materials Engineering of Babylon University as a Part of Requirements Achieve bachelor's Degree in Materials Engineering / Department of Ceramic and Building Materials Engineering

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2022-2023

بسْمِ اللهِ الرَحْمَنِ الرَحِيمِ

(يَرْفَعِ اللهُ الَّذِينَ آَمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا

العِلمَ دَرَجَاتٍ وَاللهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

صدق الله العلي العظيم

سورة المجادلة/الآية 1

ABSTRACT

In the current work, a study of the porcelain manufactured from familiar natural materials such as kaolin, feldspar and silica sand with additions of natural bauxite (5%, 10%) to the mixture. Where the original mixture was kaolin (50%), feldspar (25%), and silica (25%). After the mixing was completed, pressing was done at (70 MPa), then drying at 110c and a time (3 hours). So, the sintering is done at 1200c and a time (2 hours) with a heating rate of (5C/min). After the sintering was completed, the necessary physical and mechanical tests were carried out.

Content

Chapter one

INTRODUCTION

Chapter one

Introduction

1-1 Introduction Although the term porcelain is sometimes applied to a variety of vitreous and near vitreous ware, it is more properly restricted to translucent vitreous ware. A wide range of triaxial ceramic compositions that are used in white ware industries basically contain kaolin, quartz and feldspar [1]. Porcelain insulators and porcelain shells are important equipment in the operation of power plants and transformer substations insulation and supporting wire [2]. Porcelain materials have very interesting properties for many industrial applications. Ceramics possess an extremely low thermal expansion; low thermal conductivity, and high mechanical strength, these properties give an excellent thermal shock.

Figure (1-1) Some products of porcelain

It is well documented that nominally identical specimens of brittle materials such ceramics show a large variation of fracture stresses and in order to use brittle material as engineering ones, strength has to be characterized. Complicating factors affecting the strength of ceramics are manifested mainly in two main ways: First, strength is generally time dependent in that the applications of tension stress on a component causes a gradual dimension of its capability to withstand further stress without rupture. Second, there is a relatively large statistical variation in the strength of a batch of otherwise identical specim.

1-2 Aim of the study:

The aim of the current study is to investigate the effect of adding bauxite in certain proportions on some properties of porcelain, which is usually made of alkaline, silica and field spar, in order to try to improve the manufactured material at the lowest cost.

Chapter two

Theoretical part

2-1Introduction

The most significant development in the history of ceramics many centuries ago was the production of a vitrified, translucent porcelain body in China. Today, porcelain is produced in many countries and its technology is well known and described in different textbooks and papers. Although the term porcelain is sometimes applied to a variety of vitreous and near vitreous ware, it is more properly restricted to translucent vitreous ware. A wide range of triaxial ceramic compositions that are used in white ware industries basically contain clay, quartz and feldspar. The triaxial porcelain is one of the most widely studied ceramic systems. It has got diverse applications like whiteware, stoneware and insulators. Extensive research on porcelain for a long time confirmed its complexities, so they remain significant challenges in understanding porcelain in relation to raw materials, processing science, phase and micro structural evolution.

Porcelains 2-2

Porcelain is a type of ceramics highly valued for its beauty and strength. The raw materials used for the body compositions of porcelain can be divided into three groups of minerals, each having its own function: the clay raw materials give plasticity to the body, while the complementary non-plastic ones include melting minerals and structural ones. The clay minerals of illitic-kaolinitic or montmorillonitic origin belong to the first group and show more or less remarkable plastic characteristics with regard to their mineralogical structure and to their particle- size distributions. The melting minerals are feldspars and feldspathoids, talc, pegmatites. The feldspar is the most abundant mineral group in the world, forming around 60% of earth‘s crust, and is found in igneous, metamorphic and sedimentary deposits in most countries. They are used in the production of glass, ceramics and in polymer, paper and paint industries as fillers and extenders. Silica is often associated with the feldspars, as quartz in pegmatic deposits and silica in feldspathic sand deposits. Additionally, quartz and generally quartzites are the most refractory ones of those having a structural function.

In porcelain composition, clay serves as a dual purpose of providing fine particle size and good plasticity for forming. Feldspar acts as a flux, forming a viscous liquid at firing temperature and aids in vitrification. The quartz is mainly an inexpensive filler material which remains unreactive at low temperatures of firing and forms a highly viscous liquid at higher temperatures.

