Australian Journal of Basic and Applied Sciences, 11(2) February 2017, Pages: 50-58

AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

Study Some Properties for Manufactured Grinding Wheels by Use Different Abrasive Materials

[1]Hussein Talab and [2]Marwa Marza

[1]Assistant lecturer, Department of Ceramic and Building Materials Engineering, College of Materials Engineering, University of Babylon, hila, Iraq.
[2]Assistant lecturer, Department of Ceramic and Building Materials Engineering, College of Materials Engineering, University of Babylon, hila, Iraq.

Address For Correspondence:
Hussein Talab , Assistant lecturer, Department of Ceramic and Building Materials Engineering, College of Materials Engineering, University of Babylon, hila, Iraq.
E-mail: eng.hussein.t@uobabylon.edu.iq

ARTICLE INFO

Article history:
Received 18 December 2016
Accepted 16 February 2017
Available online 25 February 2017

Keywords:
Silicon carbide, alumina, vitrified bond, grinding wheels, wear rate.

ABSTRACT

In This paper an experimental studying for manufacturing grinding wheels from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3)) with particle size (154µm)) and vitrified bond (powder of window glass scrap with particle size (125µm)). This study made to evaluate the effect of vitrified bond percentage on the mechanical and physical properties for manufacturing grinding wheels in laboratory. The percentage of vitrified bond was (8, 14, 20 % wt). The samples of grinding wheels were produced by powder technology, where the powders of the abrasive and vitrified bond mixed together and pressed at (110 MPa) by use steel alloy molds. After that, the samples were firing at (700 ºC). The physical properties (density and porosity) and mechanical properties (hardness, bending strength, compressive strength and wear rate) were determined for all samples. The results showed that the density, hardness, bending strength and compressive strength increased and, the porosity and wear rate decreased with increasing the vitrified bond percentage for manufacturing grinding wheels from silicon carbide (SiC) and alumina (Al_2O_3). The higher hardness value was (517MPa) when silicon carbide was used with (20 % wt.) of vitrified bond and least wear rate was (0.088 g/cm^2) when alumina was used with (20 % wt.) of vitrified bod. The mechanical and physical properties improve with increasing the vitrified bond percentage for manufacturing grinding wheels from different abrasive materials, also the strength values of manufactured samples from alumina (Al2O3) higher than that of manufactured samples from silicon carbide (SiC). While the wear rat of the manufactured grinding wheels from alumina least than that of the manufactured grinding wheels from silicon carbide in the same test conditions (the wear load and time)

INTRODUCTION

The grinding is defined as a removal operation for tiny chips of material from the work by use an abrasive material and process of surface generation which used to form and finish works made of different materials. The surface finish and precision which achieved through grinding can be best of milling or turning (Vedhavalli and Annamalai, 2002). Grinding uses an abrasive tool, generally a rotational wheel came into controlled connection with a work surface. The grinding wheel is made of abrasive grains detained together in a binder (Liu *et al.*, 2007). The efficient grinding is required abrasive tools which are harder than the work, heat- and shock-

To Cite This Article: Hussein Talab and Marwa Marza., Study Some Properties for Manufactured Grinding Wheels by Use Different Abrasive Materials. ***Aust. J. Basic & Appl. Sci.,*** *11(2): 50-58, 2017*

resistant abrasive wheels and a friable abrasives. That is, they are capable of controlled fracturing (Chen *et al*., 2008).

Most used abrasives in an industry are artificial. Alumina is used in most grinding operations, and is mainly used in the grinding operation of ferrous metals. Also, ceramic is mostly used as manufactured abrasive to grind hard brittle metals. Other abrasive material is silicon carbide which used to grind high density materials and non-ferrous metals (Marinescu *et al*., 2006). Cubic boron nitride 'CBN' and diamond are used as superabrasives in about five percent of grinding. Cubic boron nitride 'CBN' is used to grind hard ferrous materials, while diamond is used to grind non-ferrous materials and non-metals (Brady *et al*., 2002). The abrasive grain size is significant to the process. Coarse, large grains quickly remove material, while smaller grains give a better finis (King, 2002). These abrasive grains are hold together by use one of the following binders (Jackson and Hitchiner, 2013):

1. Vitrified bonds, a glass-like bond made of feldspar or fused clay
2. Organic bonds, made of synthetic resins, shellac, or rubber
3. Metal bond, by use single-layer bond systems or powder metallurgy

Vitrified bonds are formed from feldspar, clays and other fusible materials in a prudently controlled process. Grinding wheels, which are made by use this bond, have a porous structure and are fired in kilns. The manufactured wheels with vitrified bond are unaffected by acids, water, oils or normal temperature difference. The strength and porosity of these grinding wheels make them supreme for high stock removal operations. In addition to, the manufactured wheels with vitrified bond have a high elasticity modulus and this rigidity makes them appropriate for applications of precision grinding. The elastic modulus of a vitrified bond is approximately 4 times that of the resin bond. The vitrified bond has a relatively higher strength to hold the abrasive grains together, and a relatively easier dressing operation (Tanaka *et al*., 2014). Zhou *et al*. (2002) believed that "In vitrified wheels wear can occur through brittle fracture of the bond materials, allowing rapid emergence of new abrasives for continued grinding. Vitrified bonds are also interest because the porosity level of the bond can be tailored to control bond facture, so that self-sharpening of facilitated and continuous grinding established."

