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Fabrication of a Polymeric Composite Reinforced with Carbon Fibers and CuO Particles for Prosthetic Applications

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Carbon fiber;
Copper oxide;
Mechanical properties;
Prosthetic limbs.

Abstract

In this research, the mechanical properties (tensile strength, bending resistance, impact resistance) of samples composed of unsaturated polyester resin reinforced with carbon fibers in the form of layers, using four layers, and copper oxide at a rate of (1%, 2%, 3%, 4%) were studied. Both separately. It is used in the manufacture of prosthetic limbs. The results showed that carbon fiber reinforcement improved all mechanical properties. Where as that the tensile strength improved and reached (10.14), while the bending resistance value was (25.34), and the shock resistance also improved by a value of (1.46). However, when reinforced with copper oxide, it failed and also that the tensile strength value decreased to (4.76), and the bending resistance value also decreased to (7.47), but the impact resistance improved and its value reached (0.72).

Introduction

A composite material can be described as the combination of two or more materials of which, one is a reinforcing material such as fiber, sheets, etc. and the other being a matrix phase is said to be conforming to the class of composite materials. In the classification of composite materials, the reinforcing matrix is the focus parameter based on which it can be classified into polymer composites, ceramic, and metal-matrix composites. Polymer matrix composites pose as the most desirable for engineering and structural applications due to their inherent ability to be tailored to the suitability of the consumer [1]. Carbon fiber reinforced polymer composites have been extensively used in a wide range of applications because of their superior strength to weight, high

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thermal stability and excellent corrosion resistance [2]. The study of the mechanical properties of engineering materials is an important and necessary study and is considered one of the things that must be taken into consideration because it studies and determines the behavior of materials under the influence of stress placed on them [3]. Industrial and technological development depends largely on progress and development in materials. Because of this industrial development that the world is witnessing in all fields, the urgent need has emerged to find alternative materials that have many uses in the field of industry, so that these materials have good specifications and good properties, and these materials are composite materials [4]. Which is defined as a system consisting of combining two materials or a group of materials in a specific way. These materials are different in shape and composition and do not dissolve with each other [5]. The use of composite materials is on the rise due to their distinctive properties and resistance to adverse weather conditions, making them strategically important for various applications, including prosthetic limb applications [6]. Polymeric-based composite materials exhibit high properties and advantages, making them among the best types of materials currently used [7]. These characteristics, including their lightweight nature compared to older materials such as unsaturated polyester, make them ideal for prosthetic limb applications [8]. To enhance the mechanical properties of polymers [9], fibers or particles are used for reinforcement and strengthening [10]. Polymeric materials have become among the most widely used materials due to their light weight, low cost, and ease of manufacture [11]. Polymeric materials are considered among the insulating materials and have developed rapidly due to their distinctive properties [12]. Overlay materials are the addition of structural changes for the purpose of improving the mechanical properties of the base material. And protecting it from damage and deformation [13]. The behavior of materials depends on the integration of three elements: the base material, the supported material, and the interface[14]. From this formation, two materials are produced that improve the mechanical properties and temperature-dependent behavior [15]. In recent years, composite materials have developed, leading to a major development in modern orthopedic devices and prosthetic limbs, and most of the upper and lower prosthetic limbs at present are made of composite materials [16]. In this study is to improve the mechanical properties of the materials from which prosthetic limbs are made.

Practical aspect:

Materials used:

- Base material: Unsaturated polyester resin was used as a base material. It is a resin that hardens by heat. It is a transparent, viscous liquid at room temperature with a density of approximately (1.2 g/cm^3), as shown in Figure.1.
- Reinforced material: Two reinforcement materials were used in this research:

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- The first: It consists of carbon fibers in the form of layers (mat). The density of these fibers is (1.9 g/cm^3).
- The second: copper oxide of microscopic size.