2-3 The main raw materials to manufacture porcelains

In order to select the suitable raw materials, the properties of the final product had to be taken into consideration. A sufficient amount of feldspar is necessary to obtain the desired glassy phase. As in all traditional ceramics, whereas, kaolin is characterized by low plasticity. Hence, the raw materials used to prepare porcelain bodies play a vital role in the ultimate product quality. These raw materials will be described below.

2-3-1 Kaolin

Kaolin (Al2O3,2SiO2,2H2O) is the most common among the argillaceous minerals used in ceramics. The degree of crystallinity of the kaolinite present in clays is highly variable. It depends largely on the genesis conditions and the content of impurities introduced into the crystalline lattice. During the heat treatment, kaolin undergoes a whole series of transformations.

2-3-2 Feldspars

Feldspar is a group of anhydrous alumina silicate minerals called orthosilicates. These silicates are in general igneous rocks. Igneous rock was at one time molten and cooled to its present form. Some examples of igneous rocks are granites, feldspars, rhyolites, basalts, etc. The composition of feldspars can vary significantly, having different end-members such as K, Na and Ca. These feldspars are orthoclase

($KAlSi_3O_8$) albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$). Feldspar is often left unaltered in certain amounts during the formation of clay deposits.

Feldspars play an important role in ceramic materials, acting as fluxing agents to reduce the sintering temperatures of the clays. Potassium is a very powerful flux during firing and determines the fusibility of the feldspars and their ability to form eutectics with other components. The formation of eutectics makes it possible to reach a high densification of the ceramic materials even at low temperatures.

Feldspars are often used in formulations of porcelain pastes for production of stoneware tiles, tableware and sanitary ware bodies. The raw materials for the manufacture of such products are mixtures composed mainly of white kaolin, talc, feldspar and quartz. In fact, the large densification and high mechanical. resistance showed by these ceramic materials after firing are due to the action of feldspars.

2-3-3 Silica sand

Silica sand is natural sand which contains high content of silica, generally higher than 98% silicon dioxide (SiO_2). It is defined as one of the commonest minerals in the earth's crust. In nature, silica sand occurs as a crystalline mineral in many and varied forms. The most common is quartz, commonly clear or white, with a specific gravity of 2.65. In many applications, silica sand is important as an exploitable industrial mineral. It is used mainly as construction materials, foundry materials, in the glass manufacture and the chemical industries.

Figure (2-3) Silica sand.

2-3-4 Bauxite

Bauxite is the primary ore of aluminum. Almost all of the aluminum that has ever been produced has been extracted from bauxite. The United States has a few small bauxite deposits but at least 99% of the bauxite used in the United States is imported. The United States is also a major importer of aluminum metal.

Many people are surprised to learn that bauxite is not a mineral. It is a rock composed mainly of aluminum-bearing minerals. It forms when laterite soils are severely leached of silica and other soluble materials in a wet tropical or subtropical climate. Bauxite does not have a specific composition. It is a mixture of hydrous aluminum oxides, aluminum hydroxides, clay minerals, and insoluble materials such as quartz, hematite,magnetite,siderite, and goethite. The aluminum minerals in bauxite can include: gibbsite $Al(OH)3$, boehmite $AlO(OH)$, and, diaspore, $AlO(OH)$.

Figure(2-4) Bauxite

Chapter Three

Experimental Work

Chapter Three

Experimental Work

3-1 Introduction

This chapter explains the experimental work which was made in this study in laboratory, as it was described below.

3-2 The materials and equipment used in this study:

1)kaolin clay

2)Feldspar (Albite)

3)Silica sand

4)Sieve

5)Sensitive Balance

6)Mixing device

7)Compression device

8)Drying Oven

9)Burning furnace

10)Microhardness device

11)Archimedes device

12)General test machine

3-3 Experimental Work:

The porcelain samples were prepared from a mixture of kaolin clay, feldspar, bauxite and silica sand. The experimental work includes the following stages:

3-3-1 Preparation of primary materials:

1) Sieving process: The kaolin powder was sieved with a sieve (98 µm) to obtain a fine powder. Figure (3-1a) shows the sieving device used in this process.

