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# MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF BRASS REINFORCED WITH COCONUT SHELL ASH POWDER

[*a]Orisadare, O. A., [b]Olawore, A. S.; [a]Ibiwoye, M. O.;
[c]Ponle, E. A. and [b]Babatola, B. K.

[*a]Department of Science Laboratory Technology, Osun State Polytechnic, Iree, Nigeria
[b]Department of Mechanical Engineering, Kwara State University, Malete, Nigeria
[c]Department of Mechanical Engineering, Osun State Polytechnic, Iree, Nigeria

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## ABSTRACT

*Metal matrix composites (MMCs) are materials in which metals are reinforced with other materials preferably of lower cost to improve their properties. In this study, Brass - Coconut Shell Ash powder (CSAp) composites having 5, 10 and 15% weight CSAp were fabricated by stir-casting method. The tensile strength of the MMCs is in the order 15% > 10% >5% > 0% of CSAp. Hardness of the MMCs increases slightly with increase in the percentage body weight of CSAp, in the order 15% > 10% >5% > 0% of CSAp. The highest impact energy of 61 J was obtained for 5% CSAp. However, significant improvement in tensile strength and hardness values was noticeable at the 15%. Scanning Electron Microscopy (SEM) analysis of the MMCs shows dendritic structures formation, the reinforcing particles (CSAp) are visible and clearly delineated in the microstructure. Hence, this study has established that reinforcing brass with coconut shell ash particles can result in the production of low cost brass composites with enhanced tensile strength, hardness and impact energy values.*

***Correspondence:*** *orisadareoluseyi@gmail.com; +234-8038112605*

## 1.0 INTRODUCTION

Metal matrix composites (MMCs) are the composites with metal as the major constituent Reinforcement materials are added to improve the properties of the matrix. Composite is a material made of two or more different phases or materials. They are made by combining two or more materials in such that the resulting materials have certain design properties on improved properties (Callister *et al*., 2007). The materials for the matrix are metals (Vivrs *et al*., 1993); (Wang *et al*., 2015); (Cikara 2009); and (Boshnakova *et al*., 2015), ceramics (Chen *et al.*, 2011) and polymers (Ashworth *et al.*, 2016) and (Braga & Magalhaes 2015). The resulting material is ductile and has higher strength than the matrix, that is, the metal (Daneshjou & Ahmadi 2006). According to GonÄ *et al*., (2003) and Al Mangourg *et al*., (2016), the final performance of a metal matrix composite depends upon three key factors which include matrix types (metal types), the reinforcement (reinforcing

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particles), and the matrix/reinforcement interface (Shorowordi *et al.,* 2003); (Ghasali *et al.,* 2015); (Ghasalia *et al.,* 2016); (Ghasali *et al.*, 2016); and (Ghasali *et al.*, 2017). In general, metals with high strength will equally produce MMC with high strength and the properties of the resulting composite are also functions of the properties of reinforcement and bonds that exist between the matrix and reinforcement.

The interphase or the region between the matrix and the reinforcement actually plays a significant role in stress transfer between the matrix and the reinforcement. If the bonding between the two is weak; which can occur due to wettability issues or lack of interaction in-between; the final composite will have poor mechanical properties (Hajjari *et al.*, 2011); (Bhav & Balasubramanian 2009); (Tang *et al.*, 2009) and (Uren˜a *et al.,* 2007).

The potential of composite materials has been recognized indifferent metal-based materials, such as aluminium-based, steel-based, brass-based materials. For example, aluminium and its versions have been widely used in automotive, aerospace industry (Donald *et al.,* 2018), while brass and its versions have been widely used where low friction is required such as locks, gears, bearings, doorknobs, ammunition casings and valves among other uses. However, the utility spectrum still avoids the tribologically sensitive purposes. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The main problem associated with the Metal Matrix Composites is the high cost of reinforcement material. To overcome this hurdle, a need arises to look for low cost reinforcement materials which are also environmental friendly. Ashes from agricultural wastes such as Rice Husk Ash (RHA), Coconut Shell Ash (CSA) and Coal Fly Ash (CFA) have been used as the reinforcement materials in MMCs (Virkunwar *et al.,* 2018); (Daramola *et al.,* 2015); and (Aminnudin & Choiron 2018). Coconut Shell Ash (CSA) is one of the most economical and low density reinforcement existing in great quantities of solid waste attained from the burning of coconut shell, hence this study will utilize the Coconut Shell Ash (CSA) as the reinforcement to modify the mechanical properties of brass.

