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Effect of Heat Treatment Temperature on Scrap Brass Reinforced With Coconut Shell Ash

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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 present study, Brass /Coconut Shell Ash powder (CSAp) composites having 0%, 5%, 10% and 15% weight CSAp were fabricated by stir-casting method. The effects of heat treatment temperatures at 300°C, 350°C, and 400°C on the mechanical properties (tensile strength, hardness and impact strength) and microstructures of the composites were investigated. The tensile strength of the MMCs is in the order 15% > 10% >5% > 0% of CSAp, while the effect of heat treatment temperature on the MMCs tensile strength is in the order 300°C > 350°C > 400°C. Hardness of the MMCs increases slightly with increase in the percentage body weight of CSAp, in the order 15% > 10% >5% > 0% of CSAp, with the highest hardness obtained at 350°C. The highest impact energy of 134 J was obtained for 15% CSAp reinforced sample at 350°C.The microstructural analysis revealed that the particle size of the reinforcing material increases with increased %CSA in the composite and was not homogeneously distributed within the particles of the matrix, and as the temperature of heat treatment increases the particle size of the reinforcement reduces in the composite, therefore reduction in the tensile strength of the composite. Hence, this study has established that reinforcing brass matrix with coconut shell ash particles and heat treating the composites, can result in the production of low cost brass composites with enhanced tensile strength, hardness and impact energy values.

Keywords*: Brass, Coconut shell ash, Matrix, Composite, Stir-casting, Mechanical properties, Microstructures, heat treatment temperature.*

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I. INTRODUCTION

Metalmatrixcomposites(MMCs) arethe composites with metal as the major composites.Reinforcementmaterialsareaddedtoimprovetheproperties of the matrix.Composite isa materialmade upoftwoormoredifferentphasesormaterials(Mussig , AG, Faruk , & Sain, 2014)(Callister, Rethisch, Calliste, Rethwisch, Callister, Jr., & Rethisch, 2007). They are made by combining two or more materials in such a way that the resulting materials have certain design properties on improved properties (Callister *et al*., 2007). The materials for the matrix are metals (Vivrs, Bas, Beltran , & Fontaine, 1993);(Wang, Z., Scudino, S., Stoica, M., Zhang, W., & Eckert, J. 2015); (Cikara, Rakin, & Todic, 2009); (Boshnakova, Markovska, & Rusev , 2015), ceramics (Chen, Beyerlein, & Brinson, 2011) and polymers (Ashworth, Rongong, Wilson, & Meredit, 2016);(Braga & Magalhaes, 2015). Usually, metals have lower strength than the reinforced materials but are of higher ductility. The resulting material is ductile and has higher strength than the matrix, that is, the metal (Daneshjou & Ahmadi, 2006). According to (GonÄ , Egizabal, Coleto, Mitxelena, Leunda , & Guridi, 2003); (AlMangourg, Grzesiak, & Yan, 2016), the final performance of a metal matrix composite depends upon three key factors which include matrix types (metal types), the reinforcement (reinforcing particles), and the matrix/reinforcement interface (Shorowordi, Laoui, Haseeb, Celis , & Froyen , 2003);(Ghasali, Alizadeh, Ebadzadeh, Pakseresht, & Rah, 2015); (Ghasalia, Yazdani-radb, & Rahbari, 2016); (Ghasali, Pakseresht, Alizadeh , Shirvanimoghaddam, & Ebadzadeh, 2016); (Ghasali , Fazili , Alizadeh , Shirvanimoghaddam, & Ebadzadeh, 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 particles and bonds that exist between the matrix and particle.

The interphase or the region between thematrix 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 , Divandari , & Mirhabibi , 2004); (Bhav & Balasubramanian, 2009);(Hajjari, E., Divandari, M., & Arabi , H. 2011);(Tang, Liu, Li, Shen, & Hu, 2009); (Uren˜a, Rams, Escalera, & Sa´nchez, 2007).

