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The effect of Sintering Time on The Properties of Ceramic Composites Reinforced By Aluminium

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Abstract: This research was including the effect of sintering time on the properties of composite ceramic matrix material and consisting of (Silicon Dioxide , Oxide Chromium (III), Titanium Dioxide) with fixed ratios of elements (Co, Ni) component. and reinforcement by a fixed Aluminium ratio of (20%) using powder metallurgy technique and (5 ton) press pressure for the purpose of forming. The effect of sintering time on physical and mechanical properties of were studied after sintering temperature of (1000 C°) sintering time of (2,4,6,8,10) hours . It was conclude that the increased sintering time acts on improve of samples physical and mechanical properties, and the relation of sintering time with apparent porosity and the ability of water absorption for composites was inverse relationship. while their relation with apparent density, specific gravity and mechanical properties of this study was linear relationship. Noting when increasing sintering time from (2) to (10) hours, some of the properties (apparent density, specific gravity and hardness) of the composite (C) :[Cr_2O_3+Al+Co+Ni] for example, has improved by (1.6%), (4%) and (11.3%) respectively, while the (B) :[TiO_2+Al+Co+Ni] and (A) :[SiO_2+Al+Co+Ni] composites were similar in behavior with composite (C) but at rates less properties depending on the type of composite, either composite (B) has recorded the best results for compressive strength at ratio of (28.4%) when increasing sintering time from (2) to (10) hours . The composite (A) has suffered from collapsing in its compression strength after a sintering time at (4) hours.

Key words: Reinforcement material, physical and mechanical properties, Sintering time, powder metallurgy technique.

INTRODUCTION

In the past years, careful and important attention for the composite materials of ceramic and metallurgical were received, due to its unique properties and characteristics as achieved the main objective of obtaining a material with high durability and lightness in weight. These material have the ability to withstand high temperatures. Thus starting the interest in producing composite materials to create exiting new material having a better and different from the original components . So one could say that it consists of two materials : material matrix and reinforcement material (Chaklader and Linger 1998).

Extended and expanded use of the composites in the last century and became the increasing rate of progress too quickly, there are many types of composites materials mismatch metal matrix, ceramic matrix and polymer matrix as well as the composite materials can be classified depending on the consolidation medium (reinforcement phase), which can be metallurgic or ceramic or polymer medium (Callister., 2007) (Shamsul *et al*., 2007).

Composite materials science have the broad scope and cannot be familiar once you know the basic principles of the subject. But that it should support the basic principles by intensively a practical work in order to find composite material suitable for application in various circumstances and manufactures low cost and best specifications (Harris., 1999).

Several attempts were held to use the composite materials in many engineering application and in the area of space sciences, especially in the critical parts of space jet engines because of their light weight and in front of high speed ultrasonic rockets and airborne radar networks Radom and in rocket engines and airframes and in military defense purpose that require high resistance and weight lightly. This includes use of a wide range of area and start representing protective equipment suit individual prevention, protection of military air craft and armored vehicles and high performance technologies as well as extensive use in marine area, such as speed boots and submarines and multiple parts of these system in the areas of thermal control embodied in the refractories industry, which is characterized by susceptibility good for thermal insulation in high temperatures.

Also it is used in many application like : furnaces, kilns and stoves as well as in filters manufacturing that are used in various areas of life such as drinking water purification filters and still ongoing scientific research in this field in order to increase the area of the use of these materials in various application (Callister. ,2000) (Rahman and Yacob 2005) (Al-muslimawi., 2006).

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The current research aims to prepare composite materials, the base phase is composed of material basis of ceramic, Silicon Dioxide (SiO_2), Oxide, Titanium Dioxide (TiO_2) Chromium (III) (Cr_2O_3) with other metal elements (Co, Ni) each individually and reinforcement by a fixed Aluminium ratio . Also aims to study its impact on some physical and mechanical properties of produced composite material.

Theoretical:

Physical Properties:

The Physical Properties of objects produced by powder technology and used in specific application after sintering is a measure of the success of the sintering process.