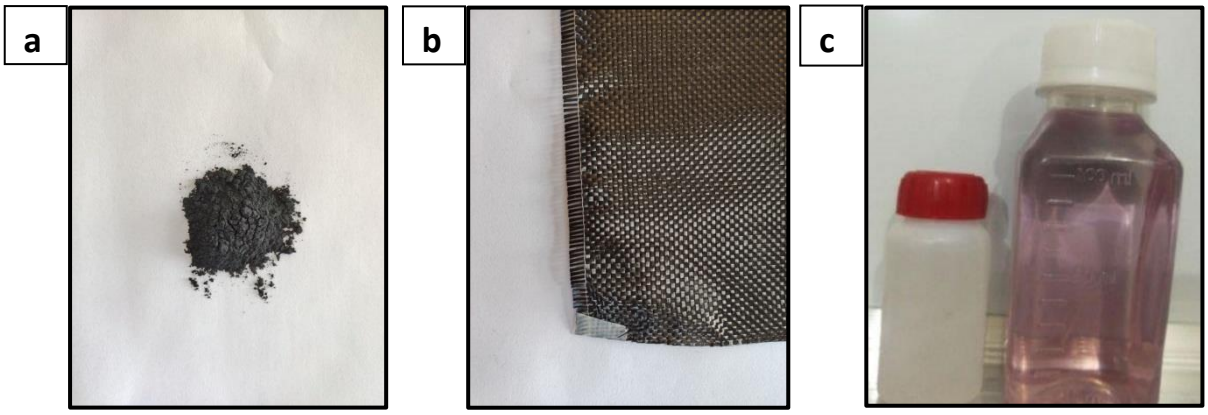

Figure 1. Real images of (a) Polyester (unsaturated with hardener) (b) Carbon fibers (c) Copper oxide

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The Method of Work

The process of preparing samples was performed by manual molding, where the molds were prepared by cleaning them and painting them with a fatty substance, after which unsaturated polyester resin was poured to which the hardener is added at (2g) for every (100g) of unsaturated polyester at room temperature to increase the speed of solidification, and it was poured. In the molds, a small amount, then it put carbon fiber in the first layer, then it put polyester on top of it. This is for the first sample to ensure good penetration of the base material with the fibers. As for the second sample, the same method only increases the number of layers to become two layers, and so on for the rest of the samples, where four samples reinforced with carbon fiber were cast. As for copper oxide, it was mixed with the resin slowly to ensure homogeneity of the materials with each other and to avoid the occurrence of bubbles inside the mixture that lead to weak mechanical properties. The mixture was poured into the molds regularly. After the material hardens inside the molds at room temperature, it was placed inside an electric furnace from In order to conduct heat treatment at a temperature of (50) degrees Celsius for (60) minutes. The heating is done gradually, and then the samples are left in the oven to gradually cool until the laboratory temperature was reached, to ensure good interlocking of the polymer chains

and also to reduce the stresses that affect the properties of the composite material. All samples are prepared in the same way and according to the required proportions.

Devices Used:

- Tensile testing device: A Laryee Yaur Tasting Solution type tensile testing device was used, where samples were prepared with standard dimensions in accordance with American specifications (ASTMD638-03).
- Bending test device: The three-point bend was tested using a tension device, and the corner samples were prepared with standard dimensions according to American specifications (ASTM D790).
- Shock testing device: An Izard Chirpy shock testing device manufactured by (Testing Machines Inc. Amityville New York) was used in accordance with international specifications (ISO-180), and the hammer energy ranges from (5.5 J).

Results and discussion:

Tensile test results: Tensile testing is one of the important mechanical tests through which the material's ability to resist the forces that affect it is determined. Figure.2:a,b shows the tensile samples of the composite material reinforced with carbon fibers and copper oxide separately, while Figure.3 shows the results of the tensile testing of the samples reinforced with layers of carbon fibers. It note that the tensile strength values increase when reinforced with carbon fibers and continue to increase with Increasing the number of layers to reach the highest value, which is (10.14) when reinforced with four layers of carbon fiber, which is considered the highest reinforcement layer used. The reason for this is due to the characteristic of carbon fiber in terms of tensile resistance and high flexibility, as carbon fiber is responsible for bearing the part. The greater the stress that is exerted on the material.

It is able to withstand the applied stress, so it notice that the base material separates from the fibers or breaks when the sample exceeds the limit allowed to withstand the stress [17]. Figure.4 shows the results of the tensile test of samples reinforced with copper oxide microparticles. It notice from the figure that the Less value obtained is (4.76)when reinforced with (4%)and then when continuing to increase the stress applied to the sample, It notice that cracks began to form and then expand after it note that it leads to the sample becoming bulging, breaking, and collapsing. The reason is that the overlaid material will gain tensile strength when reinforced with copper oxide particles because the stress will be transferred from the base material to the

reinforced material, and these particles will work to hinder the growth of small cracks [18].