The distribution of the abrasive grains and bond in the grinding wheels form a certain characteristic known as pores or structure. Where these pores are designed based on the application requirements and used for chip clearance. This pore structure forms spaces among the particles that provide areas for formation of the chips and coolant retention. The dense grinding wheels are used to grind the harder materials, while more open densities are used to grind the softer metals. The bond type, grain size and pore structure are three factors which closely relate and determine together how well a grinding wheel will accomplish (Chen *et al*., 2014).

The toughness and the color of the abrasive material are determined by the impurities amount (titanium oxide, iron oxide and silica). Also the additives are strongly influence on toughness. Alumina is commonly used to grind most steels, malleable, annealed and ductile iron, and non-ferrous cast alloys. White alumina is containing over 99 % alumina (pure alumina). The high purity of this abrasive lends it with the white color and the property of high friability (Krzysztof and Daniela, 2015).

Abrasives of silicon carbide are harder and more friable than alumina abrasives. Silicon carbide is usually used for grinding low tensile materials like unannealed malleable iron, grey iron and non-metallic materials such as gem stones, glass, aluminum, bronze, copper, rubber and plastic. Black Silicon carbide "BC" and Green Silicon carbide "GC" are two types of Silicon carbide. Black silicon carbide have a least percentage of pure silicon carbide than green silicon carbide. It is used for general grinding, Centre less, cylindrical, internal grinding and heavy duty snagging. It is also used to grind cemented carbide (Harper, 2001). In addition to performance, the cost is another critical constraint to select the material of wheel. Diamond has been the choice of abrasive for efficient grinding of engineering ceramics, but two barriers associated with diamond grinding are: cost of diamond wheels and difficulty of truing diamond wheels to a precise shape for form grinding. Compared to diamond, the cost of SiC abrasive is low. A stationary diamond tool can be used to generate the precise shape on SiC wheels for form grinding (Nadolny and Kapłonek, 2013).

Albert *et al*. (2013) used the dense vitreous bond silicon carbide wheel to grind zirconia and other ceramics including alumina and silicon nitride using wheels with fine grain size SiC. Wheel wear results showed that this type of SiC wheel could grind fully and partially stabilized zirconia (PSZ) very effectively. The same wheel was not effective on alumina and silicon nitride.

Jackson and Mills (2004) showed the effect of heat treatment on change of strength value between the abrasive grain and vitrified bond, the nature of happened fracture and wear of grinding wheels which use in applications require accuracy. They use manufactured grinding wheels from aluminum oxide (Al_2O_3) and other from cubic boron nitride (CBN). In manufactured grinding wheels from aluminum oxide (Al_2O_3) and vitrified bond, the fracture is happened at the interface between (Al_2O_3) and vitrified bond. While in manufactured grinding wheels from cubic boron nitride (CBN) and vitrified bond, the fracture is happened in vitrified bond.

Xu *et al*., (2006) studied the use effect of grinding wheel from green silicon carbide which has fine grain size and vitrified bond to grinding silicon nitride, where they saw that the surface of silicon nitride (workpiece) contains on the cracks when the rat of chips removal is high. While the surface finishing improves when the rat of chips removal is little.

Zhang *et al*. (2009) showed that the manufactured grinding wheels from cubic boron nitride (CBN) and vitrified bond, which formed from (SiO_2-Al_2O_3- Na_2O) and papered by Sol-Gel method, have high strength for oxidation of abrasive grains (CBN) because the thermal expansion coefficient of glass verged the thermal expansion coefficient of (CBN), and have good compressive strength and toughness.

Ronald *et al*. (2009) studied the effect of bond type (resin and electroplate) for manufactured grinding wheels from diamond. When the grinding wheels with electroplate bond were used and the cutting depth was little, the temperature of workpiece surface increased. While the grinding wheels with resin bond gave the best surface finishing at the higher cutting depth also the temperature of workpiece surface decreased during the grinding. The performance of the grinding wheels with resin bond better than that of the grinding wheels with electroplate bond.