## 2.0 MATERIALS AND METHODS

### 2.1 Materials

This study made use of brass as the matrix, while Coconut Shell Ash powder (CSAp) which was obtained from a controlled burning of coconut shell was used as reinforcing particulates for the brass matrix based composite. Both the brass and the coconut shell were sourced locally in Nigeria. While Figure 1 a, b presents the coconut shell and the carbonized coconut shell, respectively, Figure 2 a, b presents the scrap brass and the sieved coconut shell ash powder, respectively.

The equipment used in this study are Energy Dispersive X-ray florescence (EDXRF), used for the elemental composition analysis of the coconut shell ash powder and the scrap brass. Mechanical furnace (Bail out furnace), used for the melting of the scrap brass and Mechanical Testing Machines, used for tensile strength, hardness and impact energy tests.

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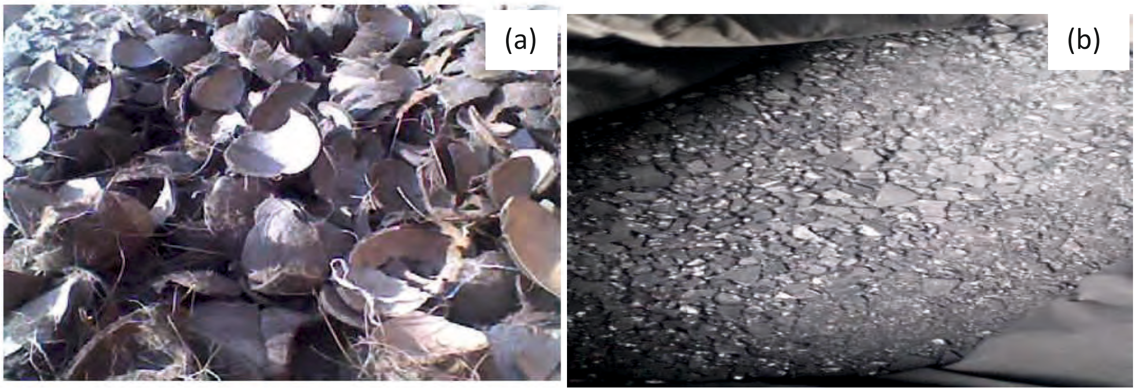


*Figure 1: Coconut shell (a) uncarbonized (b) carbonized*

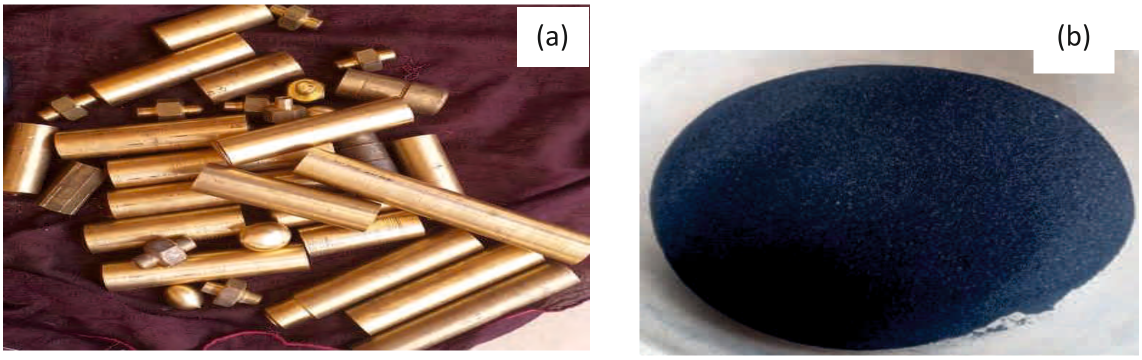


*Figure2: (a) Scrap brass sourced locally (b) sieved carbonized coconut shell power*

### 2.2 Methods

The carbonization process was carried out in accordance with Donald *et al.* (2018). The coconut shell was washed with water to remove impurities, air dried for 2 weeks and burnt in a firing chamber at 110$^{o}$C, then held for 5 hours to form carbonized coconut shell ash. It was then crushed and pounded with pestle and mortar in the laboratory to form coconut shell powder. In order to further reduce the particle size, the carbonized coconut shell ash powder was sieved using a 2.0μm sieves. About 100g of the carbonized coconut shell particle was placed unto the sieves and shaken for 15 minutes to achieve classification in accordance with Madakson*et al*.(2012).