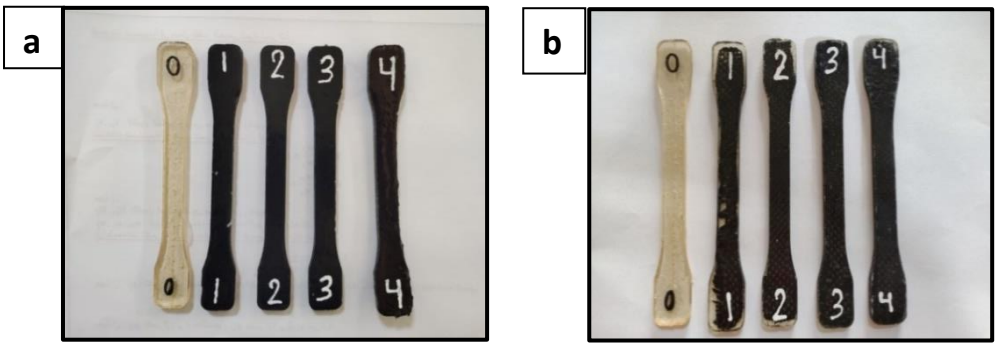

Figure 2. Tensile samples for the materials used (a) carbon fibers (b) copper oxide.

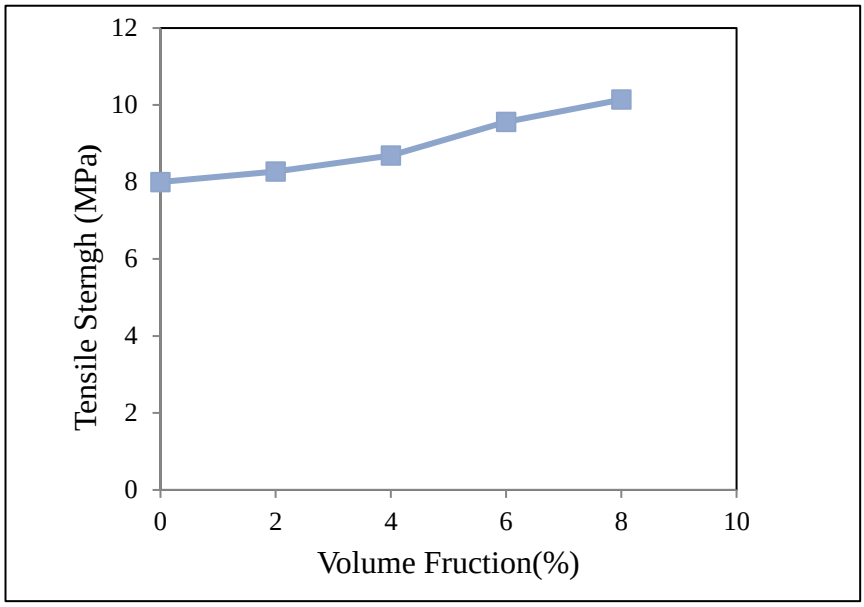

Figure 3. Results of tensile testing of carbon fiber samples.

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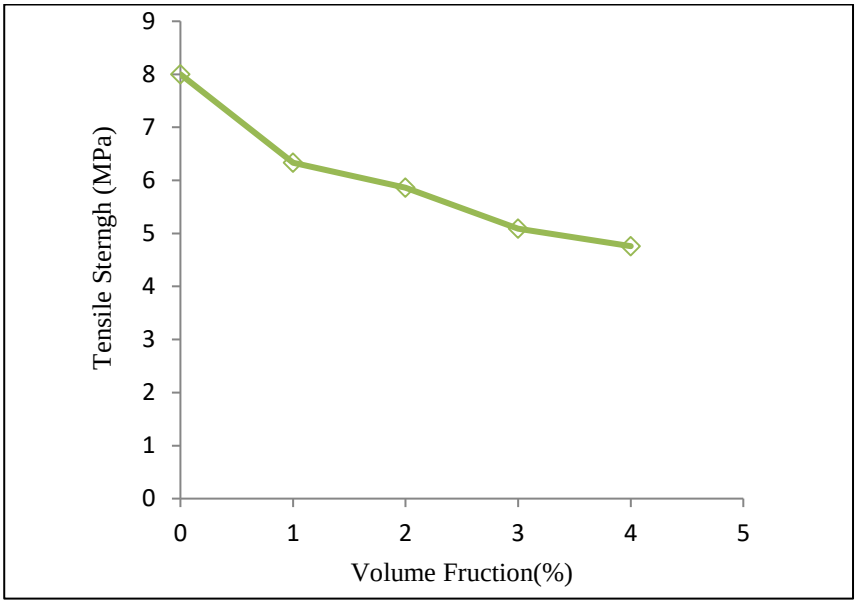

Figure 4. Results of tensile testing of copper oxide samples.