If the water absorbency ,for example less than 1% is a vitreous product . But if higher than 1% is a porous product, and water absorption depends on the amount of porosity as it is linear proportional , while suit apparent density of the body and the specific gravity directly proportional to both inversely proportional to each of the apparent porosity and water absorption These properties can be calculated using the following relation (Vasilyeva *et al*., 2002) (Shinen., 2004) (Bolarinwa., 2010) (Djambazov *et al*., 2011):-

$$A.P = \frac{Ws-Wd}{Ws-Wi} \times 100\% \quad (1)$$

$$W.A = \frac{Ws-Wd}{Wd} \times 100\% \quad (2)$$

$$A.D = \frac{Wd}{Wd-Wi} \times \rho \quad (3)$$

$$\frac{Wd}{Ws-Wi} = S.G$$

Ws : Saturated Wight gm.
Wd : dry Wight gm.
Wi : handing Wight gm.
ρ : water density gm/cm^3.

The physical properties depends on several factors, including the chemical composition of composite material, due to the importance of components melting points in the formation of the liquid phase during sintering process. as well as the size and particle distribution play a key role in determining the amount of material density because the small size of the granules before forming raw materials leads to granules compaction during pressing. Increasing stacking during the sintering process leads to increased the density on behalf of porosity and that the temperature and time of sintering has a clear impact on these properties as the sample before sintering has high porosity and then go down the pores as a result of increased grain size of some on behalf of other grains. Or an increase of the liquid phase leading to fill the pores between grains, which lead to lower water absorption and increase both apparent density and specific gravity of the sample (Shinen., 2004) (Bolarinwa., 2010) (Djambazov *et al*., 2011).

Mechanical properties:

The Mechanical properties are considered the most important properties that Mechanical properties can be studied for materials in general and that it be comprehensive material and recipes can formed and implemented in different circumstance and represent the material`s ability to resist external mechanical changes affecting it, so that describes the amount incurred for the forces , load and shocks.

Mechanical properties includes : hardness and toughness . the values of these properties vary significantly from one substance to another depending on the structure and chemical composition of the matter (Al-Haidari., 2004)

Experimental Part:

Sample Preparation:

The powders preparation method has the significant impact on its properties. It affects the : shape, particles size, size distribution, crystalline phases, impurity content and density of the powder and its fluently. The powder metallurgy technique is considered one of the main methods in the preparation and detect of the properties through controlling of the manufacture conditions.

This method include the following:

The Powders Preparation (raw materials):

The used powders in composites manufacture in this study so that the average particle size and its manufacturer are shown in the table (1).

Table 1: The used powders in composites manufacture.

	50 ≤	99.99	Riedel-De HAEN Co. Germany
	35 ≤	99.50	Chemical Industries Co. India
	50 ≤	99.50	Flukka AG , BuchsSwitzerland
	150 ≤	99.90	Indian Product
	63 ≥	99.50	Buchs Fluka AG co. GERMANY
	63 ≥	99.50	Buchs Fluka AG co. GERMANY

Powders Weight:

A quantity of know size by 1gm was taken and we create a mix weights every sample of composites with different gradients in particle size components following weighted percentages listed in table (2) and using the delicate, high degree of accuracy electric balance , due to that importance on the properties of the produced sample.

Table 2: The weight ratio of the composite.

composite	Chemical Formation %					
	Co	Ni	Al	Cr_2O_3	TiO_2	SiO_2
A	20	20	20	_	_	40
B	20	20	20	_	40	_
C	20	20	20	40	_	_

Powders Mixing:

Been put each sample mix in a bowl and then good mixing the material for half an hour and during the mixing process and to avoid loss (blowing out) any amount of powder . as well as assisting in the mixing process, ethanol was added and then put the material in a furnace at a temperature of 1000°C for (6) hours to get rid of the alcohol and excess moisture and then put the powder in another bowl . Repeated the process on a new batch of the same mixture and so continued until the completion of composite for the same amount . Repeated the process on the rest of the mixtures of the composites mentioned in table (2).

