Use of Different Graded Brass Debris in Epoxy-Resin Composites to Improve Mechanical Properties

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Received: April 8, 2018 Accepted: May 26, 2018 Online Published: June 1, 2018

doi: 10.23918/eajse.v3i3p124

Abstract: This study deals with the brass debris that is obtained from matte smelting and brass refining of different machining processes, such as grinding operation. The brass debris will be used as fillers in epoxy-resin composites. The common uses of the brass debris are recycling and production of value-added waste products. In this study, random mixing processes were utilized to prepare (Epoxy / brass) composites by using the brass debris. Three grades of brass debris with different grain size (600, 800 and 1180) µm were used as reinforcement in epoxy resin with weight percentages (2%, 4%, 6% and 8%) respectively. Tensile and impact test were used to evaluate the mechanical specifications and conditions of the composites. The results of the study showed that it is very important to decrease the weight of brass debris added to epoxy resin, in case of coarse grain size. This is to insure appropriate conditions for tensile or impact tests on (Epoxy / Brass debris) composites. On the other hand, the study resulted that very low weight percentages, such as (2%, 4%, 6%, 8%) of metal brass debris, have no significant improvement in toughness, and can significantly reduce the impact absorbed energy (impact toughness) of the composite samples. The best value of the toughness can be obtained with the epoxy-BD600 and weight percent of 8%. This research also has examined the procedure and mechanical behaviour of brass debris grades filled epoxy-resin composites. The results concluded that it will be possible to utilize brass debris as a secondary filler element for composite materials preparation and brass debris production as added-value products.

Keywords: Waste Utilization, Debris, Composites, Epoxy Resin, Reinforcement

1. Introduction

Debris of waste materials is obtained during matte smelting and refining from different machining process, such as grinding operation and they are used as filler in epoxy-resin composites. In our study, we focused on brass debris because of lack of studies using this type of filling. The best options for brass debris uses are waste metal recovery, recycling, and production of composite products. The advantage of these types of composites is that they are strong and light. By choosing a suitable combination of matrix and filler material, a new composite can be made that has the exact suitable descriptions and conditions for the requirement of the same particular application.

Liu et al. (2016) used Cu-doped graphene (graphenit-Cu) as a filler to prepare epoxy composite in their research to study the effect of Cu-doped graphene on the thermal properties of epoxy composites; and they concluded that adding graphenit-Cu has a slight effect on the thermo-mechanical properties of epoxy composite materials. Keong et al. (2017) used municipal solid waste (MSW), incineration ash, which is rich in mixture of oxide and carbonate ceramics, as fillers for composite materials. Li and Cui (2016) focused on improving the mechanical characteristics of epoxy base material by adding an amino-terminated hyper branched polymer (ATHBP) grown on glass fiber. Chang et al. (2015) investigated the characterization of tungsten-epoxy composites, for ɤ-rays radiation shielded by blending epoxy-resin through adding different weight percent of tungsten powder. Lee et al. (2016) used polyethersulfone as filler material to increase the thermal and mechanical quality of triglycidyl-p-aminophenol epoxy resin. Yang et al. (2016) used simple hot-press with vacuum treatment to prepare silk fabric reinforcing epoxy composites to achieve maximum volume fraction of reinforcement, 70% silk. They investigated mechanical description so that the flexural strength increased linearly by increasing silk volume fraction from 30 to 60 volume %, but diminished slightly at volume 70%. He et al. (2011) showed the impact strength of ceria-epoxy resin composites when ceria nanoparticles added to epoxy–resin with different shapes and sizes. Goud and Rao (2011) investigated the fibre content effect on the mechanical characteristics of unidirectional Roystonea regia of natural-fibre-reinforced epoxy composites. Couillard and Peter (1997) studied the behaviors of bending fatigue on one-dimensional continuous-carbon-fiber/epoxy composite strands by producing a maximum strain; they concluded that this type of composite undergo fatigue at high strains, the damage occurs through matrix cracking, fiber breakage, and interfacial shear failure. Papargyris et al. (2008) studied techniques of composite manufacturing using both conventional and microwave heating methods to prepare carbon fibre/epoxy composites, and they compared mechanical and physical characteristics of the composites produced using the both methods. Based on the mechanical testing conducted, they found similar values of the flexural strength are obtained for both carbon fibre/epoxy composites produced by conventional and microwave heating. Biswas and Satapathy (2010a, 2010b) used fabricate hybrid composites from bamboo fiber epoxy matrix composites with various weight proportions of red mud to study erosion characteristics and compare them with glass-epoxy composites under same test conditions. They concluded that even though the bamboo based composites behave relatively inferior, their performance of erosion wear is better than the glass fiber reinforced composites. Kim et al. (2013) prepared fiber reinforced epoxy/hybrid silica composite to study their mechanical characteristics by adding super fibers such as aramid fiber. They confirmed that the effect of the epoxy/hybrid silica on the mechanical properties affecting in a demand for a resin system with very good mechanical properties.