However, MMC can be subjected to heat treatment to modify its mechanical properties. Metal, when heat treated, will have its microstructure and mechanical properties altered. MMC is heat treated to improve its mechanical properties, (Rezaee, Kermanpur, Najafizadeh, & Moallemi, 2011). In this study, the effect of heat treatment temperature on brass reinforced with Coconut Shell Ash Powder (CSAp) is investigated.

MMCs are in market currently primarily in military and aerospace applications. Experimental MMC components have been developed for use in the areas of applications such as aircraft, satellites, jet engines, missiles and National Aeronautics and Space Administration (NASA) space shuttle. The most important commercial application to date is the MMC diesel engine piston made by Toyota. This composite piston offers better wear resistance and high-temperature strength that the cast iron piston it replaced.

Conventional materials like Steel, Brass, Aluminium etc will fail without any indication, hence conventional materials are replaced by Composite materials. 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); 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, their 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 asRiceHuskAsh(RHA),Coconut Shell Ash (CSA), Coal FlyAsh (CFA),have been used as the reinforcement materials in MMCs (Virkunwar, Ghosh, Basak, & Rao, 2018); (Daramola, Adediran, & Fadumiye, 2015); (Aminnudin & Choiron, 2018) .CoconutShellAsh(CSA)isoneofthemosteconomicalandlowdensity reinforcementexistingin greatquantitiesofsolidwasteattainedfromtheburningofcoconutshell, hence this study will utilize the Coconut Shell Ash (CSA) as the reinforcement to modify the mechanical properties and the microstructures of brass.

II. MATERIALS AND METHOD

In this study, brass as the matrix and Coconut Shell Ash (CSA) as reinforcing material were used. Both the brass and the coconut shell were sourced locally. The coconut shell was washed with water to remove impurities and air dried.The CSA was obtained from a controlled burning of the coconut shell in a firing chamber at 110^{o}C and held for 5 hours to form carbonized CSA. The carbonization process was carried out in accordance with (Donald et al., 2018). The CSA wascrushed and pounded with pestle and mortarin the laboratory to form coconut shell ash powder (CSAp). The particle size of the CSAp was further reduced by sieving it using a 2.0µm sieves.The sieving was carried out in accordance with (Madakson et al., 2012).

Figure 1: (a) Coconut shell (b) Carbonized and crushed CSA (c) Sieved CSAp (d) Scrap brass

The matrix in the metal matrix composites MMCs, (brass) and the reinforcing particles (coconut shell ash), were analyzed to determine their elemental compositions using the Energy Dispersive X-ray Florescence (EDXRF) technique. The XRF analysis was done at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Osun State.

The MMCs was casted at the Foundry Workshop of the Department of Material and Metallurgical Engineering, University of Ilorin, Kwara State. The quantity of brass and CSA required to produce 5%, 10%, and 15% CSA reinforced composites was determined (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 molten brass in the furnace and the mixture was further heated and stirred mechanically continuously for a period of 5 to 10 minutes (Daramola et al., 2015) to achieve even distribution of the CSA in the molten brass and pouring was carried out at mixture temperature of 1100^{o}C (Aminnudin & Choiron, 2018). The control samples were also casted without the addition of the CSA. After casting, the samples to be used for tensile strength test were machined according to the specifications of the equipment for the test.Figure 2 a, b shows the process and products of the casting of the MMCs.

The effects of heat treatment temperatures on the mechanical properties (tensile strength, hardness and impact strength) of the treated and untreated samples were investigated. The heat treatment was carried out at Integrated Research Laboratory, 36 Aleniboro Village OkeodoTanke, Ilorin, Kwara State. The samples were heat treated at 300^{o}C, 350^{o}C, 400^{o}C in the electric furnace with the holding time of 30 minutes and quenching was done with water (Aminnudin & Choiron, 2018).

Figure 2: (a) Casting process (b) Casting products

Thetensile strength, hardness and impact strength tests of MMCs wereconducted as per ASTM standard (ASTM E8/E8M – 16a). The mechanical tests (tensile strength and hardness) of the MMCs specimens 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.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 before and after heat treatment. Figure 3 shows the tensile test standard used in this study, the specifications of the specimen for tensile strength are shown below.

