Glass and Porcelain Waste as Abrasives Investigated at Different Conditions

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Abstract. Using waste to produce artificial abrasives is one of the options to minimize cost. In this work, two waste materials had been selected to form bonded abrasives. Porcelain tiles and window glass wastes were crushed and grinned to obtain grits of (1200, 300, 150 µm). Bonded abrasives were manufactured as composites, consisting of waste materials and epoxy as a binder. To measure the durability of these composites, different conditions were carried out. The best results of hardness and wear rate were obtained from porcelain composites at room temperature. The post cure and immersion give the highest wear rate results for both materials. To reveal the possibility of utilizing recycled materials as bonded abrasives, two ceramics material were chosen. Glass and porcelain were selected because of their good hardness and strength which make them suitable to be recycled as abrasives.

1. Introduction
Currently In mechanical engineering industry in most of the cases machining with abrasive is a final operation provide the surface finish. abrasives can be defined as an inorganic material that is used for machining, grinding or finishing a workpiece [1-2]. Abrasives are used in manufacturing process known as abrasive machining. Abrasive machining is one of the final steps in the production processes of parts and it is important because of its capability to impart high dimensional accuracy and good surface finish [3]. The global competition in manufacturing industries has focused on producing quality parts quickly and accurately and that involves the use of the latest and newest machine tools, which are expensive [4]. The price of abrasive machining tools is highly influenced by the price of grit materials .The grit price increases with the pressure and the length of the process and the overall energy consumed [5]. Which lead to high price of abrasive tool [6], In addition to the cost of the abrasive material itself. Some natural abrasives are expensive and the artificial abrasive is high in cost because of the cost of their manufacturing. Perhaps the most important criteria for abrasive selection is cost [7]. The composite includes the grit within a matrix is called bonded abrasive. The main constituent is an abrasive layer with a composite structure. The layer is made up of hard abrasive grit and bond material to retain the grit Bonded Abrasive is used for operations such as grinding, cut-off, honing, and sometimes The polishing [8]. (Mfon et al.) Investigate the abrasive properties of the periwinkle shell which regarded as industrial waste. The particulate bonded abrasive was obtained by using the polyester as a bond material. Different grit sizes were used as abrasives.it was found that the hardness and compressive strength were increased and the wear rate decreased with increasing the bond (Polyester) content [9]. (Petra and Miroslav) studied the influence of jatropha oil cake waste with different concentrations as a filler in epoxy on the wear rate, abrasive resistance, and hardness.it was found that the using of filler increases the weight loss and had no effect on hardness [10].
2. Experimental Details

2.1 Materials
Currently Window glass and porcelain tiles were collecting from the construction sites (in Iraq, Baghdad). Epoxy resin a low viscosity resin of density of 1.1 (kg/Lt) is used as a binding material because of its good adhesion property and mechanical properties. The epoxy has two parts the resin and the hardener that is used to harden the material; two parts of resin to one of hardener are mixed for about 5 minutes.

2.2 Specimens Preparation
The waste was first cleaned, following by using manual crushing. a jaw crusher was used to crush the waste to size $\geq 2\text{mm}$ and then grounded to size $\geq 150\ \mu\text{m}$ by using a ball mill. sieving was done by using a set of sieves with the mesh of 1200,300 and 150 $\mu\text{m}$ sizes in diameter. Hand lay-up technique was used to prepare two sets of particulate composite specimens as abrasives. The first set was glass composites and the other was porcelain composites. three grit sizes of Waste were used separately to produce specimens with 1200, 300 and 150 $\mu\text{m}$. A mold of 30mm height and 12mm diameter was used to make the specimens. One part of epoxy was mixed with three parts of glass or porcelain for about 3 minutes. The composite mixture was manually pressed tightly in the mold to ensure that the minimum amount of porosity remains. The specimens then left to cure at room temperature for about more than 24 h before it removed from the mold. The composition of the specimens surfaces examined by EDS spectrum is shown in figure (1). These specimens were exposed to different conditions which were post cured at 70 $^\circ\text{C}$ for two hours, immersion for 14 days in distilled water and the two conditions i.e. post curing and immersion together compared with specimens without any conditions at room temperature.

![Figure 1. EDS of the surface for (a) Glass (b) Porcelain composites specimens.](image)

2.3 Wear Test
Wear test was carried out by the pin-on-disc machine according to ASTM G 99. The test was performed under dry sliding condition. The pin specimen was held within the sample holder perpendicular to the disc. The rotating disc was stainless steel with hardness 9269 HB, was cleaned with ethyl alcohol prior to the test. the disc rotating at 500 RPM with a fixed sliding distance 282743 cm and the load of 5 N for 15 minutes. The weight of the specimen was measured by using the electronic balance .the wear rate was measured by calculating the weight difference of specimens before and after the test. and according to the equation :

$$\text{Wear rate} = \frac{\Delta w}{SD} (\text{gm/cm}) \quad (1)$$

$\Delta w$ is the weight difference(gm)

SD is the sliding distance(cm)
2.4 Hardness Shore D
The material hardness was measured by using shore D tester according to ASTM D2240, by pressing the tip of the instrument on the specimen. The hardness was found by taking three readings on each face of the cylindrical specimen. The test was done after cleaning the specimens to ensure precise reading by the tester, by taking the average of the readings the hardness was obtained.

2.5 Worn Surface Morphology
SEM examination was carried out by spraying the surface of composite specimens with a thin layer of gold. The microstructure shows debonding of the grits and resin due to wear which damaged the grits cause them to have a sharp edge (figure 2). The wear debris that forms on the surface indicates a plastic deformation. The pores that forming during the fabrication of the specimens had also been seen (figure 3).

![Figure 2. These SEM photos of the worn surface of glass composites specimens under room temperature.](image1)

![Figure 3. These SEM photos of the worn surface of porcelain composites specimens under room temperature.](image2)

3. Results And Discussion
For a material to be abrasive It should be very hard and resist the abrading action under different conditions, The most favorable materials have a high hardness and a low wear rate [2-11]. That’s why in this study the wear rate and hardness of the specimens were measured under four conditions.
The first group was tested without any conditions at room temperature and it showed the highest hardness results as well as the lowest wear rate (figure 4,5). In general, as the hardness increased the wear rate was decreased (figure 6,7). During wear, some blunting of the hard asperities or abrasive particles occurs, thus reducing the wear rate [12]. The second group was tested after post-curing, the hardness was dropped for both glass and porcelain composites. This drop because the heat would deform the chains of epoxy at the surface of the specimens. Post curing increase the stiffness and strength by increasing the crosslinking of epoxy that binds the grit of composite which shows a low wear rate. In the third group, as the time of immersion increase the effect of water on composites increase. The immersion cause swelling of epoxy which reduces The hardness and increasing wear debris which leads to increase in wear rate [13]. The fourth group which post cured followed by immersion show a better hardness than that of post cured and immersion separately. The combination of the two conditions gives the highest wear rate of all groups. The different grit sizes for both materials show high hardness and low wear rate but the best results were observed for 150 \(\mu\)m size.

4. Conclusion
The results of room temperature specimens show the best hardness and wear rate compared to the specimens that investigated in other conditions for both glass and porcelain while the post-cured followed by immersion condition had the highest wear rate. The wear rate decreases while the hardness increases as the grit size decrease, therefore, the best grit size is 150 \(\mu\)m. The porcelain composites show better properties than glass composites.

5. References
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