In our work, brass debris was combined with epoxy resin by handily cold technical process to prepare different composites with various weight percent of brass debris and different size of reinforcement. The aim of this research is to develop a composite that has a higher tensile strength than pure epoxy. On the other hand, wasted materials, such as brass debris, can be used to produce the composites. The reinforcement particles distributed over the epoxy resin randomly and homogenously, preparing these specimen for tensile and impact tests. In the experimental procedure, we explained the fabricating of all of these composites. The results are explained well in the next section and the conclusion is written in the last paragraph.

2. Experimental Design

2.1 Materials

Transparent epoxy (Sikadur -52) is used as matrix which is a liquid of low viscosity as compared with other thermosets, and is converted to solid state when hardener added to it (Sikadur -52 hardener) at 2:1 ratio. This technical description of Sikadur -52 is received from data sheet published by Sika Company shown in Table 1.

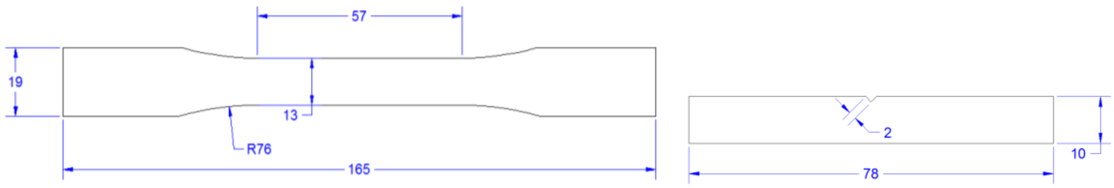
Table 1: Technical description of Sikadur -52, according to data sheet of Sika Company

Compressive Strength	Flexural Strength	Tensile Strength	Pot life	Density	Viscosity
53 MPa for 10 days at 20˚C	50 MPa at 20˚C	25 MPa	~ 120 min at 5˚C ~ 10 min at 30˚C	1.1 kg/l at 20˚C	~ 1200 MPa at 10˚C ~ 430 MPa at 20˚C

The reinforcements are brass debris with different grain size (600, 800 and 1180 µm) and different weight percentages (2%, 4%, 6% and 8%) respectively. These different grain sizes are prepared using sieve analysis (or gradation test), and this is a practice or procedure used to assess the particular size distribution of a granular material. It is a simple technique of particle sizing.

3. Preparation of Brass Debris-Epoxy Composites

A series of brass debris reinforced epoxy composites has been manufactured using simple cold techniques. The composite made using a steel mold according to standard specifications by ASTM D638. The specimen size for tensile test is shown in Figure 1a. The Universal Tensile Machine LY-1066A was used to test the specimen for tensile tests. And for the impact test, standard specification by ISO 179 I was taken into consideration, and the specimen dimension was explained in Figure 1b. LY-XBD-5 Electric Charpy Impact test machine was used for the impact tests at room temperature.



(a) (b)

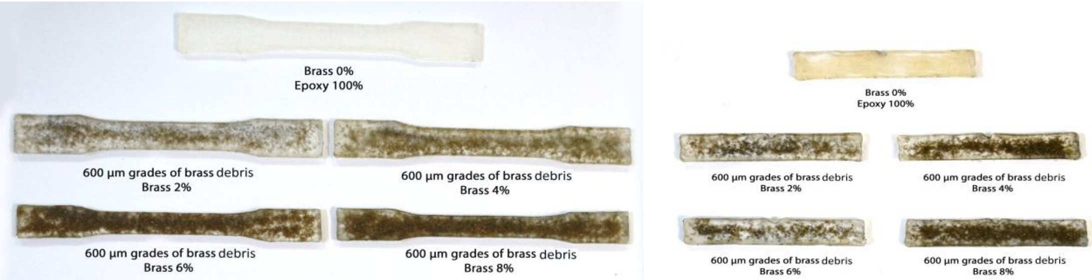
Figure 1: Specimen of (a) tensile test, (b) of Charpy Impact test, all dim. in mm

Tensile and Impact composite samples were prepared by pure epoxy matrix (rate of 2:1 base to hardness) into both impact and tensile molds; then the different grades of brass debris (600 µm, 800 µm and 1180 µm) were distributed with weight percentages (2, 4, 6, and 8%) manually into both kinds of molds. The prepared tensile and impact samples (Epoxy-BD600), (Epoxy-BD800) and (Epoxy-BD1180) properties are shown in Table 2.