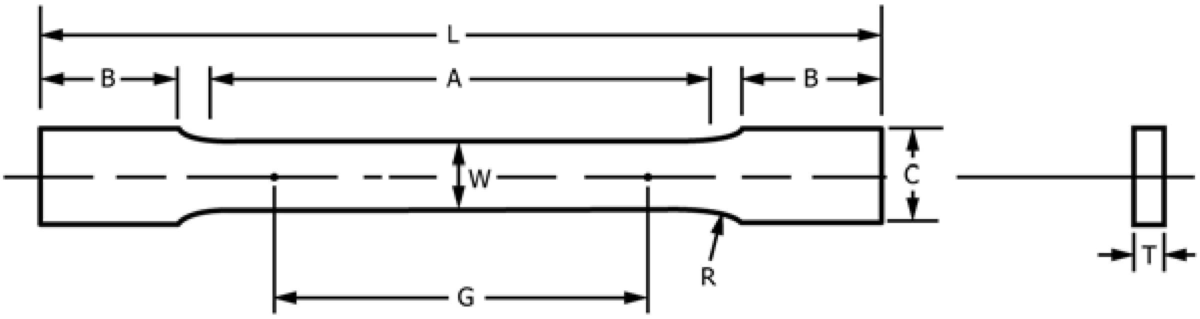


Figure 3: Tensile test standard

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 mm
W – Width – 10 mm
L – Overall length = 80mm

Figure 4: (a) Machined specimensbefore tensile strength test (b) Machined specimensafter tensile strength test

The casting products were machined according to the tensile test standard and presented in Table 4a, after the tensile strength test, the effect of the test on the MMCs is presented in Table 4b. The samples ofthe MMCs and the control, before and after heat treatment, were analyzed for their microstructures using Scanning Electron Microscope with Energy Dispersive Spectrometer (SEM/EDS), at the Department of Agricultural and Environmental Engineering, University of Ibadan, Oyo State.

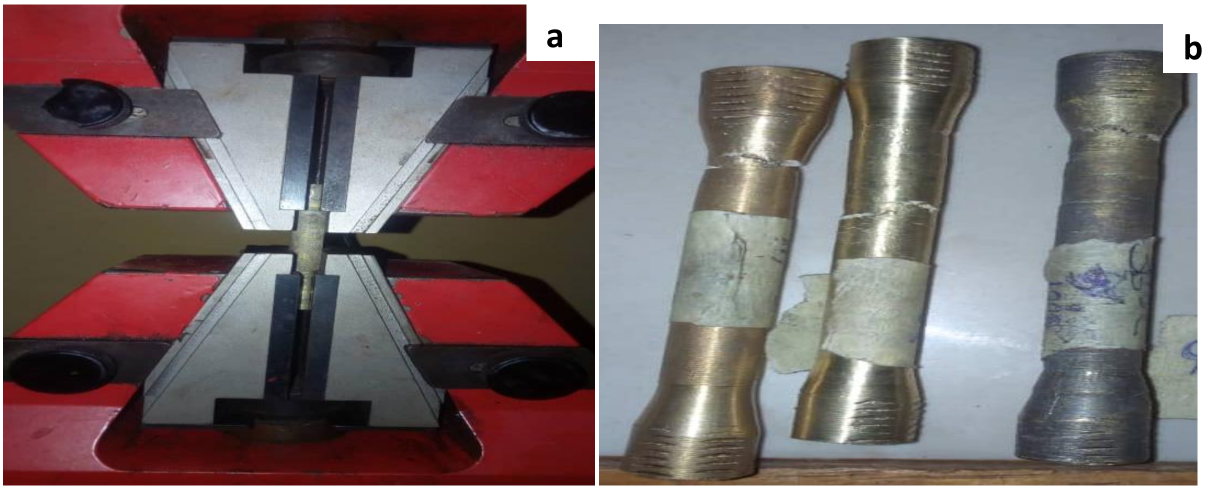


Figure 5: (a) Tensile strength test of the specimen using Tensile Test (circular comp)
(b) MMCs specimen after tensile strength test

Figure 6: (a) Hardness test of the specimens using Brinell Hardness Testing machine (b) MMCs specimen after hardness test

The samples of MMCs and the control were tested for the mechanical properties, the tensile strength testing and the specimens after the tests were shown in Figure 5 a, b. The hardness testing of MMCs samples and the specimen after hardness tests were carried out, Figure 6 a, b.