From previous explication, that the researchers studied different abrasive using in the grinding wheels manufacturing, also they studied properties of these grinding wheels and effect of the work conditions on the surface finishing by use different bond. This research is used different abrasive (black silicon carbide (SiC) and white alumina (Al_2O_3)) in manufacturing the grinding wheels by use vitrified bond (powder of window glass scrap) and studied properties of the manufactured grinding wheels to compare between them.

Experimental work:

This study is used different abrasive in manufacturing the grinding wheels (black silicon carbide (SiC) and white alumina (Al_2O_3)) with particle size (154µm)) and vitrified bond (powder of window glass scrap with particle size (125µm)). The percentage of binding material was (8, 14, 20 % wt). Some physical and mechanical properties were studied for these manufactured grinding wheels.

Materials preparation:

Raw materials of the samples were prepared, where the window glass scrap is crushed and grinding to obtain on the glass powder, after that the glass powder is sieved by use sieving apparatus (Electric Sieve Shaker) to obtain on the particle size (125µm). Also the powder of abrasives is sieved to obtain on the particle size (154µm). All powders were weighed to obtain on the required percentage to vitrified bond as shown in table (1). These powders were mixed by electrical mixer for hours to obtain on the homogenous powder.

Table 1: State the weight and percent of the abrasive and bond in manufactured sample.

No. of sample	Sample weight (gm)	Abrasive percentage (SiC or Al_2O_3) (%)	Bond percentage (%)	Abrasive weight (gm) (SiC or Al_2O_3)	Bond weight (gm)
1	11	92	8	10.12	0.88
2	11	86	14	9.46	1.54
3	11	80	20	8.8	2.2

Samples formation:

The method of semi dry pressing by single direction was employed in the formation of samples by use hydraulic uniaxial pressing device at a pressure of (110) MPa and used steel die with (d= 20mm), also it was used the solution of (P.V.A) with percentage (1%) to semi dry pressing. Other samples was formed with dimension (12.5*25*115) to the bending test. The samples were dried to remove the moisture from the samples at temperatures (110)ºC for five hours. After that the samples were fired at (700)º C by use electrical furnace. Soaking time was one hour and then cooled in furnace.

Properties test:

A) Test of physical properties (density and porosity)

Density and porosity of the firing samples were determined by use the Archimedes technique according to ASTM standard (C373 – 88). The firing samples were boiled in water in order to fill the pores with steam and the time of boiling was three hours. After that, the samples were cold to ambient temperature. Suspended mass of the sample in water was registered (m_s). After that, the water-saturated mass was determined (m_w), where the surface of the sample was dried by use a paper towel. Both m_s and m_w were determined from the three readings average for each mass. The dry mass of samples was determined (m_d) after the samples were dried in the furnace at (105)°C for two hours. Values of density were calculated from the three samples average. The density and open porosity were calculated by use the following equations (ASTM C 373- 88, 1988):

$$\text{Density } (\rho) = D/(M-S) \quad (1)$$

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

Where:

ρ = the bulk density (g/cm^3)
P = the porosity
D = the dry mass (g)
S = the suspended mass (g)
M = the saturated mass (g)

B) Test of mechanical properties

1) Hardness test : the hardness of samples were measured on polished surfaces by use hardness machine (TH-717 Microvickers) and a Vickers hardness diamond indenter at (10)kg, a load was applied for (15) seconds and the enlarge force was (20X). Values of the hardness were determined from the three indents average on each of the three samples. Vickers hardness was calculated from the following equation:

$$Hv = 1.854 * P/d^2 \tag{3}$$

Where:
Hv is the Vickers hardness;
P is the indentation load (kg);
d is the indentation diagonal (mm).

2) Bending strength test: bending strength of the samples was measured by use Three-Point Bending Test. Average of applied load (0.5KN/min). Maximum load, at which the sample was fractured, was registered. Depending on ASTM standard (C674 -88), the following equation was used to calculate values of the bending strength (ASTM C 674- 88, 1988):

$$\sigma_B = (3P_F*l)/(2w*t^2) \tag{4}$$

Where:
σ_B = the bending strength (MPa)
P_F = the applied load until fracture (N)
l = the distance between the supports (mm)
w = width of the sample (mm)
t = thickness of the sample (mm)

3) Compressive strength test**:** compressive strength was measured for the samples according to the ASTM standard (C 773-88) by use general testing machine. Each test result was determined from the three samples average, the following equation was used to calculate values of the compressive strength (ASTM C 773- 88, 1988):

$$б_c = F / A_r \tag{5}$$

Where:
$б_c$ is compressive strength (MPa).
F is applied load until fracture (N).
A_r is cross section area of sample (mm^2).