The XRF analysis was carried out at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Osun State. The elemental compositions of the cast brass and CSA powder are presented in Tables 1 and 2, respectively. The XRF analysis of the scrap brass showed that the scraps brass used in this study contained various elements with Copper and Zinc ranking the highest having the percentage compositions of 64.19% and 33.30%, respectively. Similarly, the X-ray Florescence (XRF) analysis of the reinforcement material (CSAp) revealed that CSAp contained various elements with Kalium, Calcium and Ferrum ranking the highest having the percentage compositions of 79.42%, 9.36% and 7.99%, respectively.

The casting of MMCs was carried at the

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Table 1: Elemental Composition of cast brass

| ELEMENT | Manganese | Ferrum | Cobalt | Nickel | Cuprum | Zinc | Arsenic | Selenium | Krypton |
|---|---|---|---|---|---|---|---|---|---|
| %COMPOSITION | 0.0957 | 1.1010 | 0.3319 | 0.7897 | 64.1882 | 33.2968 | 0.1431 | 0.0164 | 0.0371 |

Table 2: Elemental Composition of CSAp

| ELEMENT | Kalium | Calcium | Titanium | Manganese | Ferrum | Nickel | Cuprum | Zinc | Bromine | Rubidium | Strontium |
|---|---|---|---|---|---|---|---|---|---|---|---|
| %COMPOSITION | 79.4222 | 9.3573 | 0.7222 | 0.8059 | 7.9967 | 0.3559 | 0.5129 | 0.3454 | 0.0314 | 0.1675 | 0.2826 |

Foundry Workshop of the Department of Metallurgical and Material Engineering, University of Ilorin, Kwara State. The process started with the determination of the quantity of brass and CSA powder required to produce 5, 10, and 15% weight CSA powder reinforced brass based composites in agreement with Daramola *et al.* (2015). The CSA particle was preheated to remove moisture and to help improve wettability with the brass melt. The CSA was added to the furnace when the brass molten and the mixture was heated and stirred mechanically continuously for a period of 5 to 10 minutes to ensure even distribution of the reinforcing particulates in the molten brass and pouring was carried out at mixture temperature of 1100°C (Daramola *et al.,* 2015). Casting of the control samples was also carried out without the addition of the CSA. After casting, the specimens for the tensile

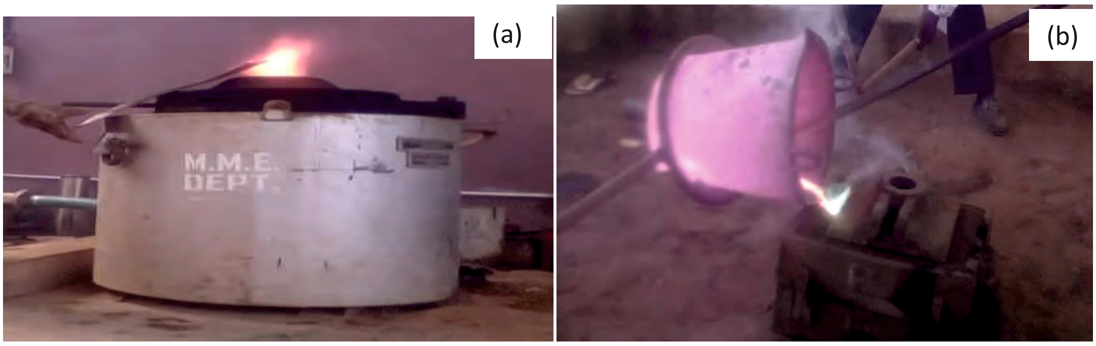


*Figure 3: Melting and pouring process of cast brass (a) mechanical furnace (b) pouring*

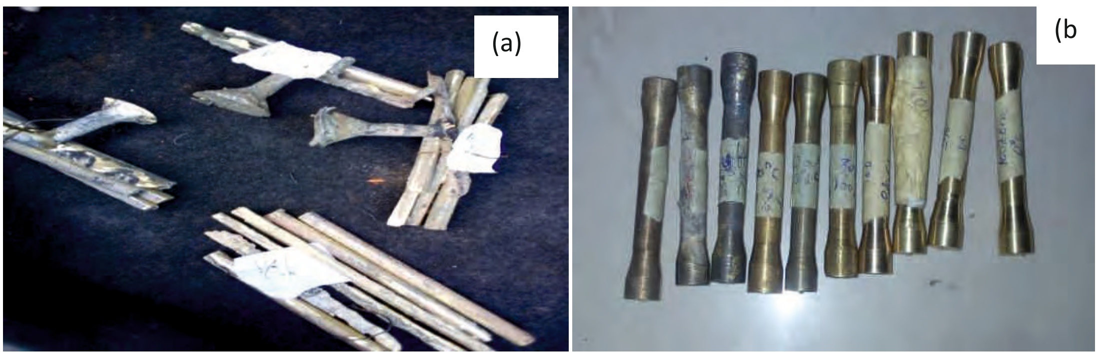


*Figure 4: (a) Products of the casting process (b) Machined specimens for tensile strength test*