III. RESULTS AND DISCUSSION

The XRF analysis was carried out on the scrap brass and CSA powder used in this study at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Osun State. The results are presented in Tables 1 and 2 respectively. The XRF analysis of the scrap brass showed that the scrap 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.

Table 1: Elemental Composition of cast brass

ELEMENT	% COMPOSITION
Manganese (Mn)	0.0957
Ferrum (Fe)	1.1010
Cobalt (Co)	0.3319
Nickel (Ni)	0.7897
Cuprum (Cu)	64.1882
Zinc (Zn)	33.2968
Arsenic (As)	0.1431
Selenium (Se)	0.0164
Krypton (Kr)	0.0371

Table 2: Elemental Composition of CSAp

ELEMENT	% COMPOSITION
Kalium (K)	79.4222
Calcium (Ca)	9.3573
Titanium (Ti)	0.7222
Manganese (Mn)	0.8059
Ferrum (Fe)	7.9967
Nickel (Ni)	0.3559
Cuprum (Cu)	0.5129
Zinc (Zn)	0.3454
Bromine (Br)	0.0314
Rubidium (Rb)	0.1675
Strontium (Sr)	0.2826

Mechanical Properties of the Materials Developed

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, for both heat treated and non-heat treated products. The tensile strength of the MMCs is in the order 15% > 10% >5% > 0% of CSAp. While the heat treated samples showed higher tensile strength compared with non-heat treated counterpart, the heat treatment temperature of 300^oC showed the highest tensile strength. The effect of the heat treatment temperature on the tensile strength is the order 300^oC > 350^oC > 400^oC. Hardness of the MMCs also increases with increase in the percentage body weight of CSAp, in the order 15% > 10% >5% > 0% of CSAp. The hardness of heat treated samples showed higher values compared with non-heat treated counterpart, the heat treatment temperature of 350^oC showed the highest Hardness. The effect of the heat treatment temperature on the hardness is the order 350^oC > 400^oC > 300^oC. The impact energy test showed in-consistency as the CSAp percentages increases and as the heat treatment temperature increases. The highest impact energy of 134 J was obtained for 15% CSAp reinforcement sample at 350^oC heat treatment temperature as shown in Table 3. The least impact energy of 34 J was obtained for 10% CSAp reinforcement MMC without heat treatment. Generally, the non-heat treated samples had low impact energy compared with the heat treated counterparts; hence it implies that heat treatment influences impact energy positively.

Effect of heat treatment temperature on the mechanical properties of MMCs

Comparison of tensile strength of the heat treated and untreated brass composites are shown in Figure 7. The figure revealed that the heat treatment temperature of 300^oC has the highest tensile strength and this occurred for 15% CSA reinforcement. Figure 8 shows the effect of heat treatment temperature on the hardness of casting products, the hardness increased with increase in reinforcement percentage, at 15% CSA reinforcement, the heat treatment of 350^oC has the highest hardness. Conversely, the percentage elongation for the untreated sample at 15% CSA reinforcement has the highest percentage elongation, as shown in Figure 9. Comparing the impact energy (J) of the heat treatment temperatures of the MMCs, the heat treatment temperature of 350^oC produced the highest impact energy and the highest value was obtained at 15% CSA reinforcement, Figure 10.

