Investigation of Mechanical Properties and Microstructure of Brass Alloys Obtained from Recycled Copper and Zinc Metals

Edward Igelegbai and Oluwaseun Alo

ABSTRACT - In this work, brass alloys were produced by sand casting using recycled copper and zinc metals. The zinc content was varied from 5 to 30 wt%. The cast alloys were subjected to homogenizing annealing heat treatment. Hardness and tensile tests were carried out on the samples from each composition. Also, the samples were subjected to microstructural investigation using optical microscopy. The results obtained showed that the hardness, yield strength, ultimate tensile strength, percentage elongation and elastic modulus of the alloys increase with increase in zinc content. Also, the micrographs of the samples reveal the presence of a single solid phase which consists of a solid solution of zinc in alpha copper. It was concluded from the study that brass alloys with good mechanical properties can be produced from recycled copper and zinc metals.

(Keywords: Recycling; Brass alloys; Microstructure; Mechanical properties)

1. INTRODUCTION

Copper and copper-based alloys have been utilized in quite a variety of applications since antiquity. Copper metal in the pure form is so soft and ductile that it is difficult to machine. However, mechanical and corrosion resistance properties of copper can be improved by alloying (Haque and Khan, 2008). Also, copper alloys may be endowed with a wide range of properties by varying their composition and the heat treatment to which they are subjected. For this reason they probably rank next to steel in importance to the engineer (Zuhal, 2015).

In alpha brasses, the zinc atoms replace copper atoms to form a random non homogeneous substitutional solid solution. The replacement process is quite indiscriminate so that the concentration of zinc atoms can vary considerably throughout the structure. This enhances diffusion to take place to produce more stable and uniform distribution **(**Higgins, 1975, Haasen, 1978 and Cahn and Haasen, 1983). Nowadays, brasses are widely applied in technology, and they belong to the most commonly used alloys in the group of non-ferrous metals. Thanks to the specific properties of brasses they are applied in various domains of industry, among others in civil engineering, armaments industry, aircraft industry, machine building, the production of motor cars, electrical industry, ship building, precision mechanics, chemical industry and many others, even in the production of musical instruments. These alloys are characterized by a considerable ductility and resistance to corrosion, particularly atmospheric corrosion and corrosion in seawater. They also display good casting properties (Ozgowiczet al., 2010).

It has been reported that increasing the zinc content in brass alloys above 45% increases their brittleness, and that the optimal mechanical properties are displayed by brass containing about 30% zinc. Those are characterized by considerable plastic properties together with high tensile strength and hardness (Nowosielski, 2001, Staszewski and Rdzawski, 2007, Freudenberger et al., 2010, Kommel et al., 2007 and Nowosielski 2006).

The mechanical properties of brass depend mainly on the content of zinc and the degree of deformation in the course of the production (Ozgowicz et al., 2010). Several studies have been carried out to investigate the parameters affecting the microstructure and mechanical properties of brasses. For example, Haque and Khan (2008), investigated the microstructure and properties of brass produced by sand casting and metallic chill casting methods, representing the slow and fast cooling rates of the castings, respectively. Their results showed that the slow cooling rate in the sand mould produces larger grains, while the metallic chill mould produces smaller grains in the castings. They also reported that as the grain size decreases, the strength of the cast brass increases; micro-porosity in the casting decreases and the tendency for the casting to fracture during solidification decreases.

Since brasses are widely used in various engineering applications, their production from recycled scrap waste metals is an important activity since it will enhance the production of these alloys at lower cost. The present study focuses on the investigation of the mechanical and microstructural behaviour of alpha brasses produced from recycled copper and zinc metals.

2. MATERIALS AND METHODS

The major materials used during the study are used copper wires, used zinc obtained from the casings of used dry cells, emery papers and etchant. The major equipment used in the study include furnaces, hardness tester, universal tensile testing machine, grinding machine, polishing machine and optical microscope.

The brass alloys were produced by sand casting using used copper wire and zinc from used dry cell casings. Five different compositions of the alloy were cast by varying the zinc content from 5 wt% to 30 wt%. The melted alloys were cast into cylindrical rods. The furnace charge calculations are as shown in Table 1.