Compressing the Samples:

Pressing process was conducted using electric hydraulic piston type (Hoytom) which was used later on measuring the compressive strength of the composites under study, after putting a sample of the chemical composition of the composites in the form of one cylindrical pressing for example . Pressure compress was used for formation amount of (5) tons for 60 seconds , repeated pressing process for the of the samples and for all composites The produced samples from the pressing process was in the form of (CD) with diameter ranging (13.5 - 13.85) mm. and thick of (2.5 - 2.9) mm.

Sintering:

After a pressing process was conducted the samples is not ready to conduct tests, as conducted sintering process is complete, sintering time was determined (2,4,6,8,10) hours for each sample and a formation ratio , then samples were put in the furnace and temperature raised to (1000°C) in average of 8 °C/ min. and stay at this detected degree for the times mentioned earlier. Then switch off the furnace and keep the sample slowly cooling inside the furnace till reach the room temperature. Specimens were cleaned, grind and polished to be ready for physical tests, while the microstructure test and phases detection and growth direction were conducted using x-ray diffraction device (XRD). Hardness was measured by using digital micro hardness device type (Equotip2) and on average of five readings for each sample. And fig. 1 shows the flowchart of the practical part.

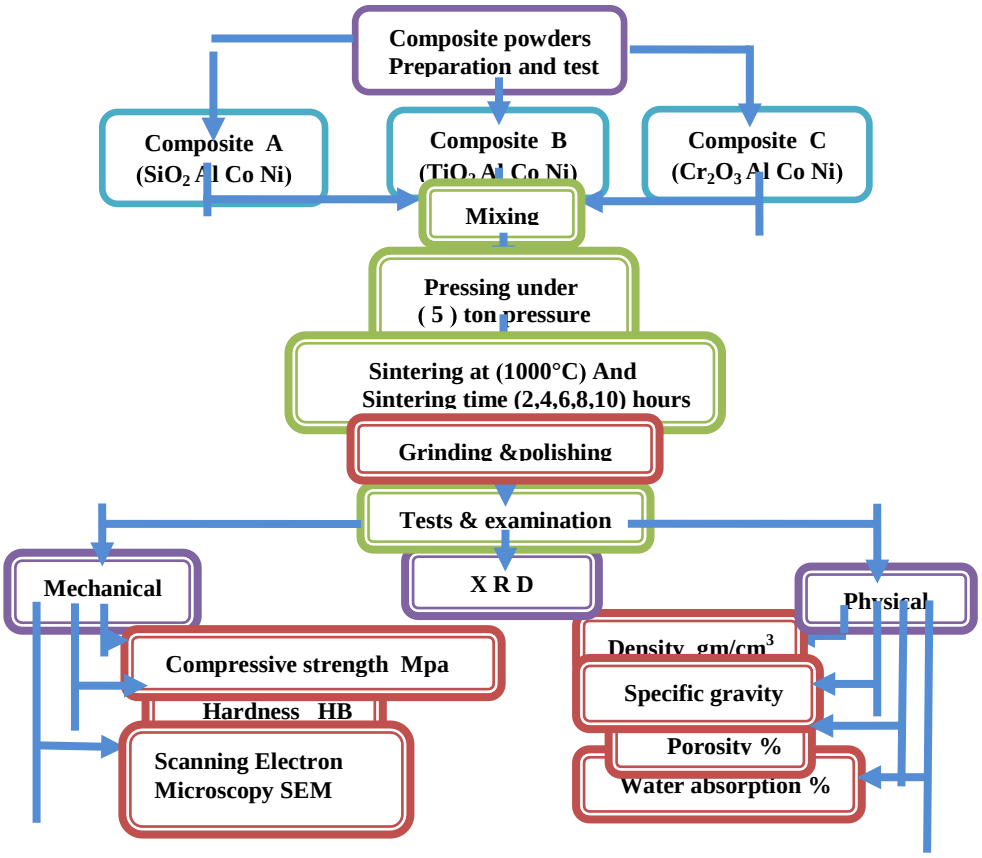

Fig. 1: Flow chart of practical part.

RESULTS AND DISCUSSIONS

Physical Properties:

Apparent porosity (A. P), water absorption ability (W.A), apparent density (A.D) and specific gravity (S.G) were calculated by using Archie's method and using the relations (1) to (4) Low apparent porosity for all composites with sintering time increase as shown in figure (2) and the value of the apparent porosity of composite (C) is at least , while the composite (A) record the higher values with increase different sintering time due to the nature and phases structure that formed , figures (3) , (4) and (5).