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strength test were machined according to the specifications of the equipment to be used for the test. Figure 3 a, b showed the melting and pouring processes of the MMCs. Figure 4 a, b showed the products of the casting process and the machined specimen for tensile strength test.

The study of mechanical properties of tensile strength, hardness and impact strength of coconut shell ash powder reinforced composite was conducted as per ASTM standard (ASTM E8/E8M – 16a). The mechanical tests (tensile strength and hardness) of the MMCs specimens shown in Figure 7 a, b,were carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State. The tensile strength testing was carried out using Tensile Test (Circular comp) with Machine number: 0500-10080 at test speed 10.000 mm/min using sample length of 80.000 mm, with gauge length of 40 mm. The hardness testing was carried out using Brinell Hardness Testing machine of 1000 kgf at preload speed of 10.000 mm/min using sample height of 10.000 mm. The impact test was conducted in accordance with ASTM Standard Method. Impact strength was carried out using Avery Denison Impact Testing Machine (joules), with the impact velocity of 5.24 m/s for Charpy mode, at the Department of Mechanical Engineering, Mechanics of Material Laboratory, University of Ilorin, Kwara State. The samples of MMCs and the control were tested for the mechanical properties.The specimens after mechanical tests were shown in Figure7 a, b. The specifications of the specimen for tensile strength are:

$$\Delta_{ST} = -0.0294{B_g}^2 + 1.7943B_g + 1.0060$$

$$R^2 = 91.56\%$$

*Figure 5: Tensile test standard*

Where:

A – Length of reduced parallel section = 60 mm

B – Length of grip section = 10 mm

C – Width of grip section = 14 mm

G – Gauge length = 40 m

W – Width – 10 mm

L – Overall length = 80mm

## 3.0 RESULTS AND DISCUSSION

Table 3 shows the mechanical properties of the developed materials. The tensile strength of the MMCs increased generally as the percentages of the reinforcement increases. The tensile strength of the MMCs is in the order 15% > 10% >5% > 0% of CSAp as shown in Figure 9. Percentage elongation of the MMCs showed irregular trend where MMCs with 15% CSAp reinforcement having highest % elongation, as shown in Figure 9. Hardness of the MMCs increases slightly with increase in the percentage body weight of CSAp, The hardness of the MMCs is in the order 15% > 10% >5% > 0% of CSAp as shown in Figure 10. The impact energy test showed in-consistency as the CSAp

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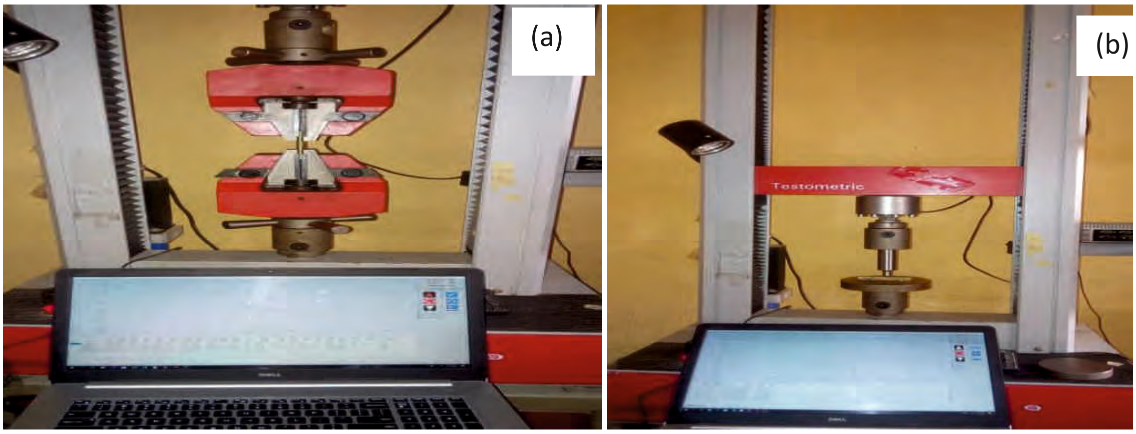


*Figure6: (a) Tensile strength test of the specimen using Tensile Test (circular comp)*
*(b) Hardness test of the specimens using Brinell Hardness Testing machine*


*Figure7: (a) Tensile strength specimens after the tensile test*
*(b) Impact energy test specimens after the impact test*

percentages increases, with the highest impact energy of 61 J obtained for 5% CSAp reinforcement as shown in Figure 11. The least impact energy of 34 J was obtained for 10% CSAp reinforcement MMCs.