Table 1: Furnace Charge Calculation for Cu-Zn alloys

Alloy	Copper (Kg)	Zinc (Kg)	Total mass (Kg)
Cu 5% Zn	4.275	0.150	3.0
Cu 10% Zn	2.700	0.300	3,0
Cu 15% Zn	2.55	0.45	3.0
Cu 20% Zn	2.40	0.60	3.0
Cu 30% Zn	2.25	0.75	3.0

Samples from each alloy composition were then machined into standard tensile test pieces (Fig.). The test pieces and the remaining (i.e. not machined) samples were then annealed in order to homogenize the composition. They were heated in an OMSZOV electrical furnace which was set to a temperature of 550 ^{o}C. They were then soaked at this temperature for five hours and furnace cooled.

Samples of the alloys were subjected to hardness test, using the Brinell hardness test accessory of the Monsanto Hounsfield Tensometer. Tensile tests were then carried out on tensile test pieces from each alloy composition by using an Instron Universal Testing Machine.

Also, parts of the heat treated cast samples were cut to suitable sizes. The samples were ground and then polished with 0.5 µm followed by 0.3 µm alumina paste by hand over velvet cloth. The specimens were etched in a solution containing 100 ml distilled water, 5 g ferric chloride and 50 ml hydrochloric acid for a few seconds. The etched samples were then mounted on an ACCUSCOPE metallographic microscope and the microstructures were examined using a magnification of ×400. Attached to the microscope were an ocular camera and a computer system through which the micrographs were viewed and captured.

3. RESULTS AND DISCUSSION

3.1 Hardness Test

Figure 1 shows the results of the Brinell hardness test for the Cu-Zn alloys. As can be observed from the figure, for all the alloys produced, the hardness value increases with increase in zinc content. Since plastic deformation in crystals is caused by the motion of dislocations, any obstacle to dislocation motion will hinder deformation and the crystal is thereby strengthened (Ajaja, 2014). Therefore, the increase in the hardness values of the alloys with increase in zinc content is attributable to solute hardening caused by the zinc solute atoms.

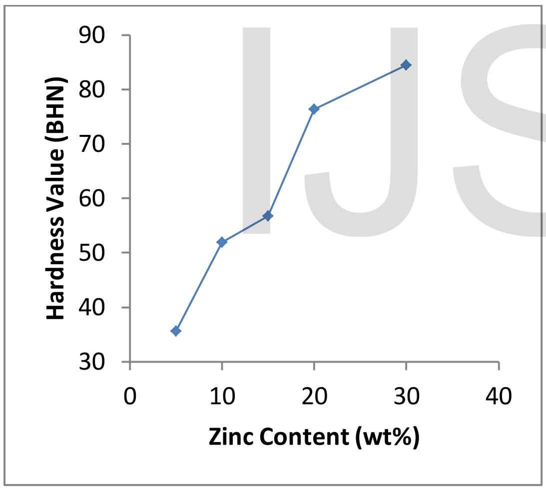

Figure 1: Variation of the hardness value of the alloys with increase in zinc content.

3.2 Tensile Test

The results of the tensile test are presented in Figures 2 to 5. The yield strength and the ultimate tensile strength, percentage elongation and elastic modulus of the cast alloys increase with increase in zinc content. Dislocation dissociation (the process which is energetically favorable in F.C.C. structure metals and alloys) results in the formation of stacking faults, and cross slip becomes difficult especially in case of wide stacking faults in low stacking fault energy metals and alloys (Seeger, 1955). Also, the lattice can reduce its internal energy either through the dissociation of some of its dislocations forming stacking faults or by the segregation of the present solute atoms on dislocations. The movement of such dislocation configurations actually needs more energy to be applied (Childs and Claire, 1954; Fleischer, 1966). Therefore, the observed increase in strength of the alloys by increasing the zinc content is attributable to the fact that the presence of solute atoms causes distortion of the lattice.

The observed increase in ductility of the alloys with increase in zinc content can be due to the fact that in non homogeneous alloys like α-brasses, preferential solute bonds are cut by the pass of the already present dislocations and successive ones find an easier passage on the same slip plane, so increasing slip distances (Carter and Ray, 1977).

