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Effect of Particle Size on Mechanical Properties of the Recycling Compact Disks Reinforced Epoxy

Abstract- *The recycling of CDs or DVDs (compact disks) as a filler in polymer composites can be used in many engineering applications such as electrical, automobile, and building applications. In the present paper, composite materials were prepared of epoxy resin reinforced with three different particles size (600<d<850, 200<d<600, d<200 µm) of recycling of CDs or DVDs (a very thin aluminum layer is used to record information). Hand lay-up technique was conducted to produce composite material samples. Different types of tests, such as tensile, bending, impact, and hardness were applied on these samples. The mechanical characteristics of the composite samples were analyzed. The finding observed that smaller chopped of CDs or DVDs reinforced epoxy had better tensile, bending, hardness, and impact properties.*

Keywords- *composite materials, tensile, bending, impact, hardness, epoxy resin, and recycling of compact disk.*

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1. Introduction

Nowadays, billions of CDs and DVDs were manufactured, while millions of these disks end up in landfills and incinerators. Compact Disks (CDs or DVDs), when recycled properly, will stop unnecessary pollution, and conserve natural resources. CDs or DVDs were content of a variety of materials such as: (polycarbonate, paint, and a very thin aluminum layer was additionally used to record information). CDs was manufacturing by injection of the polycarbonate in mould, polycarbonate is a type of thermoplastic materials [1]. Epoxy resins are class of thermoset materials that used extensively in structural and specialty composite applications because they offer a unique combination of properties that are unattainable with other thermoset resins. The advantages of epoxies are high strength and modulus, low toxicity, excellent adhesion to various substrates, low shrinkage, good chemical resistance, low cost, and ease of processing [2]. Particulate reinforced polymer composites offer several advantages such as they provide reinforcement to the matrix material thereby increase in strength and toughness, these reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. The matrix transfers some of the applied stress to the particles, which bear a fraction of the load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix–particle interface. In addition, the principle advantage of these materials are reduce the cost and ease of fabrication. The particulate phase is harder and stiffer than the matrix. [3]. Several researchers studied this field, Camelia, studied the bending behavior of the composites samples made by epoxy with recycling of compact discs as reinforced materials was prepared by using hand lay-up method [4]. Nervana, studied the effect of salt, acid and base solutions on bending behavior of CDs reinforced epoxy, The results indicated that the 45% CDs reinforced epoxy chosen was good chemical resistant to NaCl and NaOH [5]. Jabbar, studied composites specimens of epoxy with varying concentration of kaolin were prepared by using hand lay-up method, it is observed that the tensile strength, modulus of elasticity, and compression strength increase with decrease in particle size of filler materials [6]. Kamalbabu and Mohan, studied the effect of three different particle size on tensile properties of composite materials were prepared of epoxy matrix/cuttle bone powder, rustles revealed that smaller particle size had better mechanical strength and uniform distribution [7]. Nasution et al. studied the effect of filler content and particle size of cockleshell powder in epoxy on the water absorption and impact strength of the composite, results showed that the high impact strength was occurred with 170 mesh of cockleshell powder [8]. In this paper, chopped particle of CDs or DVDs was used as a filler in epoxy matrix. Three different particle size of chopped CDs & DVDs materials were used, then study the tensile, bending,