2) Weighting process: The weights of kaolin, feldspar and silica sand were taken using the sensitive scale shown in Figure (1-3b). Table No. (1) shows the mixing ratios of the materials used in this study. The total weight of one sample was (5) g

3) Mixing process: The powders of the materials were mixed according to the mixing ratios shown in Table No. (1) using the electric mixer shown in Figure (1-3C) for a period of (3) hours to obtain a homogeneous mixture.

(a) (b) (c)

Figure (3-1): a) The sieving device, b)The sensitive balance, and c) The electrical mixer

Sample	Raw material in the first stage						Raw materials in the second stage			
	Kaolin clay		Silicon		Feldspars		Porcelain		Bauxite	
	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)
A	50	2.5	25	1.25	25	1.25	100	5	0	0
B	50	2.5	25	1.25	25	1.25	95	4.75	5	0.25
C	50	2.5	25	1.25	25	1.25	90	4.5	10	0.5

Table (1) shows the mixing percentages of materials

3-3-2 Forming of samples:

Single direction Semi-dry pressing method was used in samples formation by using hydraulic uniaxial pressing machine which shown in figure (3-2 a) at a pressure of (70 MPa) with using stainless-steel die with (d= 20mm). Liquid paraffin wax was used as the lubrication to reduce the friction between the two parts of the die and to prevent adhesion between the particles with die wall during getting out the sample from the die after the pressing. Polyvinal alcohol (PVA) binder was used to prepare the samples as the pressing is semi-dry.

3-3-3 Drying process

The samples were dried at temperature (110C) for three hours by use the drying furnace which shown in figure (3-2 b) to remove the moisture from the samples.

3-3-4 Burning process

An electrical furnace, which shown in figure (3-2 c), was used for burning the samples in this study at temperature (1200C) with heating rate (5C/min) and soaking time for (2 hours).

(a) (b) (c)

Figure (3-2): a) Pressing machine, b) Electrical drying Oven, and c) Electrical firing furnace.

3-4 Test

Several tests were carried out for the samples produced to study their properties, and these tests can be divided into: Physical test and mechanical tests.

Physical test

a)Linear shrinkage

Linear shrinkage on firing (L.S.%) was evaluated for samples by measuring the outer diameters of the samples before and after sintering process (which are D1and D2 respectively). Linear shrinkage (L.S.%) was calculated by the equation below according to (ASTM C326):

$$L.S.\% = D1 - D2/D1 \times 100\% \text{ .... } (1$$

b)Porosity

Calculation of porosity for the samples was based on ASTM standard (C373-88) [19]. The percentage of porosity was calculated by the equation (2). Archimedes device was used in this test, which shown in figure (3-4 a)

$$Porosity\%=((M-D)/(M-S))*100 \text{ .... } (2)$$ Where

M: saturated weight (g), D: dry weight (g)

S: Suspended weight (g).

c)Density

The density of samples (ρ) was calculated according to ASTM standard (C373-88) by use the following equation

$$\rho = D/ M-S \text{ .... } (3)$$

Mechanical Test

a) Fracture Strength

The fracture strength of the samples was calculated according to the ASTM (C 773-88) standard by use the following equation (20):

бc = F / Ar

where: бc= Fracture strength in (MPa)

F = Applied load until fracture (N).

Ar= Cross section area (mm2)

b) Hardness

The hardness of samples was tested by Vickers hardness. Vickers hardness values were measured on surfaces by Vickers indentation technique at (10) kg load applied for (12) seconds using the device shown in figure (3-4 b).

(a) (b)

Figure (3-4): a) Archimedes device, and b) Microhardness devise

Chapter Four

Results and Discussion

Chapter four

Results and Discussion

4-1 Result and Discussion

4-1-1 The physical tests

Figures (4-1), (4-2) and (4-3) show the effect of bauxite additive on the linear shrinkage, apparent porosity and bulk density of porcelain samples. Where, the porosity of samples decreases with increasing of bauxite content. While the linear shrinkage and density of the samples increases with increasing of bauxite content. Generally, the presence of the liquid phase facilitates the sintering process. This may be due to the formation of a liquid phase and due to the filling of most of the open pores with bauxite particles, in addition to the transformation of residual open porosity into closed porosity. Thus, good dense body was produced.