Table 3: Mechanical Properties Results

Heat Treatment Temperature (^oC)	CSA %	Tensile strength (N/mm^2)	Percentage Elongation (%)	Brinell Hardness (kg/m^2)	Impact Energy (J)	Young modulus (N/mm^2)
0	**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**
300	**0**	**95.690**	**31.644**	**50985.12**	**104**	**1790.136**
	5	**127.617**	**23.779**	**56027.608**	**108**	**1230.440**
	10	**201.681**	**25.517**	**61205.134**	**94**	**1462.294**
	15	**341.732**	**27.734**	**65737.892**	**102**	**1345.451**
350	**0**	**90.616**	**14.178**	**52338.181**	**112**	**1799.350**
	5	**103.718**	**15.807**	**56813.540**	**95**	**2123.489**
	10	**186.657**	**23.507**	**64912.921**	**110**	**1143.799**
	15	**295.750**	**27.345**	**89571.235**	**134**	**2214.754**
400	**0**	**54.864**	**7.658**	**49197.749**	**99**	**2337.952**
	5	**68.793**	**7.494**	**49428.372**	**91**	**2409.492**
	10	**86.186**	**13.247**	**55770.901**	**98**	**1643.899**
	15	**216.960**	**24.740**	**82591.358**	**122**	**1335.706**

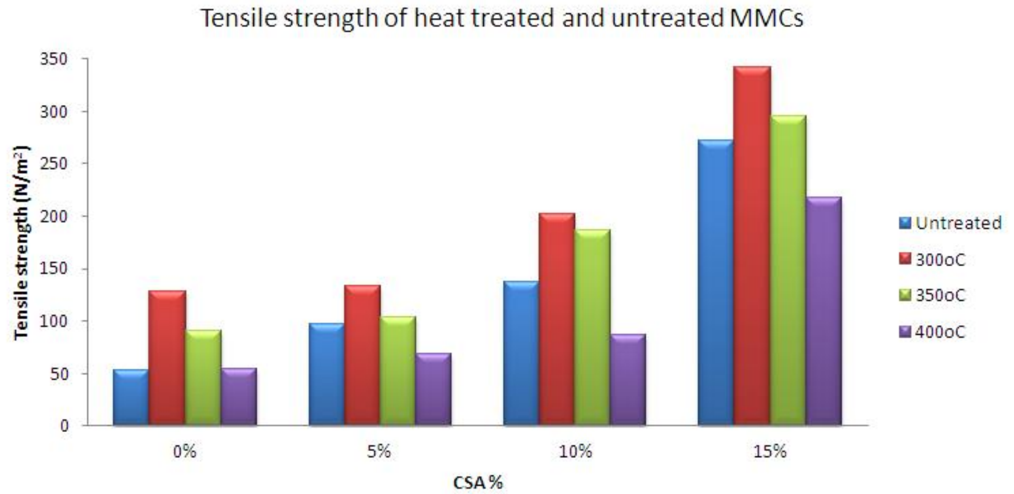


Figure 7: Comparison of tensile strength of MMCs at varied heat treatment temperatures