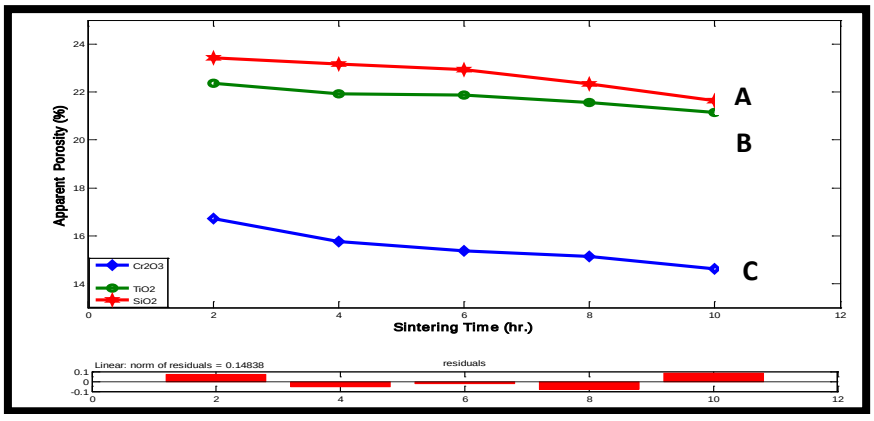

Fig. 2: Sintering time with apparent porosity relationship.

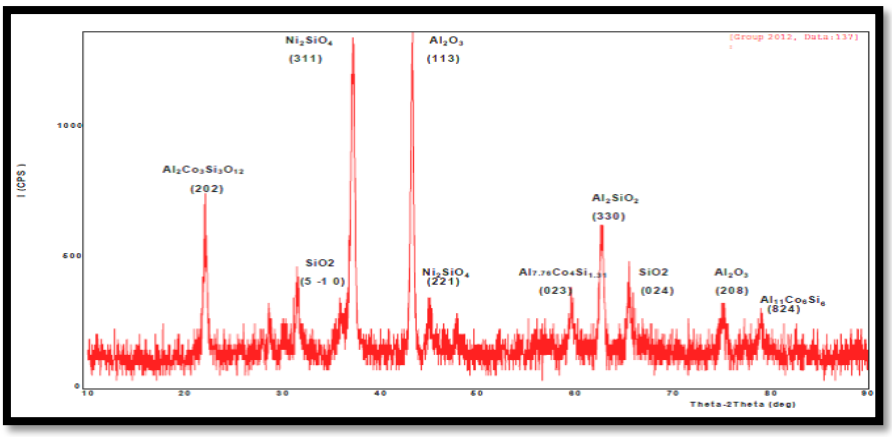

Fig. 3: X-Ray diffraction spectrum intensity of composite (A) at Sintering time (10) hours.

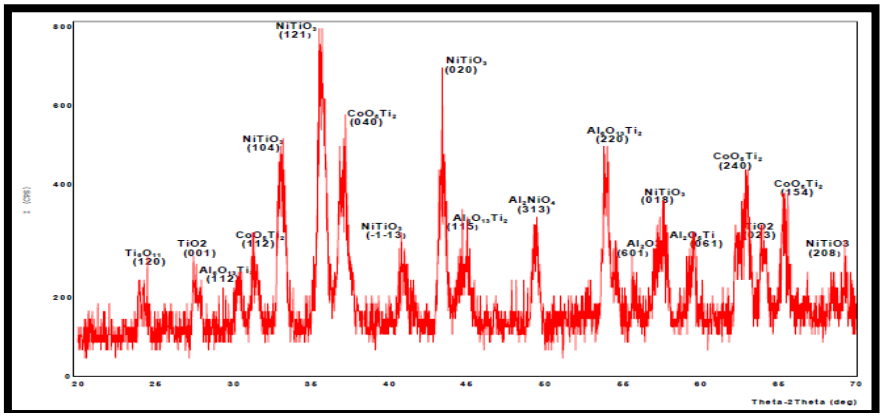

Fig. 4: X-Ray diffraction spectrum intensity of composite (B) at Sintering time (10) hours.