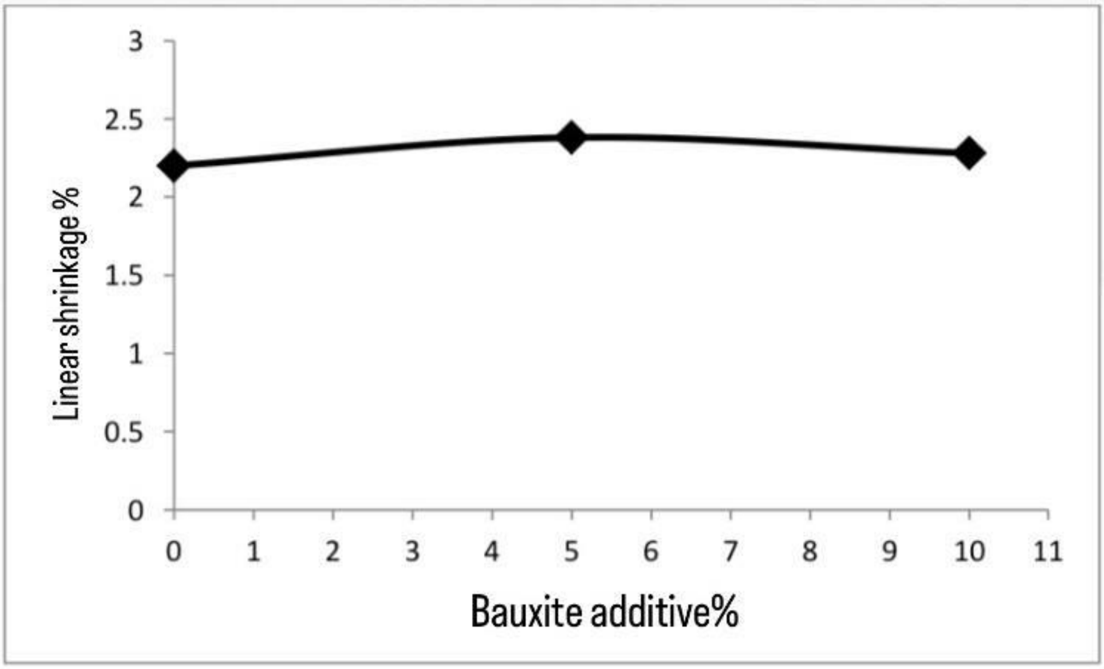

Figure (4-1) the effect of bauxite additive on the linear shrinkage of porcelain samples.

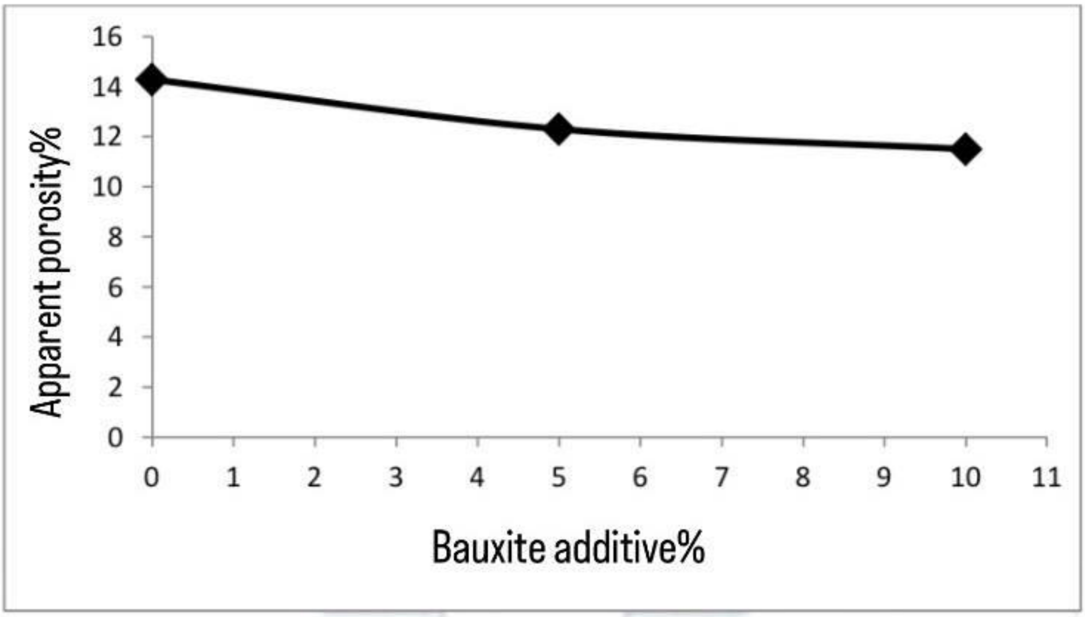

Figure (4-2) the effect of bauxite additive on the apparent porosity of porcelain samples.