4) Wear test (frictional wear): the wear rat was measured for the samples by method (Pin on Disc) without use coolant. Weight of sample was registered before the test then the sample was put in the machine of wear rat measure, the test time for each sample was (30 min) accrual where the weight was measured for each (10 min) under effect of the lever weight (200 g). the wear rat was calculated from the equation below:

$$Wr\ (g/cm^2) = W_\circ - Wt_n\ / B \tag{6}$$

Where:
Wr is the wear rat
$W_\circ$ is the original weight of sample(g)
B is the sample area (cm^2)
Wt_n is the sample weight after (t_n) from the time (g)
(tn =10, 20, 30 min).

RESULTS AND DISCUSSION

1) Physical properties (density and porosity): figure (1) shows the effect of vitrified bond percentage on the porosity of manufactured samples from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3), where the porosity of manufactured samples decreases with increasing the vitrified bond percentage. While figure (2) shows the effect of vitrified bond percentage on the density of manufactured samples from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3), where the density of manufactured samples increases with increasing the vitrified bond percentage by reason of the increasing in the glassy phase which formed from the vitrified bond at sintering process and which fills the present paces and pores between the abrasive grains (Krzysztof and Daniela, 2015). The glassy phase resemble the viscous liquid which forms from vitrified bond melting which moistens and covers the abrasive grains (increasing the vitrified bond percentage means increasing amount of the melting material which fills the paces) that leads to decrease of the porosity and increase of the density of manufactured samples. While the difference between the density of manufactured samples from silicon carbide (SiC) and the density of manufactured samples from alumina (Al_2O_3) is come back to the difference in the specific gravity for these abrasive (the specific gravity for silicon carbide higher than alumina).

2) Mechanical properties: the study of hardness, bending and compressive strength for material gives the idea about strength of such material and magnitude of forces which expose for it during the use. The strength of ceramic material circumscribes by many of the factors, from these factors type and density of material, internal structure of material, firing temperature and chemical interactions which obtain between constitutes during the firing (Nadolny and Kapłonek, 2013). Figure (3) shows the effect of vitrified bond percentage on the hardness of manufactured samples from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3), where the hardness values of manufactured samples increase with increasing the vitrified bond percentage due to increase the interlink which result from increase in the formed glassy phase and because of the high hardness of the binding material. From the figure was noted that the hardness values of manufactured samples from silicon carbide (SiC) higher than that of manufactured samples from alumina (Al_2O_3) because of the hardness of silicon carbide higher than that of alumina (because of the constitutional composition). While figure (4) and figure (5) show the effect of vitrified bond percentage on the bending and compressive strength respectively of manufactured samples from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3), the bending strength values of manufactured samples increase with increasing the vitrified bond percentage also with respect to compressive strength due to increase the interlink between the abrasive particle and the binding material with increasing the vitrified bond percentage, where the vitrified bond transform at the firing to viscous liquid which form physical interlink with the abrasive particle and also decrease the porosity, that lead to increase the mechanical strength (Krzysztof and Daniela, 2015). The strength values of manufactured samples from alumina (Al_2O_3) higher than that of manufactured samples from silicon carbide (SiC) because of that the manufactured grinding wheels from silicon carbide are harder and more friable than the manufactured grinding wheels from alumina.

3) Figure (6) and figure (7) show the relationship between the wear rat and time for the manufactured grinding wheels from silicon carbide and from alumina respectively. From these figures show that the wear rat increase with increasing the time by reason of the friction between the abrasive particles and the workpiece, where it is removed part from the surface workpiece and because the friction that the losing in the abrasive particles happens and the temperature of the interfacial rises (Chen *et al.*, 2014). Figure (8) shows the effect of vitrified bond percentage on the wear rat of manufactured samples from different abrasive materials (silicon carbide (SiC) and alumina (Al_2O_3), where the wear rat decreases with increasing the vitrified bond percentage because of the good interlink between the abrasive particles and the binding material, where the binding material hold the abrasive particles weller after the sintering process (Albert *et al.*, 2013), this interlink increase with increasing the vitrified bond percentage. Also the wear rat of the manufactured grinding wheels from alumina least than that of the manufactured grinding wheels from silicon carbide in the same test conditions (the wear load and time) because alumina more toughness than silicon carbide and the manufactured grinding wheels from silicon carbide are harder and more friable than the manufactured grinding wheels from alumina. For future work