Results of the bending test: The bending test is a mechanical test through which the sample is affected by two forces, which are the tensile force and the compressive force together. As for the tensile test, the sample is exposed to the tensile force only, and this is the difference between the two tests. Figure (5a, b) shows the bending samples of the composite material reinforced with carbon fiber mat and copper oxide particles separately, while Figure 6. shows the results of the bending test samples for the material reinforced with carbon fiber mat, and it notice from the figure that the bending resistance values increase when reinforced. With carbon fiber mat, it increases with the increase in the number of layers, and the highest value obtained is (25.34) when reinforced with the highest layer and given four layers, and the reason for this is due to the strength of the bond between the base material and the fibers, which greatly affects the bending values of the overlay material and also due to the increase Cross-linking of overlapping material[19]. Figure.7 shows the results of the bending resistance test for samples supported with copper oxide particles. It notice from the figure that the Less value of bending resistance is (7.47) at the volume fraction (2%), and the reason for this is due to the increase in cross-linking between the polymeric chains and the copper oxide particles[20].

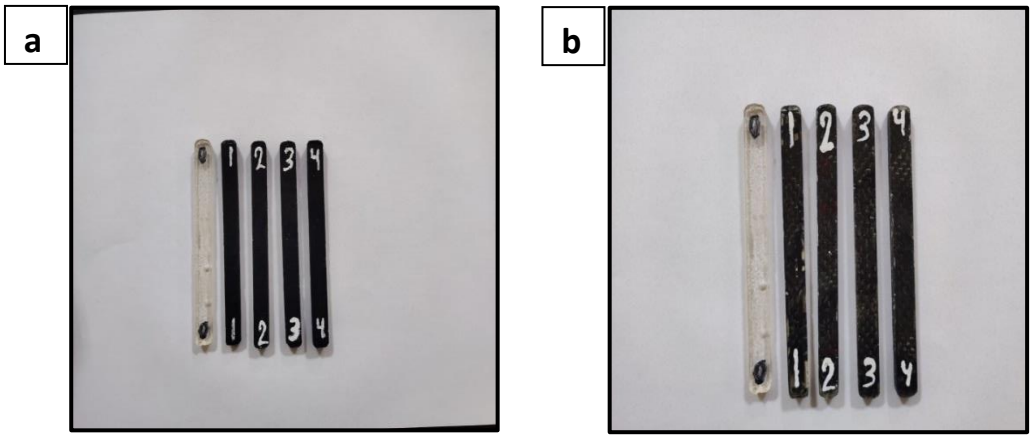

Figure 5. Bending samples for the materials used (a) carbon fiber (b) copper oxide.

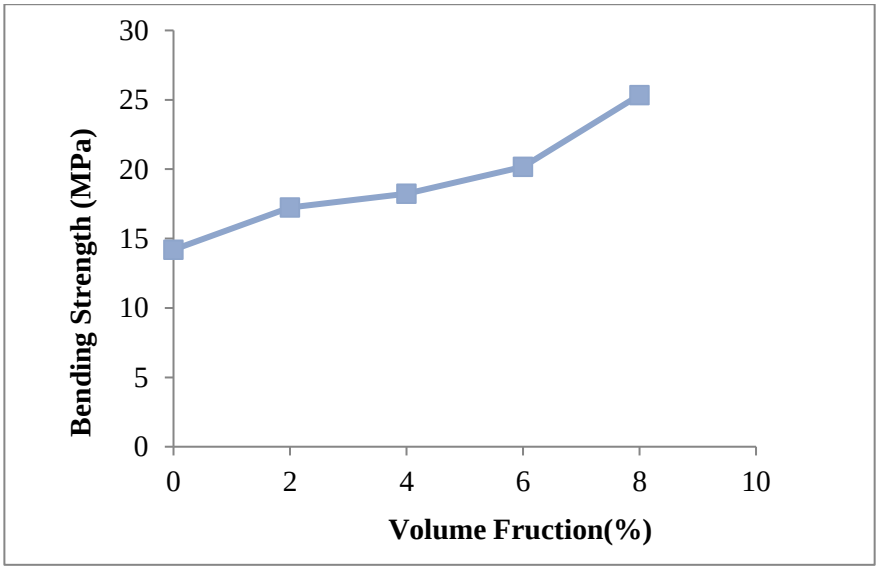

Figure 6. Bend test results for carbon fiber samples.