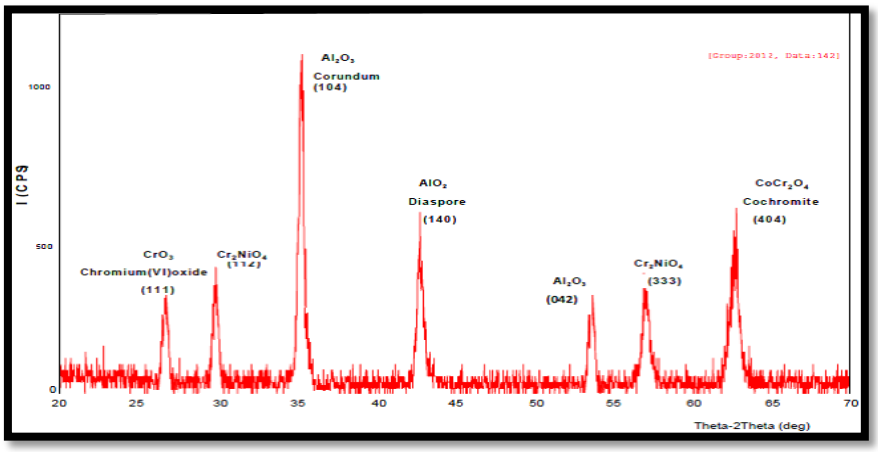

Fig. 5: X-Ray diffraction spectrum intensity of composite (C) at Sintering time (10) hours.

Composite (C) less porous at ratios (30%) and (32%) about composites (B) and (A) ,respectively when sintering time is (2) hours fig.(2). This may be attributed to the increase sintering time leads to chemical reaction between the components of the composites and composition of the liquid phase addition to the relative homogeneity and cohesion between composites particles and convergence with each other, which acts on filled the spaces between the pores and thus reduse the apparent porosity as shown in figures (5), (6).

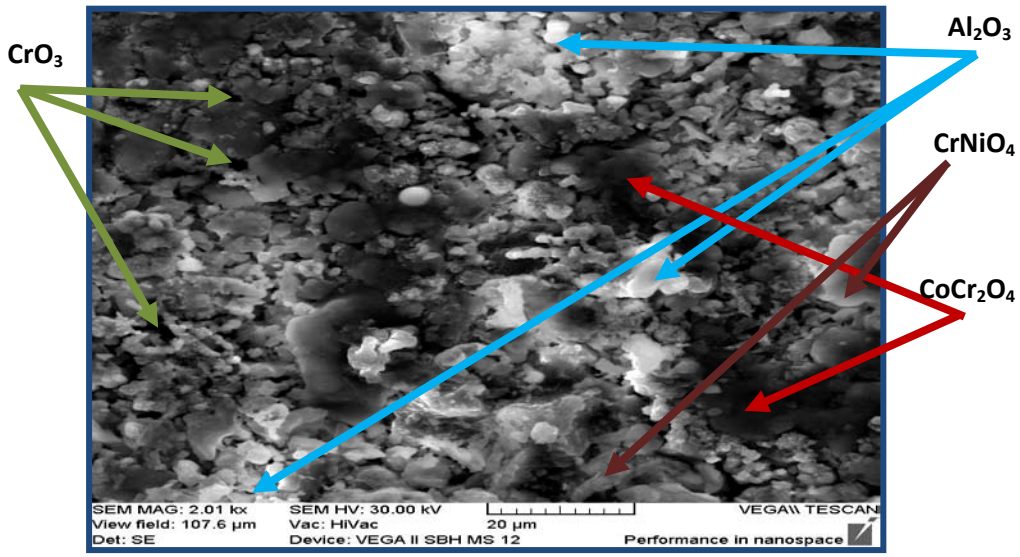

Fig. 6: Microstructure of composite (C) at sintering time (10) hours.

The relation between sintering time via ability of water absorption is an inverse relationship as shown in fig.(7), as happens a decrease in water absorption values with increasing sintering time . This behavior is similar to what has been seen through apparent porosity relationship with increasing sintering time fig.(2).