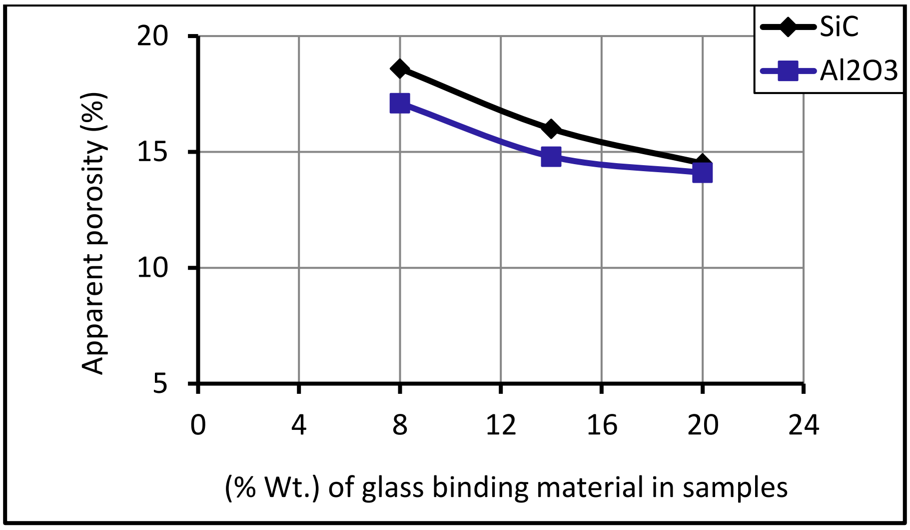

Fig. 1: Shows the effect of vitrified bond percentage on the porosity of samples.

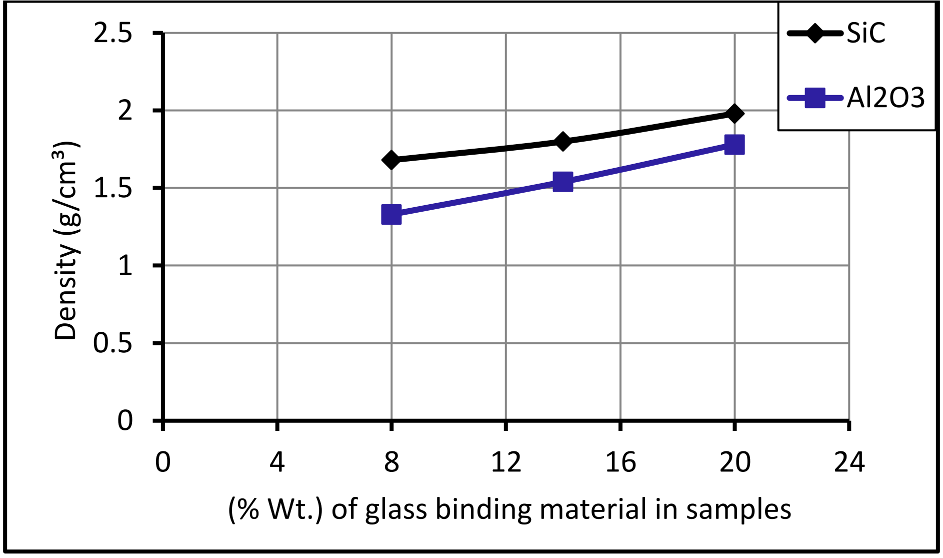

Fig. 2: Shows the effect of vitrified bond percentage on the density of samples.

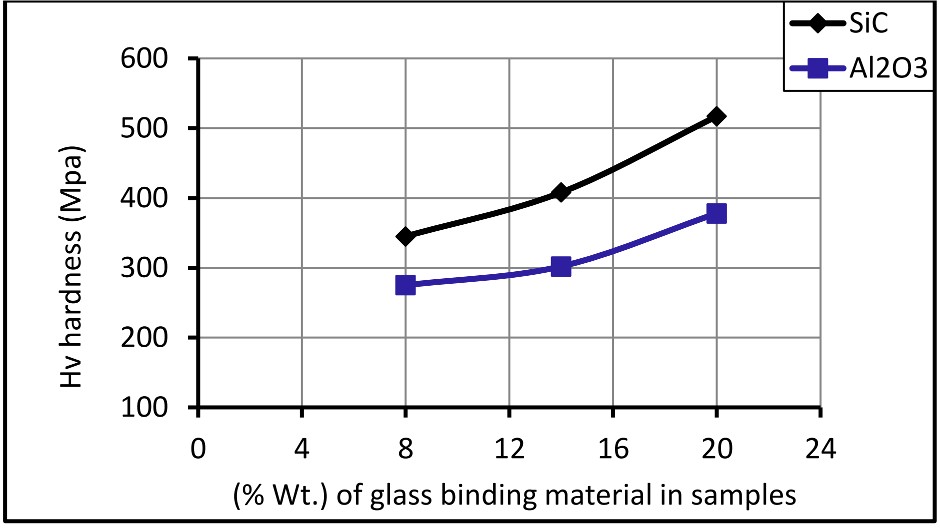

Fig. 3: Shows the effect of vitrified bond percentage on the hardness of samples.