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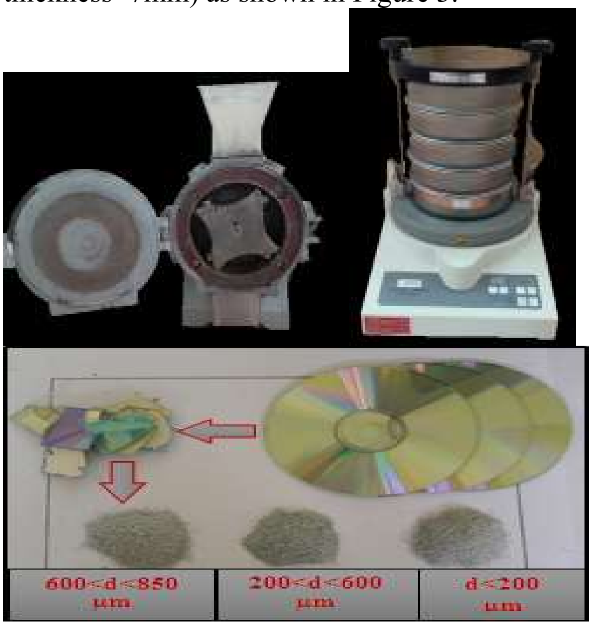
impact, and hardness properties for the composite specimens, also this study was not been addressed in beforehand from where the particle size of chopped compact disks and from the type of mechanical properties. The next objectives of this paper is to experimentally determine the same of the mechanical properties by using different weight fraction of chopped particles with polyester resin.

2. Materials and Methods of Test

The hand lay-up technique was used to product a composite specimens. At the first, the compact disks were cutting at approximate dimension of 1x1 mm^2. Then, they were chopped by using a mill (type: JF SD-100 PULVERIZED) with sieve having different mesh dimension were (600<d<850, 200<d<600, d<200 µm), as shown in Figure 1. Epoxy resin used for the present paper had properties and structure as shown in Table 1 and Figure 2. The epoxy resin and its hardener were added at approximate (3:1) mixed and slowly added for different particle size. Finally, the mixture was introduced in a mould and was allowed to cure for 24 hr. at room temperature and then the composite was taken out from the mold to post cure at 100 ^{o}C for 4 hr. produce a new composite material plate. Tensile test were carried out according to ASTM (D-638 type I) standard [9] on the tensile testing machine had capacity load (50 KN) and strain rate (1mm/min.). The dimension of specimens in this test were (length=75mm, width=12.5mm, and thickness=7mm) as shown in Figure 3.



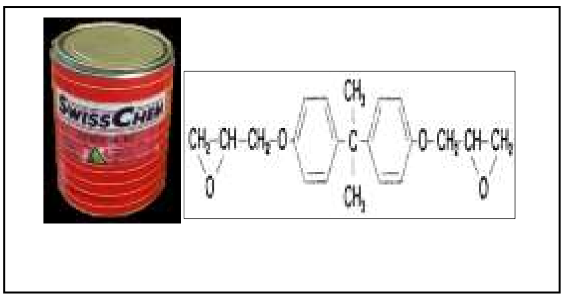


Figure 1: Stage in preparation of chopped compact disks (Milling, Sieving, and types of particles results)

Figure 2: chemical structure of epoxy.

Table 1: properties of epoxy.

properties	quantity
Density, g/cm^3	1.1-1.2
Modulus of elasticity, GPa	1.5
Tensile strength, MPa	40.5
Compressive strength, MPa	82.3

Figure 3: Tensile device and samples specimens before and after test.

Flexural or bending test (three-point method) was performed also by using universal test machine. The testing machine gives us the curve of relationship between the force and deflection at midpoint of the composite samples. Flexural specimens were prepared according to the ASTM (D-790) standard [10]. The dimension of specimens in this test were (length=100mm, width=10.3mm, and thickness=7.3mm), as shown in Figure 4.

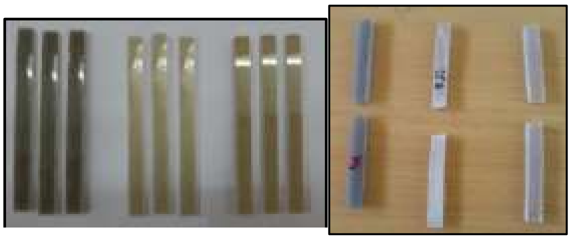


Figure 4: Flexural device and samples of specimens before and after test.