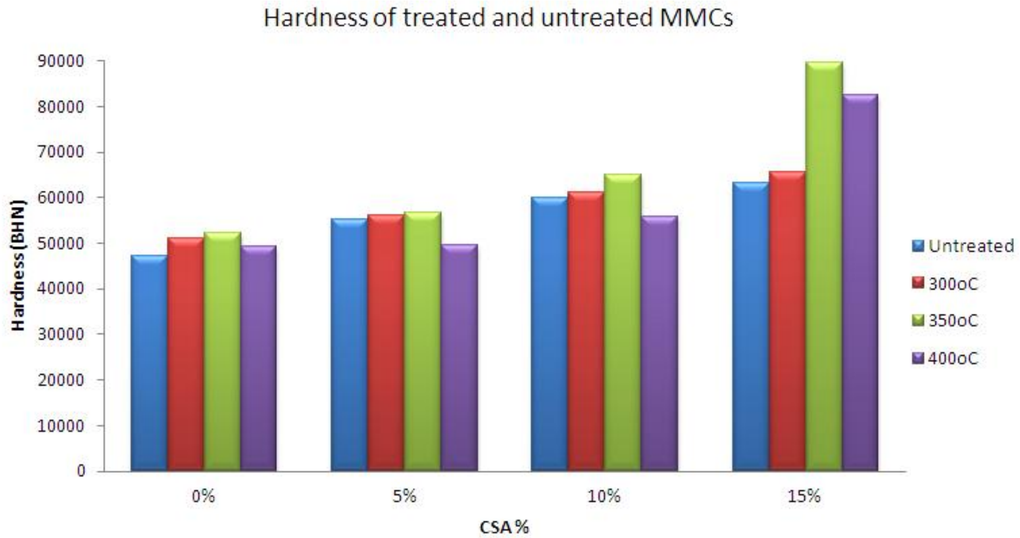


Figure 8: Comparison of hardness of MMCs at varied heat treatment temperatures

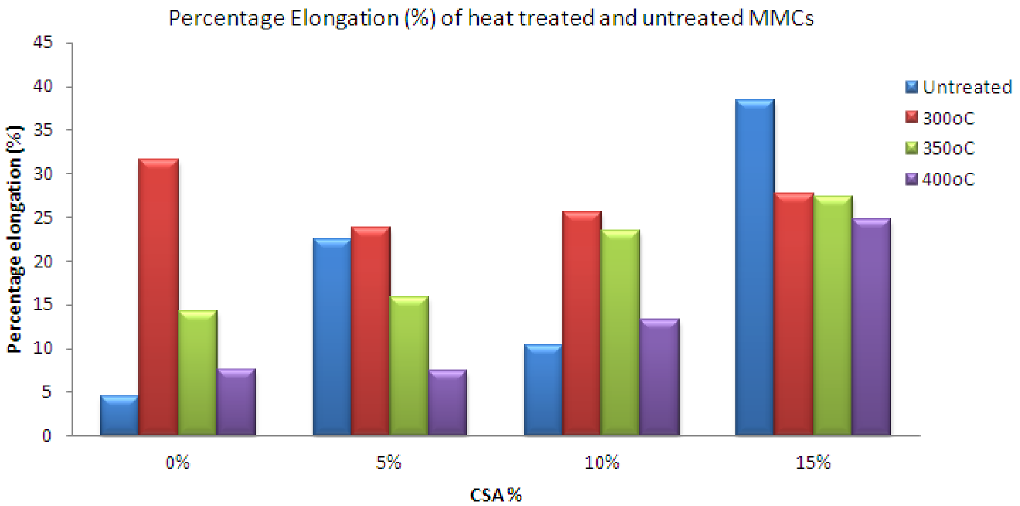


Figure 9: Comparison of percentage elongation of MMCs at varied heat treatment temperatures