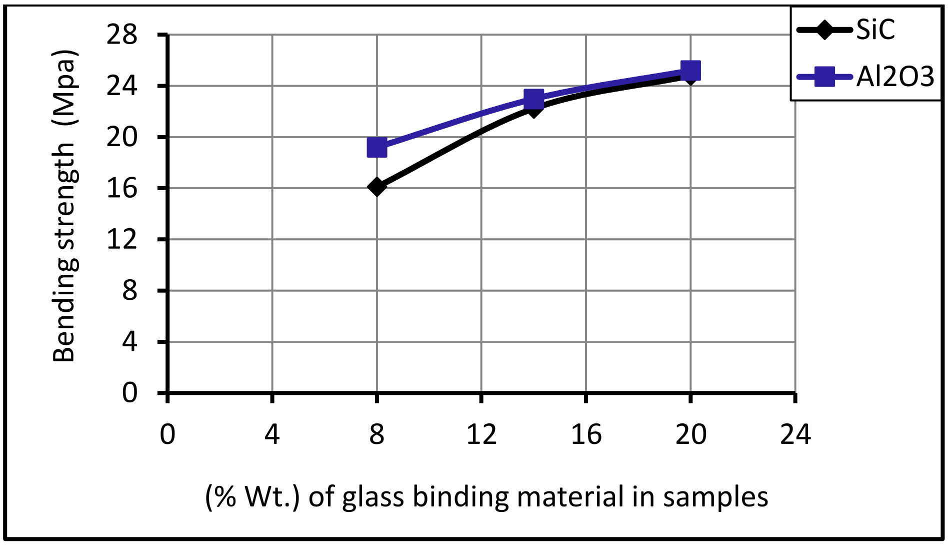

Fig. 4: Shows the effect of vitrified bond percentage on the bending strength of samples.

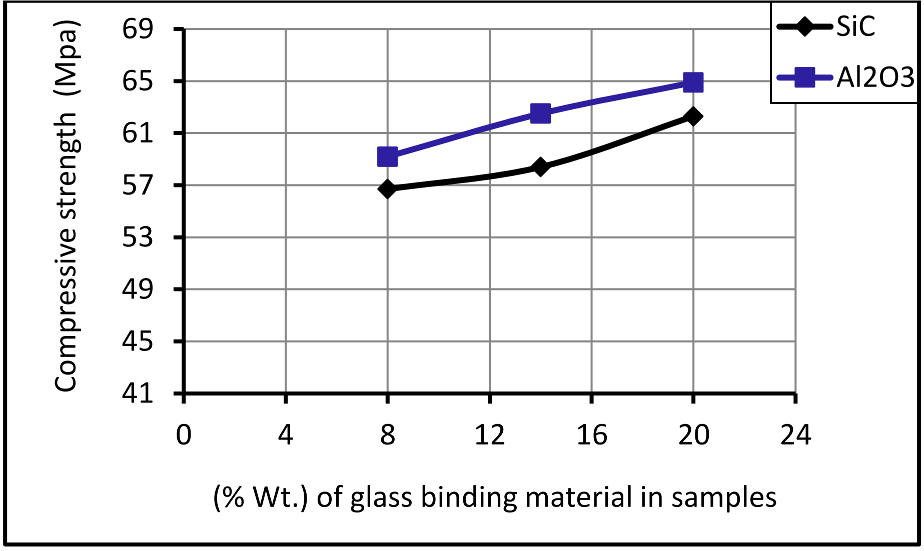

Fig. 5: Shows the effect of vitrified bond percentage on the compressive strength of samples.

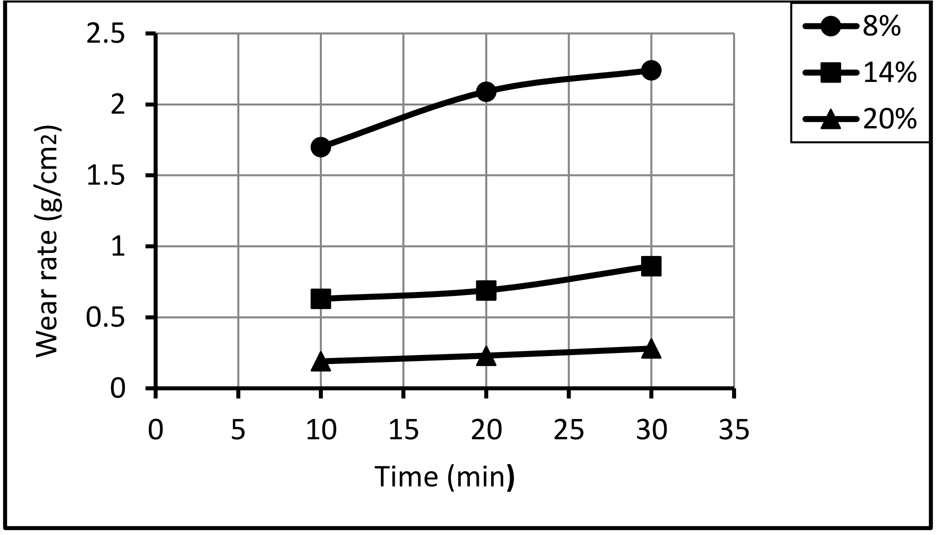

Fig. 6: Shows the relationship between the wear rat and time for the manufactured grinding wheels from silicon carbide.