Table 2: Specifications of the prepared specimen for tensile and impact tests

No.	Symbol	Refinement	Weight fraction of Refinement WtR %
1	Epoxy	-	-
2	BD 600	brass debris of grain size 600 µm	2%, 4%, 6%, 8%
3	BD 800	brass debris of grain size 800 µm	2%, 4%, 6%, 8%
4	BD 1180	brass debris of grain size 1180 µm	2%, 4%, 6%, 8%

Both tensile and impact samples were left for one week at room temperature to be kept as shown in Figure 2.



(a) (b)

Figure 2: Samples of prepared specimen of (a) tensile and (b) impact tests for 600 µm

4. Results and Discussion

4.1 Tensile Test

We noticed that the fracture has occurred in different areas. This phenomenon can be interpreted physically, by the random distribution of brass debris particles and the agglomeration of some particles in some locations; while the densities of these particles were microscopically changed from a location to another. The results in Figures 3a, 3b, 3c and 3d indicated that the tensile strength of the brass debris-epoxy composite increased as compared with the pure epoxy, and the elongation also is increased for different sizes of reinforcement (600, 800 and 1180 µm) and different weight percent (2, 4, 6 and 8%); this is because of the increasing bonding area between the brass particle and epoxy resin.

The existence of brass particles leads to more elongation and more strength as well. We noticed that the enhance of tensile characteristics reaches the maximum value at Epoxy-BD600 with 8% of brass debris weight percent; and, the tensile strength becomes 48.9 MPa when compared to pure epoxy of 33,65 MPa. Whereas, for the composite Epoxy-BD800 with 6% of brass debris, the weight percent of the tensile strength reaches the maximum value of 49.16 MPa, which is a little greater than the tensile strength of Epoxy-BD600. In addition, we found that the maximum tensile strength can be obtained by Epoxy-BD1180 with brass debris weight percent of 2%, and it becomes 45.95 MPa. For other composite, such as Epoxy-BD800 with brass debris weight percent of 6%, it can reach the maximum tensile strength.