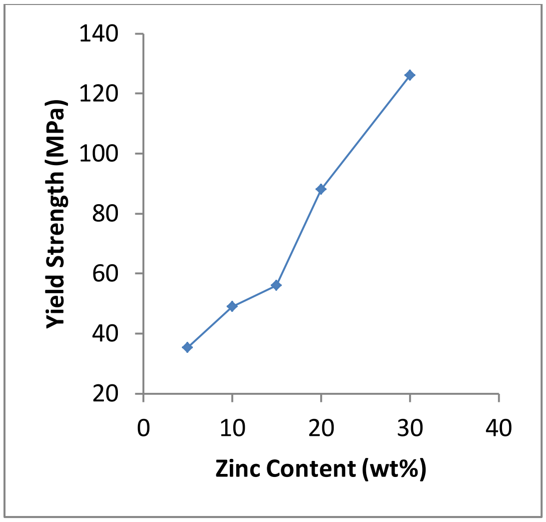

Figure 2: Variation of Yield Strength of the Cu-Zn Alloys with Zinc Content

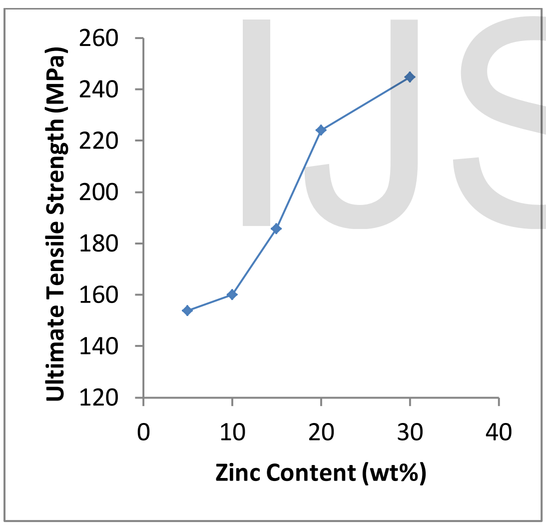

Figure 3: Variation of Ultimate Tensile Strength of the Cu-Zn Alloys with Zinc Content

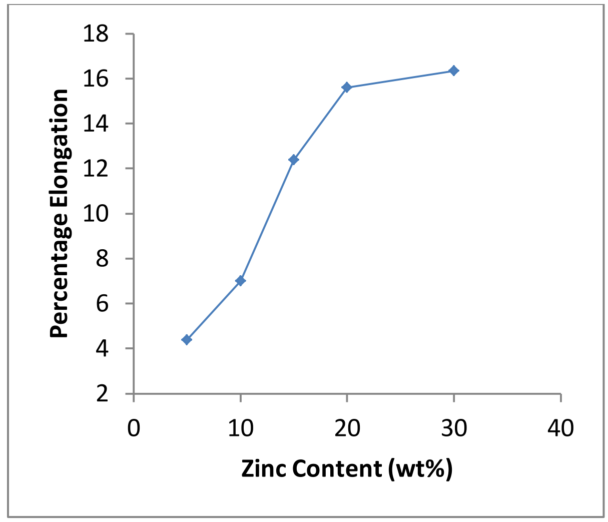

Figure 4: Variation of Percentage Elongation of the Cu-Zn Alloys with Zinc Content