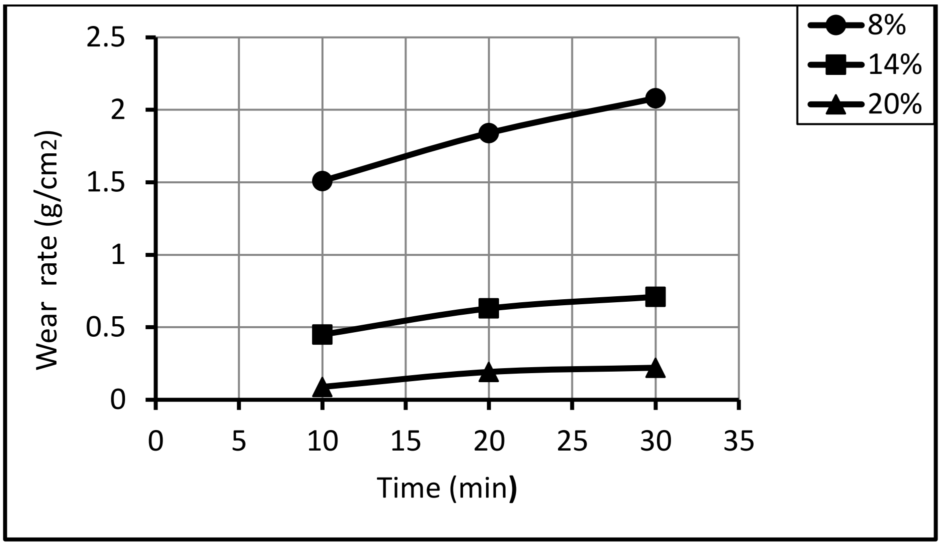

Fig. 7: Shows the relationship between the wear rat and time for the manufactured grinding wheels from alumina.

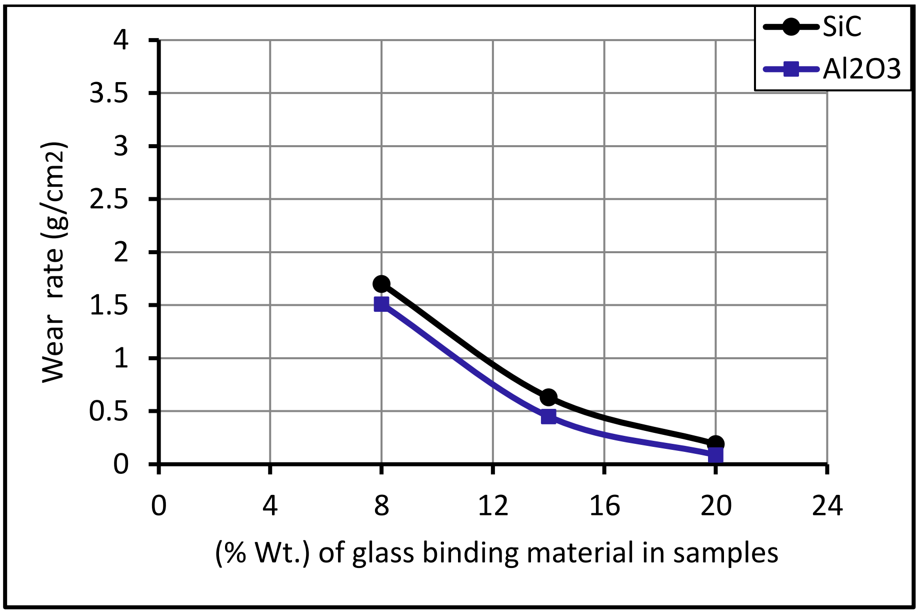

Fig. 8: Shows the effect of vitrified bond percentage on the wear rat of samples.

Conclusions:

1. The porosity of the manufactured grinding wheels from silicon carbide and from alumina decreases with increasing the vitrified bond percentage.
2. The density of the manufactured grinding wheels from silicon carbide and from alumina increases with increasing the vitrified bond percentage, and the density of manufactured grinding wheels from silicon carbide higher than that of manufactured grinding wheels from alumina.
3. The hardness values of the manufactured grinding wheels from silicon carbide and from alumina increases with increasing the vitrified bond percentage, and the hardness values of manufactured grinding wheels from silicon carbide (SiC) higher than that of manufactured grinding wheels from alumina (Al_2O_3).
4. The bending strength values of the manufactured grinding wheels from silicon carbide and from alumina increases with increasing the vitrified bond percentage, and the strength values of manufactured grinding wheels from alumina (Al_2O_3) higher than that of manufactured grinding wheels from silicon carbide (SiC).
5. The compressive strength values of the manufactured grinding wheels from silicon carbide and from alumina increases with increasing the vitrified bond percentage.
6. The wear rat of the manufactured grinding wheels from silicon carbide and from alumina increases with increasing the grinding time and decreases with increasing the vitrified bond percentage .
7. The wear rat of the manufactured grinding wheels from alumina least than that of the manufactured grinding wheels from silicon carbide in the same test conditions (the wear load and time)..