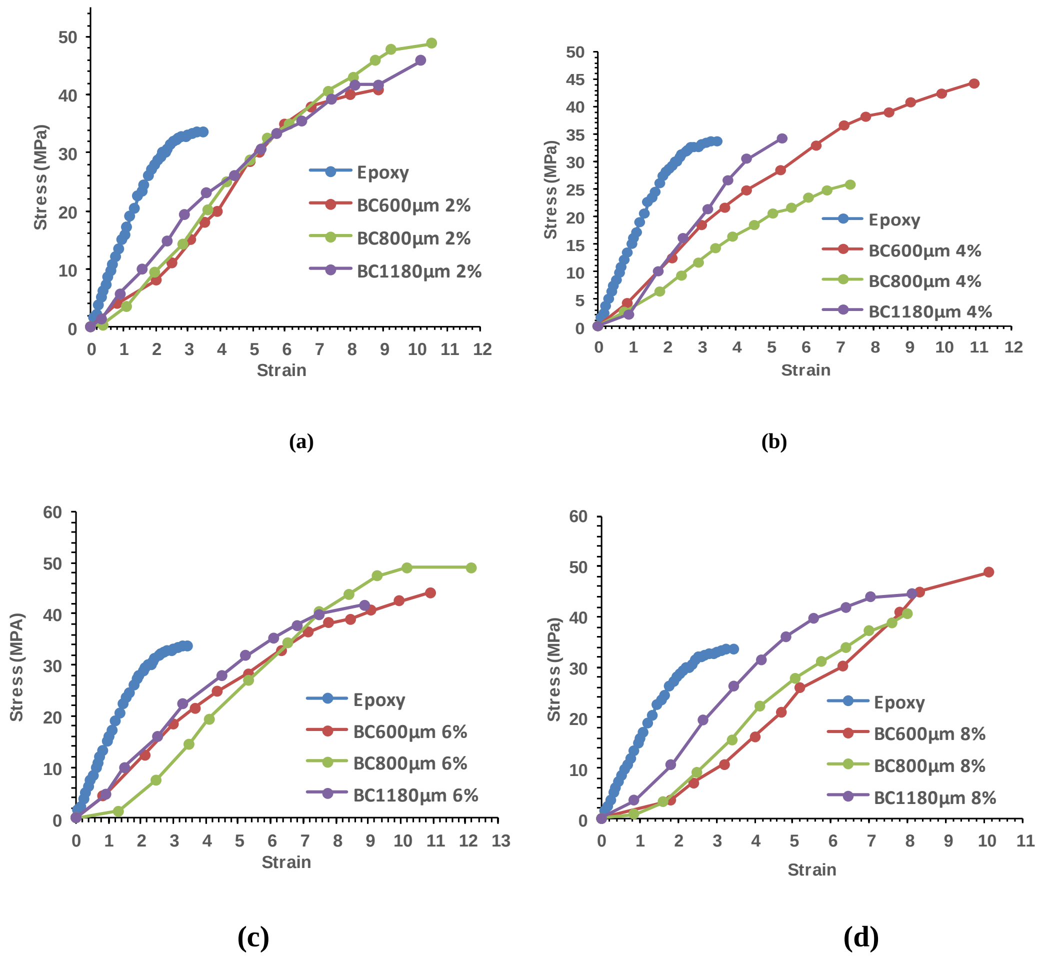


Figure 3: Stress-Strain curves of Epoxy and BD (600,800 and 1180 µm) for weight percentage (a) 2%, (b) 4%, (c) 6%, and (d) 8%

Comparing all the combined results explained in figure 4; depending upon the practical data obtained, we found the overall maximum tensile strength can be reached (by the composite Epoxy-BD800) to 6% of brass debris weight percent, as noted in the figure, and reaches 49.16 MPa, which is very important to be selected to produce a composite with higher tensile strength properties. Understanding the mechanical characteristics of composite materials is very crucial for scientific professions and technical works. This comprehensive understanding helps to select a fitting composite material. The materials test provides essential data in a quantified manner. We can conclude that with increasing the grain size of the brass debris added to pure epoxy matrix, it is worthy to decrease the amount of weight percentage added; and, the best of all specimen is 6 wt% (Epoxy-BD800) because it has the highest value of maximum stress (49.16 MPa) with the highest value of strain (12.17 mm/mm). Depending upon the results of this research, it is workable to use the waste materials, such as brass debris, to fabricate new developed composite with higher tensile strength that can be used for different purposes.

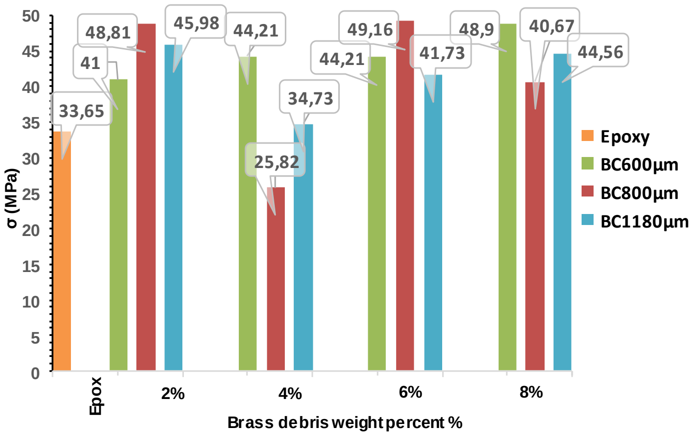


Figure 4: Maximum stress value of [(Epoxy-BD600), (Epoxy-BD800) and (Epoxy-BD1180)] for all weight percentage (2, 4, 6 and 8%)

4.2 Impact Test

The second group of the tests was impact test. We noticed that the entire specimen is broken in the notch location, for different size of reinforcement composites and different weight percent of brass debris. The results, as shown in Figures 5a, 5b, 5c and 5d, indicate that the toughness of the composites increases with the increasing in the size of the reinforcement was as far as 800 µm. Then, any increase in the reinforcement size will lead to a slight decrease in the toughness aspect, since the brass debris particles are randomly distributed in the epoxy-resin.