Absorption ability was reduced gradually when increasing the sintering time from (2) to (10) hours and in linear type, and it is less value was the composite (C) of (4.79%) at the time of sintering (10) hours, either value of composites (B) and (A) have increased at percentages of (37%) and (48%) respectively, compared with composite (C) fig.(7).

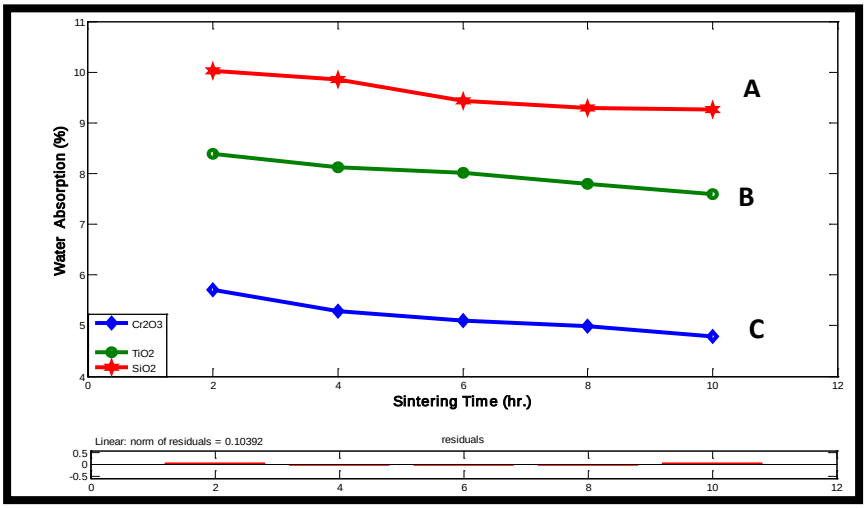

Fig. 7: Sintering time with water absorption relationship.

Fig.(8) demonstrate the general direct behavior between sintering time and apparent density, as the composites density increased with increase sintering time except composite (A) after (6) hours sintering time . This can be due to the affect of increased ratio of Aluminium transition to its oxide (Al_2O_3) , which was characterize by high porosity, also by other formed phase, which can play the same role , and finally its impact on apparent density amount fig.(3).

The behavior of different composites as the sintering time increased was agree with that of (Ribeiro. and Strecker. 2004) (Andic1. *et al.*, 2006) (Nader. 2009) for identical physical properties of another composite and materials.

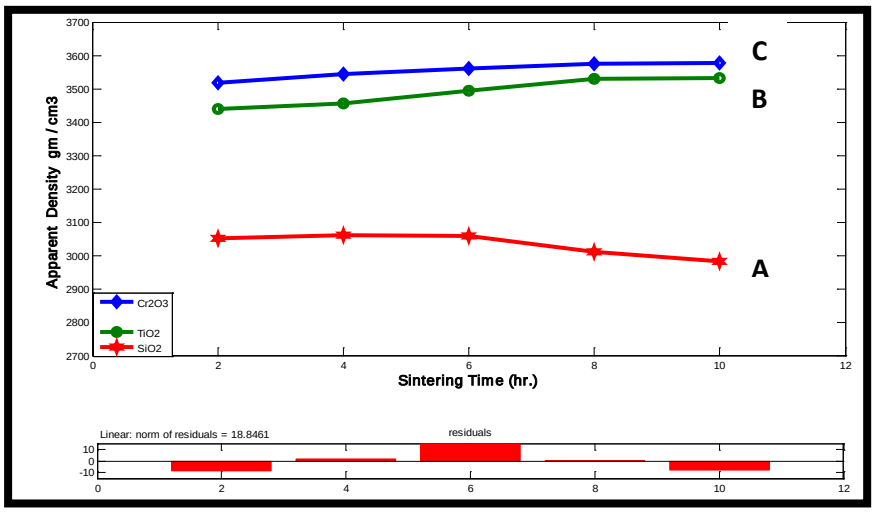

Fig. 8: Sintering time with apparent density relationship.