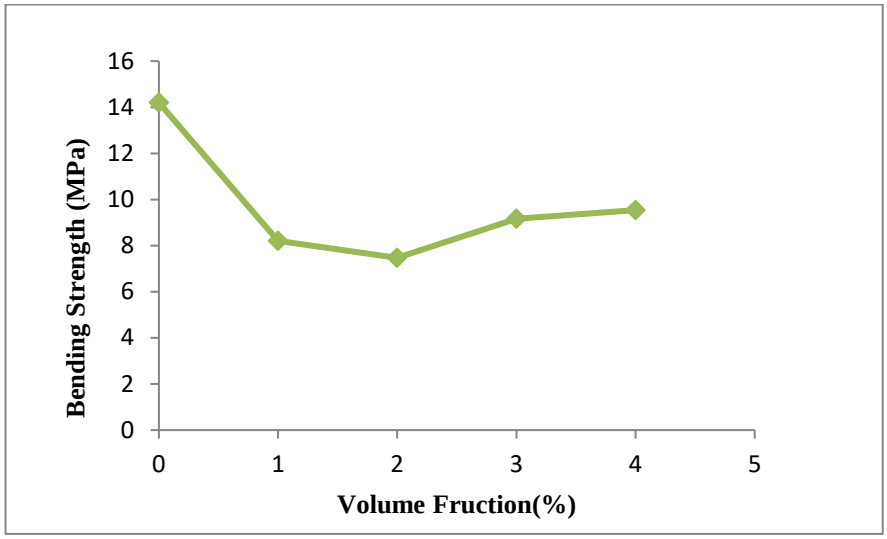

Figure 7. Bend test results for copper oxide samples.

Shock resistance test results: Shock test is a mechanical test through which the behavior of materials is identified when subjected to rapid kinetic stress. Figure.8:a, b shows the shock samples of the composite material reinforced with carbon fibers and copper oxide separately, while Figure.9 shows the results of testing the shock samples of the material reinforced with carbon fiberes. From the figure you can notice that the shock resistance values increase when reinforced with layers of fibers. Carbon. The highest value obtained is (1.46) when reinforced with four layers of carbon fiber, which is considered the highest layer used. The reason is that the fibers will bear the bulk of the shock energy applied to the composite material, which improves this resistance [21]. Figure.10 shows the results of testing shock samples reinforced with copper oxide micro particles. It notice from the figure that the shock resistance value increases when reinforced with these particles, and that the highest value obtained is (0.72) when reinforced with the highest volume fraction of particles, which is (4%), and the reason for this is that these minutes will act as a barrier. In front of the crack that is formed because it bears the largest part of the load that is applied, and thus works to impede the growth of cracks that form as a result of the increase in the load imposed on the sample [22].

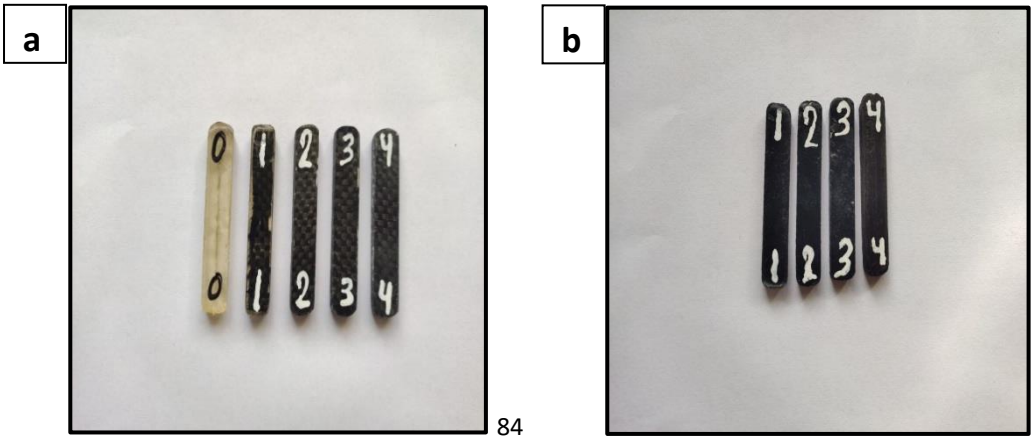

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Figure 8. Impact samples of the materials used (a) carbon fiber (b) copper oxide.