Impact strength was obtained from impact test by Unnotched Izod method which involved breaking the composite specimens and the specimens were prepared according to (ISO-180 standard) [11]. This test carried out at (impact device) with energy of pendulum reach to (5.5 J). The dimension of specimens in this test were (length=65mm, width=10mm, andthickness =7mm), as shown in figure (5). Hardness test for composite specimens was performed by using (Shore-D device), the specimens were prepared according to ASTM (D-2240) standard [12]. The dimension of specimens in this test were (diameter=25mm, and thickness=7mm) as shown in Figure 6.

Figure 5: Impact device and samples of specimens before and after test.

Figure 6: Hardness device and specimens.

3. Results and Discussion

Tensile test

After processing the machine data, tensile tests curve stress-strain was made, as shown in Figure 7, and the experimental results for tensile test as shown in Table 2.

Figure 7 shows the stress-strain curves recorded in tensile test for specimens in this paper. This figure that illustrate the smaller size particle of chopped compact disks reinforced epoxy composites had higher modulus and strength than other composites. Generally, particles were stiffer than epoxy. Smaller particle size restricts the mobility of the polymer chain and reduces the strain value. Modulus value decreased by increase in particle size of chopped compact disks. Higher particle size tends to result in poor adhesion between the filler and epoxy or matrix. Elongation percentage at fracture for reinforced epoxy composites with different particle sizes of chopped compact disks was decrease with increase particle size. At higher filler loading, elongation percentage at fracture was higher in large particle size of chopped compact disks. The higher surface area and agglomeration of smaller particles lead to higher reduction in elongation percentage at fracture. These results matches with reference [7], has proved the tensile strength and modulus of elasticity were increase with smaller marine coral particle in epoxy but the elongation percentage at fracture increase with use large particle of powder in polymer composite.

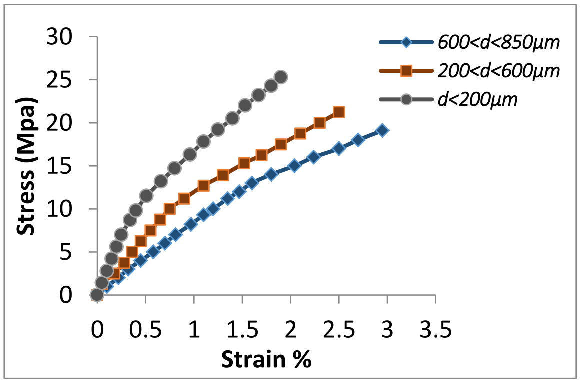


Figure 7: Stress-Strain curves for specimens

Table 2: Experimental results for tensile test

Properties	Particle size of chopped compact disks		
	600<d<850 µm	200<d<600 µm	d<200 µm
Modulus of elasticity (MPa)	1011	1562	2801
Tensile strength (MPa)	19.1	21.24	25.3
Elongation at fracture %	2.95	2.5	1.9

Flexural test

In the Figure 8 were shown F-υ (force-displacement) curves of the bending data in case of the composite specimens, while Table 3 shows the values of flexural strength and flexural modulus. It was observed that the smallest particle size of d<200 µm has flexural strength of 17.93MPa. It decreases to 12.55MPa at 200<d<600µm particle size. The last largest particle size, which is 600<d<850µm, reads 9.93MPa. It is noted that flexural strength is increased with the small in particle size as a result of increasing wettability of chopped particles by epoxy resin (small interface region) which cause an increase in the transmitting stresses from epoxy to chopped particles. In addition, small chopped particle size leads to increase in boundary grains of chopped in composite material, which leads to increase the flexural strength of composite materials. These results can be compared with reference [4], has found the load at maximum load, flexural strength and flexural modulus were increase with smaller chopped particle in epoxy but the extension at maximum load increase with use large chopped particle of powder in polymer composite, the percentage of increase in flexural strength, flexural modulus, and load at maximum applied load for specimens of this paper compared with reference [4] were (6.5%, 35.26%, and 29.6% respectively).