The relationship between the sintering time and specific gravity for all composites was linear fig.(9) and similar to that of fig.(8) the behavior changes between sintering time and apparent density, which reflect positively on physical properties . whereas the effect of increase sintering time was negatively on each of apparent porosity and water absorption ability fig.(2) and (7) . This can be due to the role of chemical reaction between the components and the quality of phase and chemical compounds figures (3) ,(4) and (5).

Composite (C) recorded highest value of specific gravity, as reached (305.48%) at the sintering time (10) hours, while at (2) hours sintering time the value reached (278.77%) for the same composite, and can be attributed to the outcome of overlapping effects, whether positive or negative on composite physical properties fig.(5) and (6).

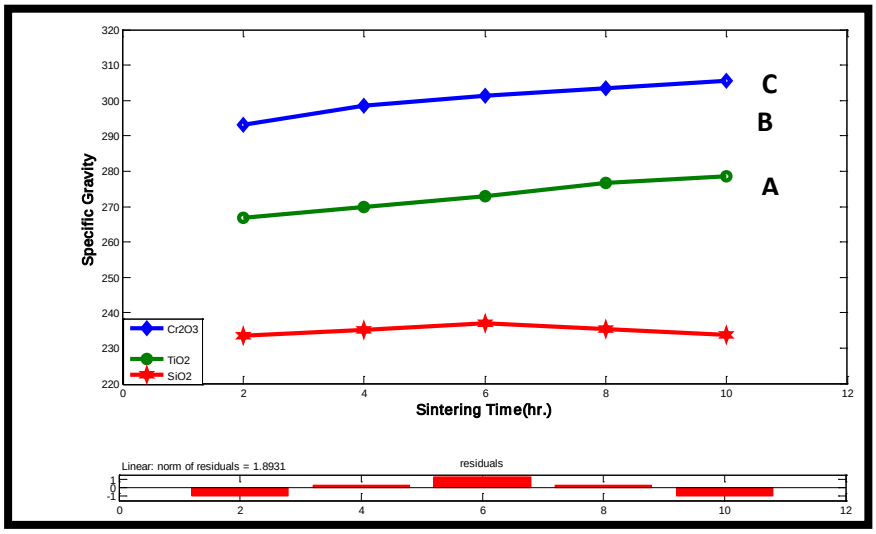

Fig. 9: Sintering time with Specific gravity relationship.

Mechanical Properties:

The relationship of sintering time with hardness was positive fig.(10) as hardness increased with increasing sintering time as composite (C) has for example higher hardness values compared with composites (B) and (A) , and increasing sintering time from (2) to (10) hours hardness increased by (11%) for composite (C) . the reason for this increase is attributable in hardness values to increase in density and assemble grained case of close contact between strengthening particles and base material and thus remove gases and fading or receding internal gaps and this is consistent with the findings of the (Ribeiro and Strecker 2004) (Andic *et al*., 2006) (Nader ., 2009) (AL-Saady., 2008) for materials and other composites.