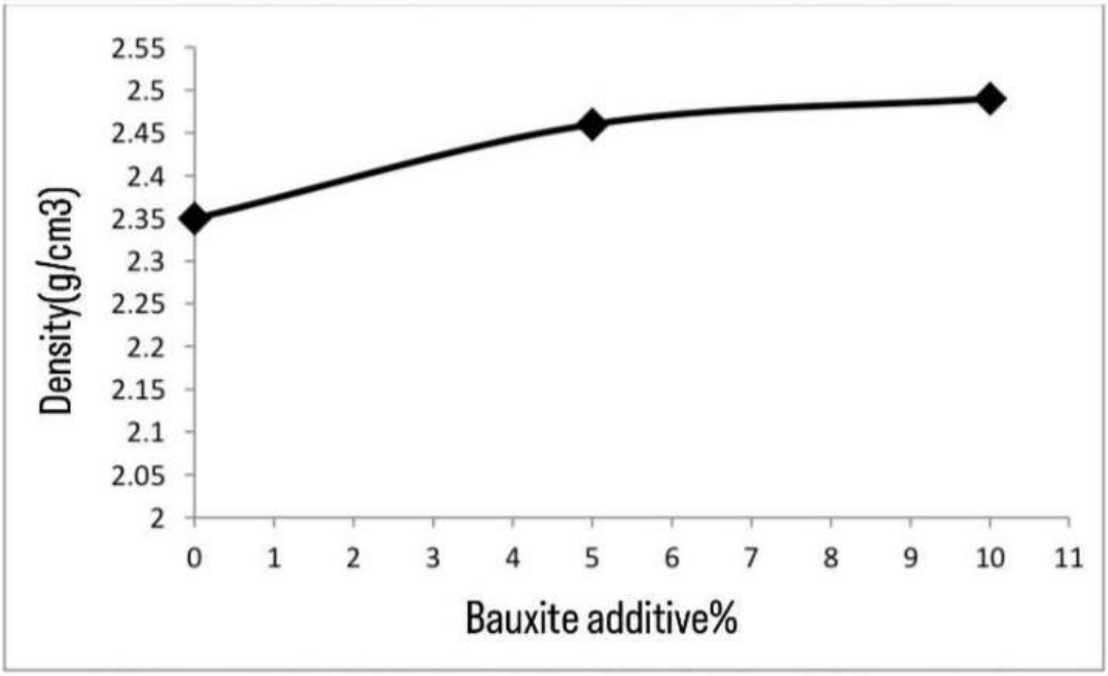

Figure (4-3) the effect of bauxite additive on the bulk density of porcelain samples.

4-1-2 The mechanical test

Figures (4-4) and (4-5) show the effect of bauxite additive on the fracture strength and hardness of porcelain samples. Where, the fracture strength and hardness of the samples increase with increasing of bauxite content. This is because of the formation of glassy phase in the porcelain matrix for the presence of an amount of different fluxes which means theincrease in the bond between the material particles and the decrease the pores between them for this reason and due to the filling of most of the open pores with bauxite particles, that makes the network more rigid, which lead to increase in mechanical strength of the samples.