This study is interesting to limit the best percent of the vitrified bond which use in the grinding wheels fabrication and select the best abrasive for the suitable use.

REFERENCES

1. Albert, J. S., O. S. Ronald., C. Adam and M. Thomas., 2013. Cost-effective grinding of zirconia using the dense vitreous bond silicon carbide wheel. Journal of Manufacturing Science and Engineering, Vol. 125.
2. ASTM C 373- 88, 1988. Annul Book of standards.
3. ASTM C 674- 88, 1988. Annul Book of standards, p. (200-203).
4. ASTM C 773- 88, 1988. Annul Book of standards.
5. Brady, G., S, Clauser., H. R. and A. V. John., 2002. Materials Handbook. Fifteenth edition, McGraw-Hill Inc, New York, p. 3.
6. Chen, M., Y, Julong and Y, Yang., 2008. The Characteristic of organic Bond Grinding Wheel. Engineering Materials, Vol. 5,359–360, pp.(63–67).
7. Chen, Z., J, Xu., W. Ding and C. Ma., 2014. Grinding performance evaluation of porous composite-bonded CBN wheels for Inconel 718. Chinese Journal of Aeronautics, Vol. 27, No.4, 1022-1029.
8. Harper, A. C., 2001. Handbook of ceramics. Glasses and Diamonds, McGraw-hill Inc, U.S.A.
9. Jackson, M. J. and B. Mills., 2004. Micro scale wear of vitrified abrasive materials. Journal of Materials science Vol. 39, 2131- 2143.
10. Jackson, M. J. and M. P. Hitchiner., 2013. High Performance Grinding and Advanced Cutting Tools. Springer Briefs in Applied Sciences and Technology ,DOI 10.1007/978-1-4614-3116-9_2, Springer Science Business Media New York.
11. King, A. G., 2002. Ceramic Technology and Processing. Noyes publications, New York.
12. Krzysztof, N. and H. Daniela., 2015. Effect of vitrified bond microstructure and volume fraction in the grinding wheel on traverse internal cylindrical grinding of Inconel alloy 600. Int J Adv Manuf Technol Vol. 81,905–915.
13. Liu, J. H., Z. J. Pei and G. R. Fisher., 2007. Grinding Wheels For Manufacturing Of Silicon Wafers: Literature Review. International Journal Of Machine Tools and Manufacture, Vol. 47, No. 1, p.(1 -13).
14. Marinescu, I. D., H. Mike., U. Eckart., W. R. Brian and I. Ichiro., 2006. Handbook of Machining With Grinding Wheels.
15. Nadolny, K. and W. Kapłonek., 2013. Assessment of working conditions of the grinding wheels in grinding process of the hard-to-cut materials. Adv. Res. Eng. Sci. Vol. 1, No.1, 16–28.
16. Ronald, B. A., L. Vijayaraghavan and R. Krishnamurthy., 2009. studies on the influence of grinding wheel bond material on grindability of metal matrix composites. Materials and Design, vol. 30, 679 – 686.
17. Tanaka, T., S. Esaki., K. Nishida., T. Nakajima and K. Ueno., 2014. Development and application of porous vitrified-bonded wheel with ultra-fine diamond abrasives. Key Engineering Materials, pp. 251-256.
18. Vedhavalli, L. and V.E. Annamalai., 2002. The Characteristic of organic Bond Grinding Wheel. NDT for Grinding Wheels, p.4.
19. Xu, L. M., S. Bin and J. S. Albert., 2006. Vitreous bond silicon carbide wheel for grinding of silicon nitride. Original Research Article, International Journal of Machine Tools and Manufacture, Volume 46 ,Issue 6 , p(631- 639).
20. Zhang, A., L. Zhihong., L. Zicheng and Z. Yumei., 2009. Preparation and characterization of SiO_2-Al_2O_3 -Na_2O glass coated CBN abrasive particles via sol - gel route. J. Sol – Gel Sci. Technol. Vol. 49, (6-11).
21. Zhou, Y., M. Atwood., D. Golini., M. Smith and P.D. Funkenbuseh., 2002. Wear and self-sharpening of vitrified bond diamond wheels during sapphire grinding. Wear, Vol. 219, pp. 42-45.