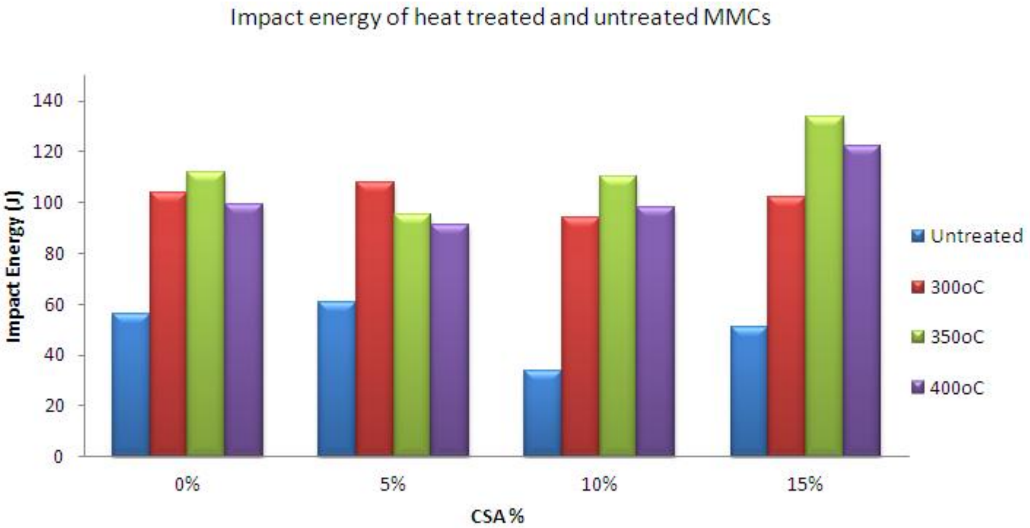
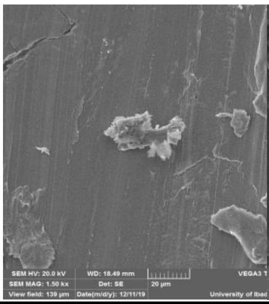
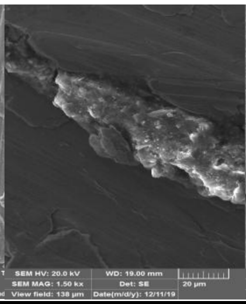
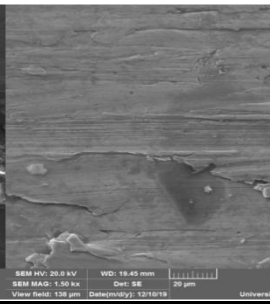
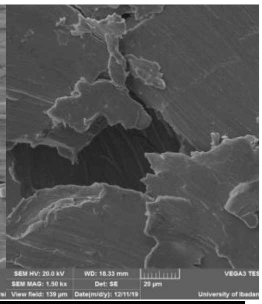


Figure 10: Comparison of impact energy of MMCs at varied heat treatment

Effect of heat treatment temperature on the microstructures of MMCs

The microstructures of the untreated and heat treated composite products of the experiment as obtained from scanning electron microscope (SEM) are presented Figure 11. SEM images showed the presence of small and larger particles within the layers of the brass on the surface composite particles. There was a relatively less deformed CSA particles embedded into a continuous brass matrix. Brass generally is characterized by its metallurgical microstructure on the basis of the Zn composition. The microstructure of commercial brass is formed by alpha, alpha + beta, and gamma + beta phases. The brass used in this study according to the result of XRF was alpha phase brass with 64.20% of Cu and 33.30% of Zn composition.Column 1 of Figure 11 representsMMCs without heat treatment and there was homogeneity within the particles of the brass with similar patterns at different particle sizes.Column 2 of Figure 11 represents the heat treated composite at 300^{o}C, there was a presence of huge white pattern centrally located in the image due to quenching of the heat treatment, which gradually disappears as the particle size increases. The SEM images of heat treatment at 350^{o}C of the MMCsis shown in Column 3 of Figure 11, small black grain was seen within the pattern formed by the brass, which gradually distributed as smaller grain with the structure as the particle size increases. Figure 11 column 4 shows the SEM image of 400^{o}C heat treated MMCsthere was a presence of huge black pattern centrally located in the image due to quenching of the heat treatment at 400^{o}C, which gradually reduces as the particle size increases. It is evident that as the temperature of heat treatment increases, there were modifications in the microstructures of the samples, resulting in the reduction in the tensile strength and hardness of the samples.