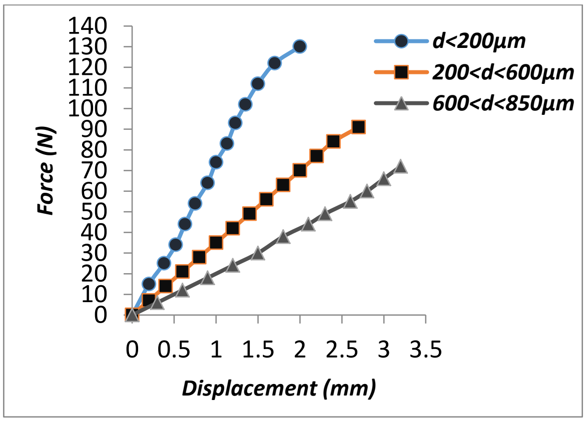


Figure 8: Force-Displacement curves for specimens

Table 3 :Experimental results for flexural test.

Properties	Particle size of chopped compact disks		
	600<d<850 µm	200<d<600 µm	d<200 µm
Flexural Modulus(MPa)	710	1120	1500
Flexural strength (MPa)	9.93	12.55	17.93

Impact test

Impact strength was the amount of energy absorbed before fracture for composite specimens. The effect of particle size on impact strength of composite specimens can be seen in Figure 9, shows that using finer chopped of compact disks particles in epoxy increases its impact strength. Chopped of CDs or DVDs powder was a hard material and also had capable of making a good mechanical bonding with the epoxy so incorporating it can increase the impact strength of composite specimens. The smaller chopped particle size of powder can withstand the crack prorogation and can serve as the load transfer medium in the composite specimens.

These results agree with reference [8], has proved that the smaller particle size of cockleshell powder in epoxy can increase impact strength of the composite.

Hardness test

The effect of particle size on hardness of composite specimens can be seen in Figure 10.

It can be seen that the fine chopped particle composite material shows higher hardness compared with the large particle which in this paper can give the maximum value of hardness at (d<200 µm=83.4) of particle fillers. This was because the fillers with fine chopped particles size have larger surface area than large particle size fillers, which in were contact with matrix mostly by physical bonds than large particles. Composite with strong bonds makes it harder and have good surface properties.

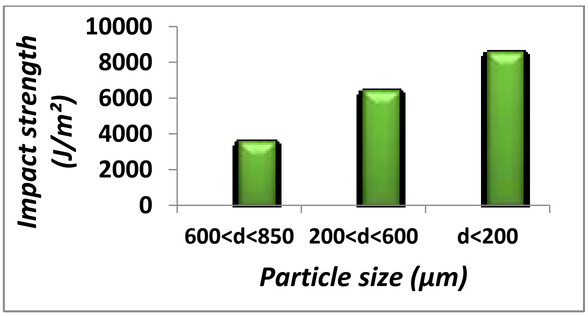


Figure 9: Impact strength results for specimens.

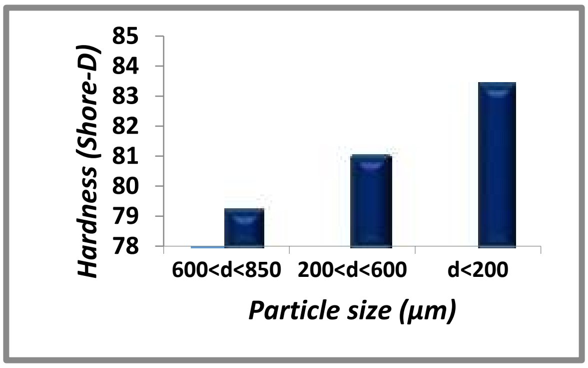


Figure 10: Hardness (Shore-D) results for specimens

Conclusion

It can be concluded that chopped particles of CDs and DVDs powder was capable in improving the mechanical properties of epoxy resin, so could be used in many applications such as electrical, automobile, and building applications. The weight fraction of filler content in this paper was reach to 30%, this percentage was constant for all different particle size. Smaller chopped particle size (d<200 µm) reinforced epoxy resin showed better results of tensile, flexural, impact, and hardness properties than other particle size.

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