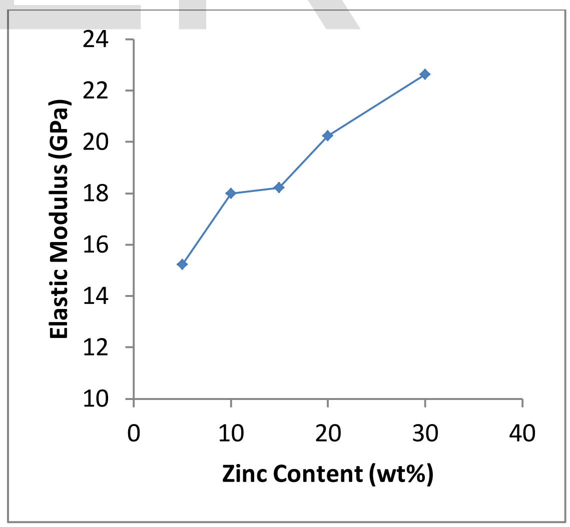

Figure 5: Variation of Elastic Modulus of the Cu-Zn Alloys with Zinc Content

3.3 Microstructure

From Figures 6 to 10, micrographs of the various alloys reveal the presence of a single solid phase which consists of a solid solution of zinc in alpha copper. This is expected because based on the Cu-Zn phase diagram; zinc has complete solid solubility in copper up to 35% (Smith, 2010). The presence of α-solid solution observed in the microstructure of all the alloys also

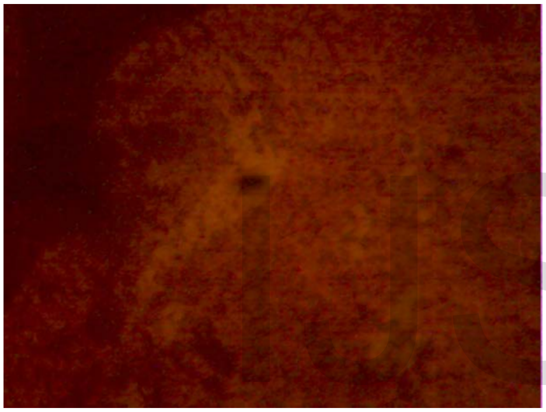

Figure 6: Micrograph of Cu 5% Zn alloy (X400)

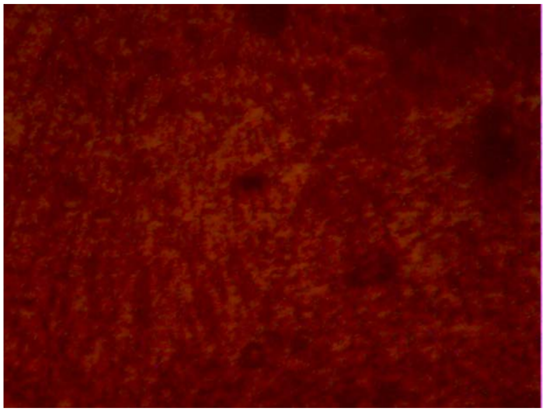

Figure 7: Micrograph of Cu 10% Zn alloy (X400)

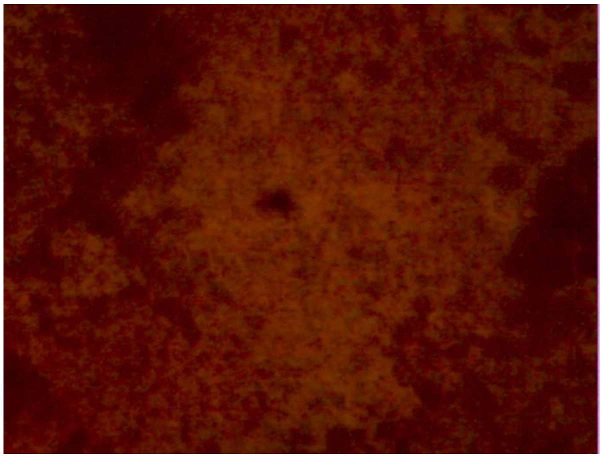

Figure 8: Micrograph of Cu 15% Zn alloy (X400)

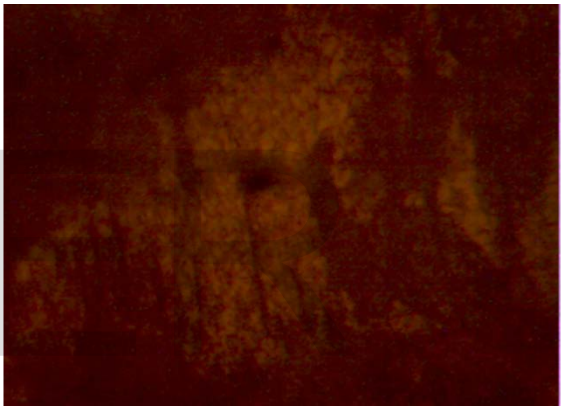

Figure 9: Micrograph of Cu 20% Zn alloy (X400)