Heat treatment temperature	0^{o}C	300^{o}C	350^{o}C	400^{o}C
Reinforcement 0%				

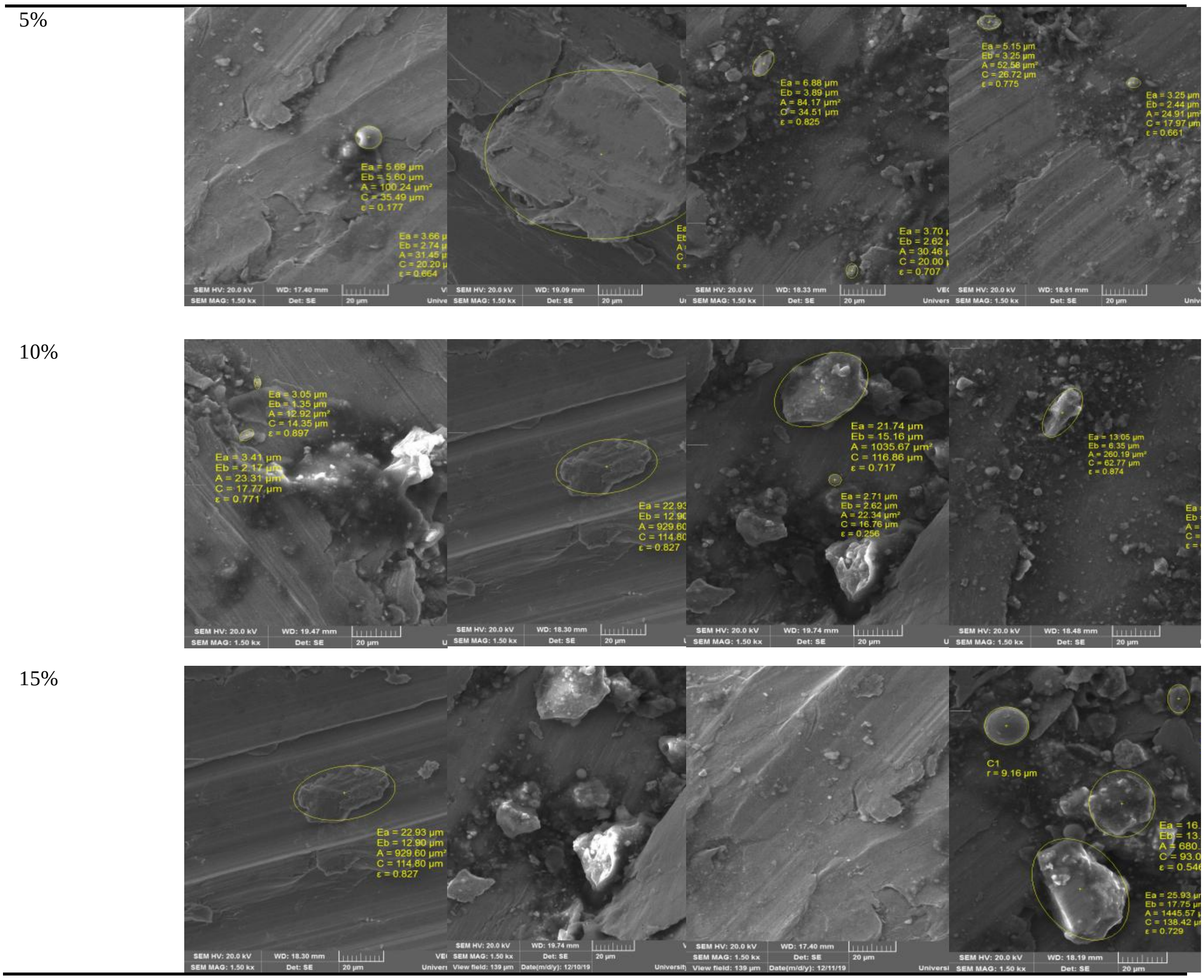


Figure 11: Microstructure of heat treated and untreated MMCs

IV. CONCLUSION

The results obtained from all experiment show that the mechanical properties of MMCs obtained increased with increase in coconut shell ash (CSA) content. MMCs of 15% at heat treatment temperature of 300^{o}C gave the best mechanical properties. The results obtained in this work revealed that the hardness property of brass alloys can be improved by addition of certain amount of CSAp and heated treated.Also,the heat treatment temperatures of the composites influenced the morphology and the microstructures positively.Tensile strength, impact energy and hardness increased as the reinforcement increased. 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. Hence, to obtain an optimum brass cast, the coconut shell ash added to the brass must be at an optimum value. Therefore, recycled brass reinforced with coconut shell ash is useful for good number of engineering applications where high strength and strong rigidity is required.

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