Generally, brass is characterized by its metallurgical microstructure on the basis of the Zn composition. The microstructure of

Table 3: Mechanical Properties of the MMCs

| CSA % | Tensile strength (N/mm$^2$) | Percentage Elongation (%) | Brinell Hardness (kg/m$^2$) | Impact Energy (J) | Young modulus (N/mm$^2$) |
|---|---|---|---|---|---|
| 0 | 53.260 | 4.525 | 47315.469 | 56 | 1393.434 |
| 5 | 137.892 | 22.570 | 55351.372 | 61 | 1500.933 |
| 10 | 197.034 | 10.400 | 60079.632 | 34 | 1569.979 |
| 15 | 271.455 | 38.395 | 63217.413 | 51 | 1277.495 |

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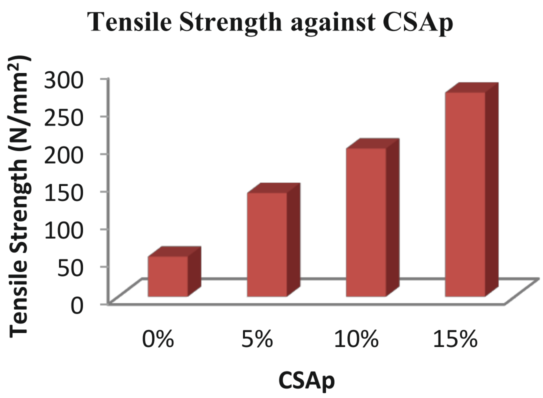


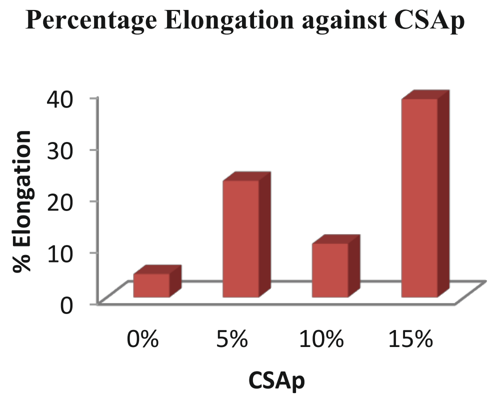
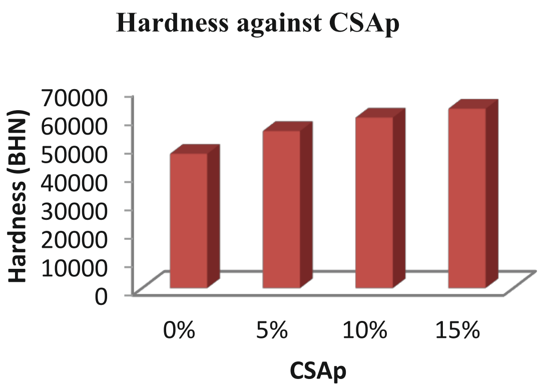