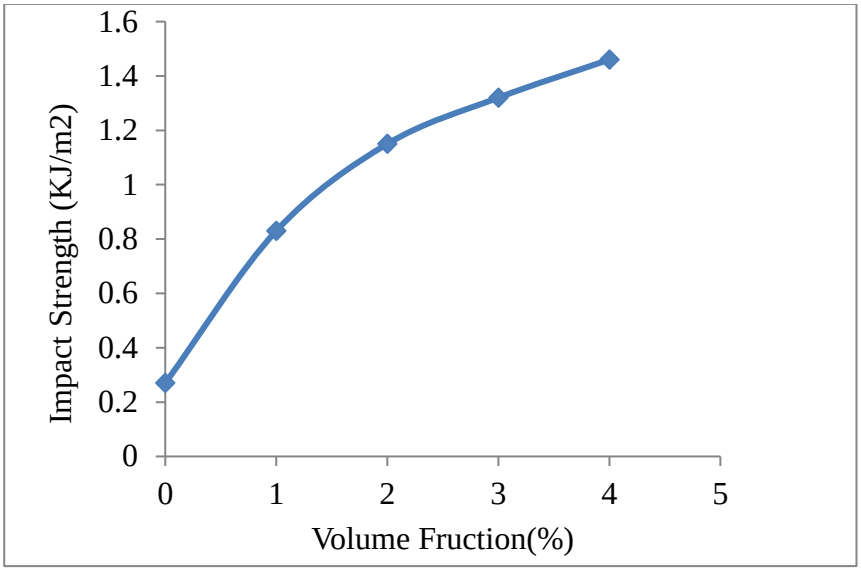

Figure 9. Results of impact testing of carbon fiber samples.

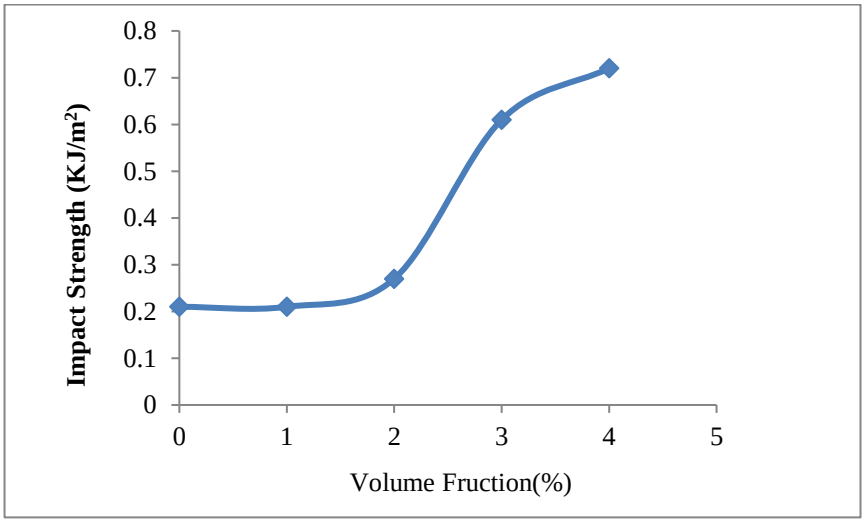

Figure 10. Results of impact testing of copper oxide samples.

Conclusion

Based on the results obtained, it is evident that the mechanical properties (tensile strength, bending resistance, and shock resistance) were all improved when reinforced with carbon fibers, and gave ideal results. This indicates that the use of carbon fibers in the manufacture of prosthetic limbs is ideal. When reinforced with copper oxide, we notice that the tensile strength and bending resistance have decreased in value, while the shock resistance to melting has clearly improved. This indicates that carbon fibers are much better than copper

oxide when making prosthetic limbs.

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