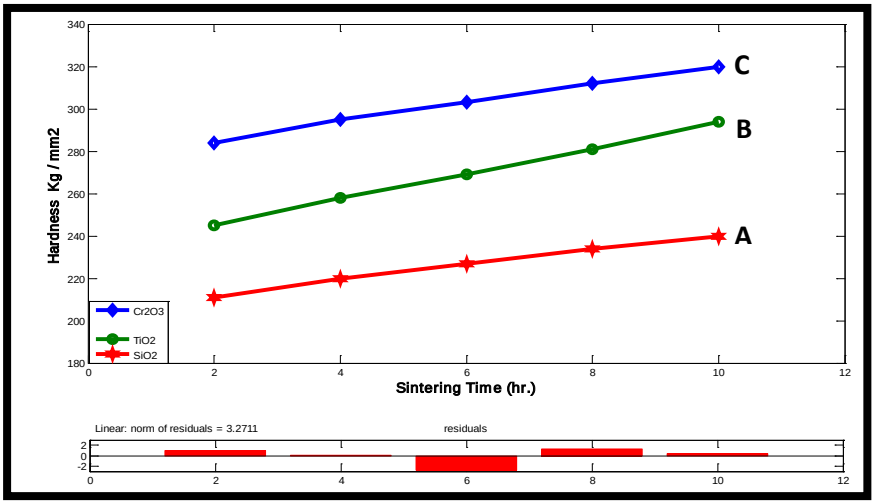

Fig. 10: The relationship of Sintering time with Hardness

Compressive strength and hardness were increased as the sintering time increased for all composites in fig.(10) and (11). Composites (B) and (C) were behaved similarly fig. (11), as for example, the difference in compressive strength ratio for both composites (B) and (C) at sintering time of (2) hours higher than of increase sintering time to (10) hours as ratio difference between then reach (29%) and (10.3%), respectively. This can be due to the increasing of sintering time and difference of milting temperature for different composite elements and this has relation with liquid phase quantity generated due to increase sintering time, which can affect the composite durability and its resistance to external loads. This is agree with the conclusion of (Ribeiro and Strecker 2004) (AL-Saady., 2008) for materials and other composites, and moreover as hardness values increased to certain limits, then decrease the compressive strength. This has distinctively noticed through the correlation between each of composite (B) and (C).

While the composite (A) has the same behavior as in composites (B) and (C) until sintering time of(4) hours but at different percentages of compressive strength with the increased sintering time, whereas noticed its compressive strength failure after (4) hours sintering time, this can be due to the high porosity, gaps and internal cracks that characterize the composite (A) and already be generated by the different thermal expansion between silica and formed phase, which can help on stress concentration during apply stress and then decline the mechanical properties, that can be quick of failure and collapse the composite, this is agree with that of (Ting and. Lin 1991) (Lohr and Morrell 1989) also with particles roughness (SiO_2) table (1) which has negative and direct affect on mechanical properties of the composite.

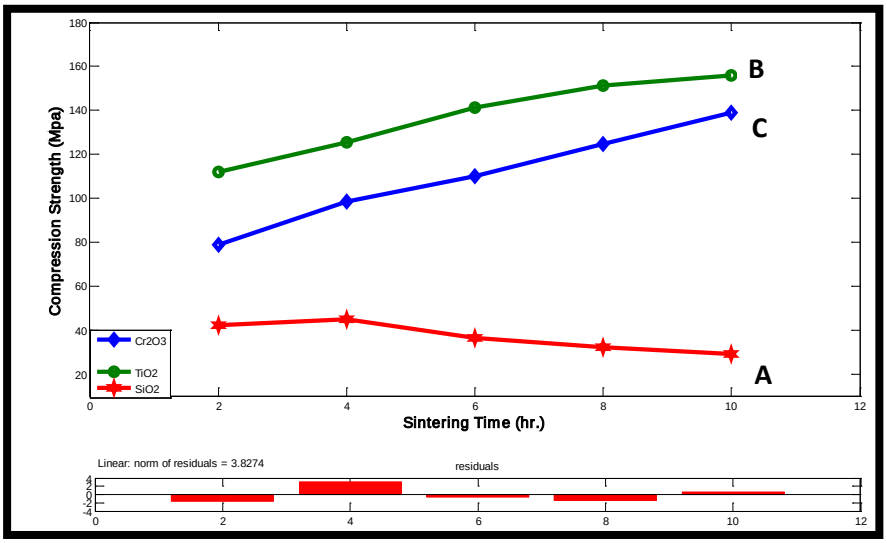

Fig. 11: The relationship of Sintering time with compressive Strength.

Conclusions:

Porosity of composite (C) is reduced by (30%) and (32%) for the composites (B) and (A) respectively , at the time of sintering (2) hours, while composite (A) record higher value.

The increase sintering time relationship with water absorption ability for composites (A,B,C) is an inverse relationship, and that this behavior is similar to what has been seen through apparent porosity relationship.

Composite (C) recorded less valuable for water absorption ability which is equal (4.79%) at sintering time (10) hours, worth either for composites (A) and (B) have increased (37%) and (48%) respectively.

The behavior increase sintering time with both apparent density ,specific gravity and hardness generally proportional and composite (C) was supreme.

Increasing hardness (to certain limits) reduce the compressive strength at variably two composite while noting the collapse of the compressive strength after sintering time (4) hours.

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