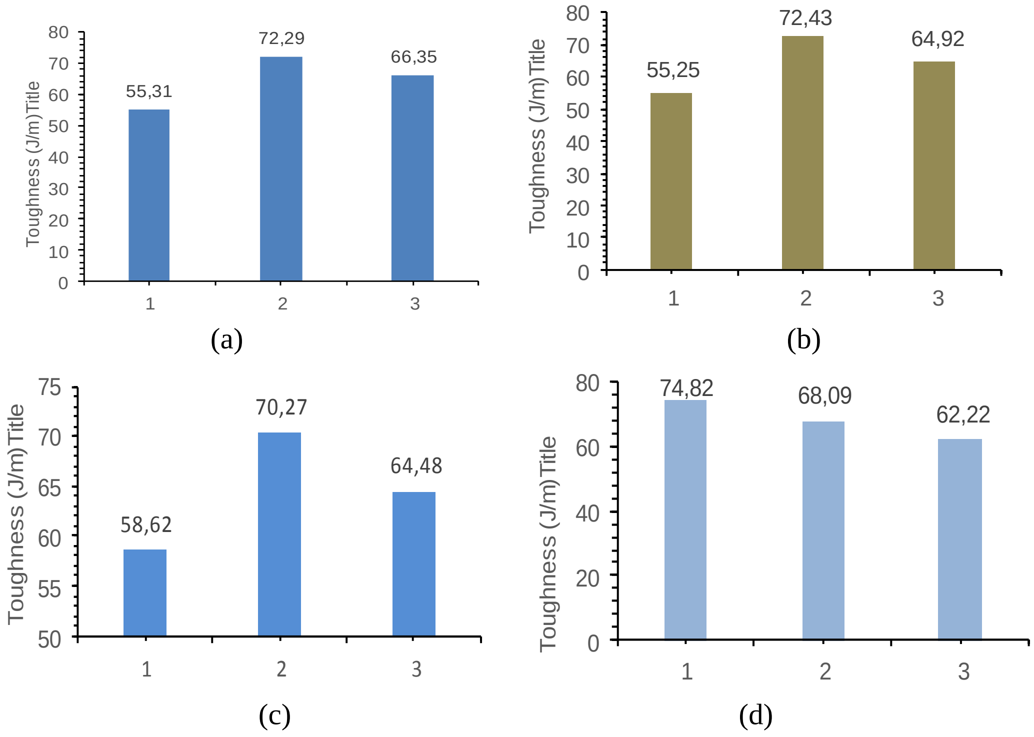


Figure 5: Impact toughness of (a) 2%, (b) 4%, (c) 6% and (d) 8% for [(Epoxy-BD600), (Epoxy-BD800) and (Epoxy-BD1180)]

The increase of weight percentage of the reinforcement particles to 8% along with particle size increased from 600 µm to 1180 µm, as showed in figure 5d leads to decrease of the toughness of the composite. If we compare all the results of toughness obtained together with the toughness of pure epoxy (see Figure 6) we find that different grades of brass debris (600 µm, 800 µm and 1180 µm) congregated with weight percentages of (2, 4, 6, and 8%), the best value of the toughness is obtained by the epoxy-BD600 and weight percent of 8%. It is important to note; despite the change in weight percentage added to brass debris with different grain sizes, there is no significant improvement in toughness. By way of conclusion, Epoxy sample without any reinforcement has a higher toughness than the other samples, and there is no significant effect for toughness to be considered for examined composites in this research.

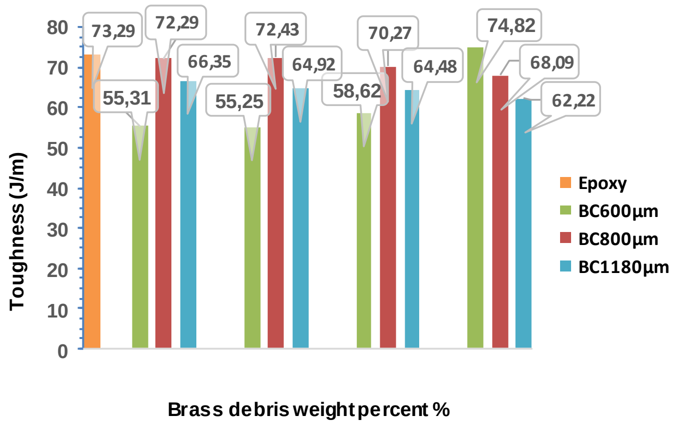


Figure 6: Impact toughness of Epoxy reinforced by (Epoxy-BD 600, Epoxy-BD 800 and Epoxy-BD 1180 µm) for weight percentage (2%, 4%, 6% and 8%)

5. Conclusion

1. It is possible to fabricate a new epoxy composite using waste materials such as brass debris, with higher tensile strength.
2. To improve the tensile characteristics of (Epoxy-Brass debris) composites, it is very important to decrease the amount of weight percentage added to epoxy resin, when grain size of added reinforcement is increased.
3. Pure epoxy has slight difference toughness when compared to the other epoxy brass composites; nonetheless there is no significant improvement in the toughness.
4. The best value of the toughness can be obtained only with the epoxy-BD600 and weight percent of 8%.

Acknowledgments

We would like to thank to engineers Mustafa Sabah, Goran Ghafur and Rawand Younis for their efforts helping us in the practical part.

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