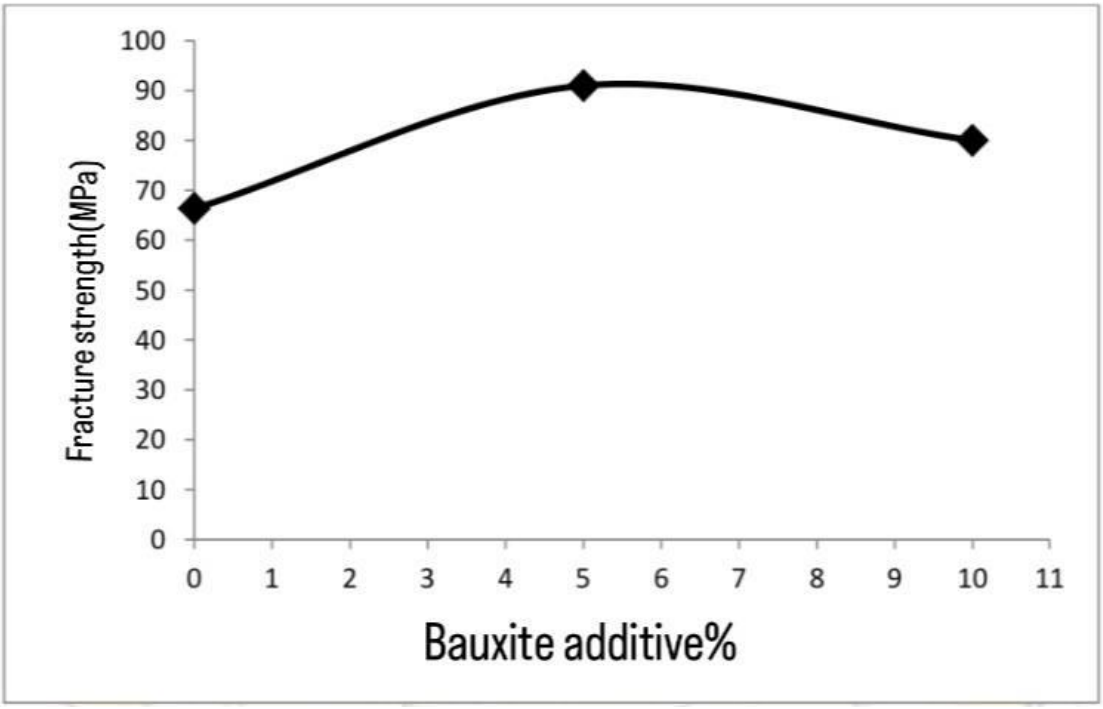

Figure (4-4) the effect of bauxite additive on the fracture strength of porcelain samples.

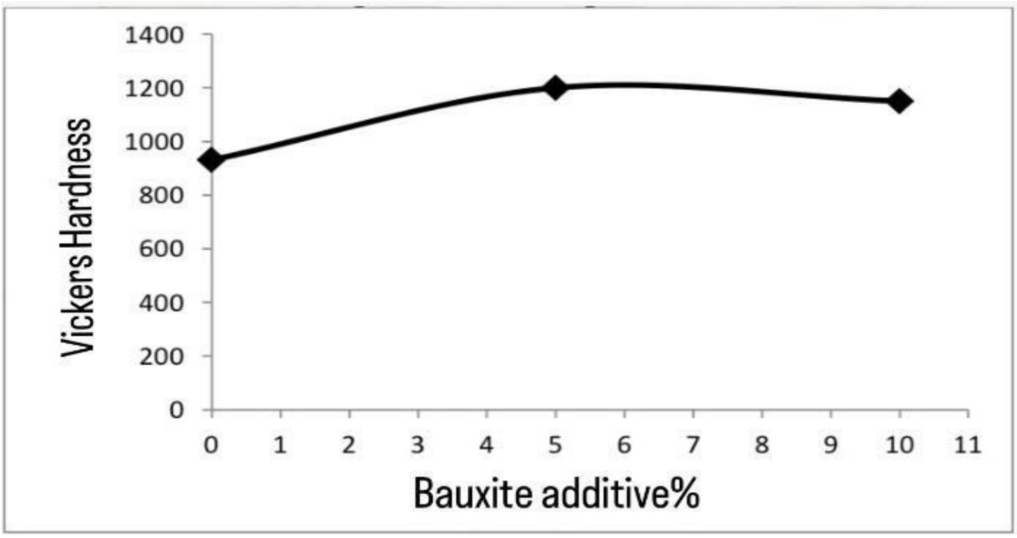

Figure (4-5) the effect of bauxite additive on the hardness of porcelain samples.

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendation

5-1 Conclusions:

1-The linear shrinkage on firing and density of the porcelain samples increase with increasing of bauxit content. While the porosity of samples decreases with increasing of bauxit content.

2-The fracture strength and hardness of the porcelain samples increase with increasing of bauxit content.

3-The improving of some properties of porcelain by addition of bauxit to it.

5-2 Recommendations:

1-Study the effect of another material to improve the mechanical properties of porcelain products

2-Study the effect of increasing of zirconia percent in the porcelain samples on its properties.

3-Study the effect of zirconia additive on the thermal properties of porcelain.

4-Study the effect of zirconia additive on the properties of other ceramic products.

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