*Figure 8: Tensile Strength of MMCsFigure 9: % Elongation of MMCs*



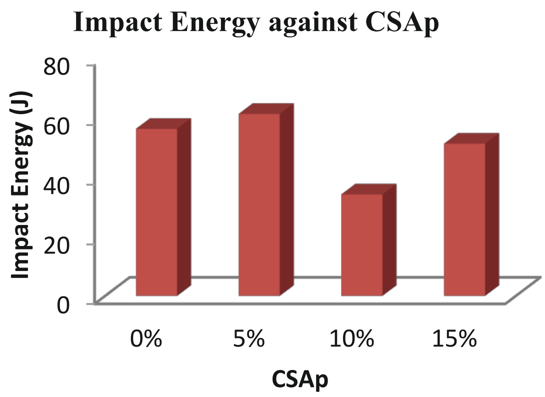




*Figure 10: Hardness of MMCsFigure 11: Impact Energy of MMCs*

commercial brass is formed by α, α + β, and ɤ + β phases. This study used α phase brass with 64.20% of Cu and 33.30% of Zn composition. The Scanning Electron Microscope results of the MMCs are presented in Figure 12 a, b, c, and d, for MMCs reinforced with 0, 5, 10, and 15 % CSAp respectively. In each case, the magnification and particle size were 1500X and 20 µm. There were microstructural variations in the SEM results of the MMCs. Figure 12a shows the microstructure of MMCs with 0% CSAp, there was homogeneity within the particles of brass. Figure 12 b, c and d, show the microstructures of the MMCs with 5, 10 and 15% CSAp reinforcement with dendritic structures formation and the reinforcing particles (CSAp) are visible and clearly delineated in the microstructure of the MMCs. The reinforcement influenced the morphology and the microstructures of the MMCs positively with evidence of increase in the mechanical properties of the MMCs.

## 4.0 CONCLUSION

The results obtained from all experiment show that the mechanical properties of MMCs obtained increased with increase in coconut shell ash (CSA) content. The best tensile strength and hardness were obtained for the highest percentage of CSA (15%) used in this

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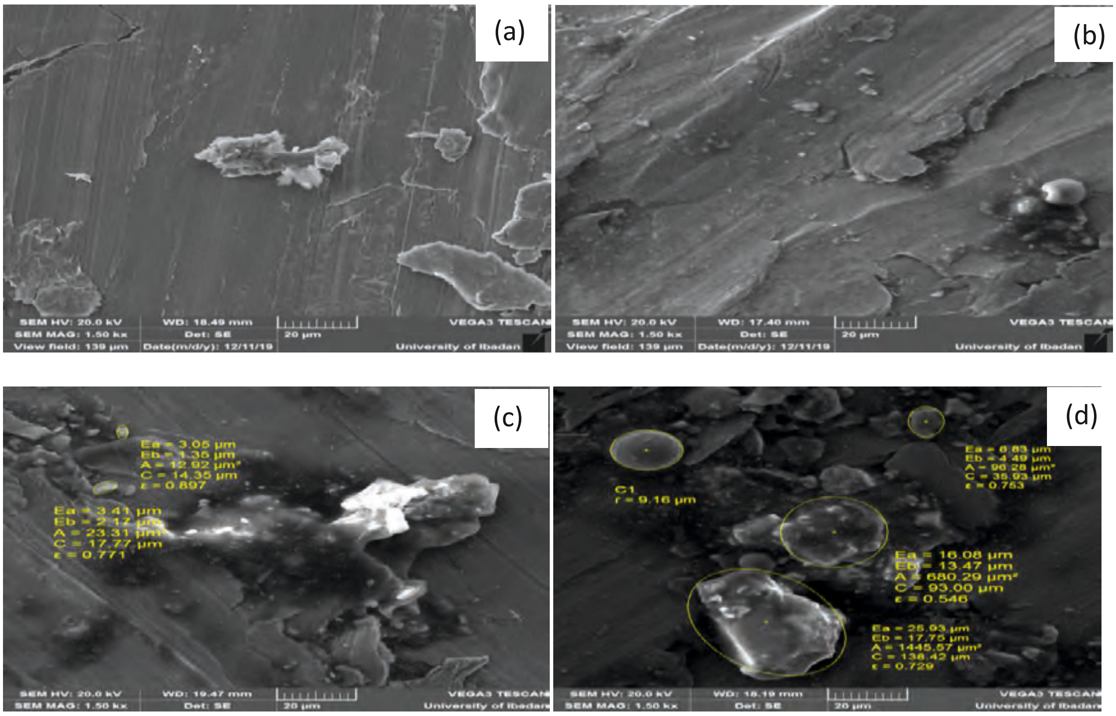


*Figure 12: Microstructures of MMCs: (a) 0% (b) 5%, (c) 10%, and (d) 15%*

study. The highest impact energy was obtained for MMCs with 5% CSA reinforcement. The addition of higher %CSA as reinforcement in brass composite produced MMCs with high tensile strength, low ductility, and high degree of brittleness. Generally an increase in the hardness of the cast brass obtained brought about an equal increase in the tensile strength and decrease ductility of the metal. Brass reinforced with coconut shell ash is useful for good number of engineering applications where high strength and strong rigidity is required. It is also applicable in the manufacture of valve stems, railway track and other manufacturing activities. With this study, the problem of sudden failure of conventional engineering materials as addressed can be reduced by modifying their properties using reinforcement and the environmental pollution experienced through littered brass scraps and agro wastes could also be drastically reduced if not completely eliminated.

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