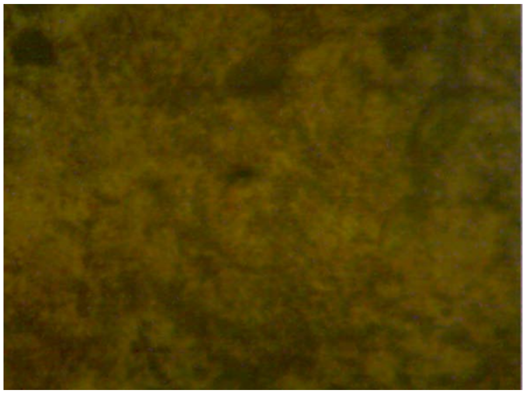

Figure 10: Micrograph of Cu 30% Zn alloy (X400)

relates to the observed trend in the strength and ductility since, as reported by Higgins (1977), when brasses have the structure of α-solid solution, an increase in the zinc content causes an increase in both strength and ductility.

CONCLUSION

Increase in zinc content in brass alloys obtained from recycled copper and zinc metals leads to improved hardness, yield strength, ultimate tensile strength and ductility of the alloys. Brass alloys with good mechanical properties can be produced from recycled copper and zinc metals.

REFERENCES

1. Ajaja ,O. (2014). Material science and engineering, lamlad publications, Ado-Ekiti ,Nigeria, p 108.
2. Cahn, R. W. and Haasen, P. (1983), Physical Metallurgy, North Holland Physics Publishing Amsterdam Oxford New York Tokyo p. 1343.
3. Carter, C. B. and Ray, J. L.(1977), ‘On the Stacking-Fault Energies of Copper Alloys’ Phil. Mag., 35:189.
4. Childs, B. G. and Le Claire, A.D., (1954), Relaxation effects in solid so1utions arising from changes in 1ocal order, *Acta Met*., **2**, 718.
5. Fleischer, R. L. (1966), The Strengthening of Metals, *Acta Met*., 14, 1867.
6. Freudenberger, J., Kaumann, A., Klauß, H., Marr, T., Nenkov, K., Subramanya, V. and Schultz, L. (2010), Studies on recrystallization of single-phase copper alloys by resistance measurements, Acta Materialia, 58: 2324-2329.
7. Haasen, P. (1978), Physical Metallurgy, Cambridge university press, Cambridge pp. 175-181.
8. Haque, M. M. and Khan, A. A. (2008), Investigation on Structure and Properties of Brass Casting, J. Mater. Sci. Technol., 24(3): 299-301.
9. Higgins, R. A. (1975), Engineering Metallurgy” The English universities press Ltd, st. Paul’s House Warwick Lane, London Ec4P4 AH printed in Great Britain.
10. Kommel, L., Hussainova, I. and Volobueva, O. (2007), Microstructure and properties development of copper during severe plastic deformation, Materials and Design 28:2121-2128.

11. Nowosielski, R. (2001) Ductility minimum temperature in selected mono-phase, binary brasses, Journal of Materials Processing Technology 109:142-153.
12. Nowosielski, R., Sakiewicz, P. and Mazurkiewicz, J. (2006), Ductility minimum temperature phenomenon in as cast CuNi25 alloy, Journal of Achievements in Materials and Manufacturing Engineering 17:193-196.
13. Seeger, A. (1955),Handbuch d. phys. VII, 1, p. 1 Berlin Gottingen Heidelberg springer.
14. Staszewski, M., Rdzawski, Z. M. and Wrona, A. (2007), Residual stresses in the strips from copper-based alloys, Journal of Achievements in Materials and Manufacturing Engineering 25(2):35-38.
15. W. Ozgowicz, E. Kalinowska-Ozgowicz, B. Grzegorczyk, (2010) The microstructure and mechanical properties of the alloy CuZn30 after recrystallizion annealing, Journal of Achievements in Materials and Manufacturing Engineering 40(1):15-24.
16. Zuhal A. K. (2015) Effect Of Annealing On Mechanical Properties Of Brass Alloy Type C38500, Diyala Journal of Engineering Sciences, 8(1):16-26