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COMPARATIVE STUDY OF MECHANICAL BEHAVIOUR OF Al-Cu METAL COMPOSITES FABRICATED BY STIR CASTING PROCESS

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Abstract: *Metal composites (MCs) are drawn considerable attention for improvement of mechanical properties like high specific strength, specific modulus, damping capacity and wear resistance etc. of materials. This study represents the fabrication of Al-20-wt%-Cu and Al-30-wt%-Cu composite bar by stir casting process. Stir casting technology is found to be most economical, simple, and flexible among varieties of manufacturing process available for metal composites along with that it is used for large quantity of production of metal composites which is discussed in this paper. It is noted that hardness, density, impact energy absorption, tensile strength are tested for Al-20-wt%-Cu and Al-30-wt%-Cu composite bar where 4.84% lower density, 10.74% lower strength, 17.84% lower strain are obtained for Al-20-wt%-Cu composite compared with Al-30-wt%-Cu composite. Moreover, absorbed energy for Al-20-wt%-Cu composites is obtained as E=0.73j whereas E=0.93j for Al-30-wt%-Cu composites which is 27.4% higher compared with Al-20-wt%-Cu composites. It is worthy to mention that better tensile strength, hardness properties of Al-30-wt%-Cu composite cause greater energy absorption capability due to presence of enhanced copper content. At present times, composites are being used in automotive, aerospace, electric equipment, sports goods, furniture, medical equipment, packaging elements and modern machinery for its high stiffness, strength, low mass, low weight and low manufacturing cost. This paper represents comparative study of mechanical properties between Al-20-wt%-Cu and Al-30-wt%-Cu composite bar fabricated by stir casting process.*

Keywords: Composites, Metal composites, Stir casting, Mechanical properties.

1. INTRODUCTION

From ancient time, people are making bricks with the help of mud which is a thousand-year-old composite making technology. Composites are being used in almost every aspect to make products more efficient and usable till from ancient time to present [1]. However, composites are most often used in automotive, aerospace, electric equipment, sports goods, furniture, medical equipment and packaging element. It is noted that resistance to chemicals and corrosion is one of the most important features of metal composites. It is worthy to mention that metal composites are being widely used as functional material for its great stiffness, strength, low mass, low weight, and low density. Metal composites is being appealed to researchers for its unequal manufacturing, processing possibility, easy producing of complex material body, producing of very large and small product, low tooling cost, and satisfactory surface finish can be obtained with it [2]. Metal composites of aluminum and steel possess four to six times tensile strength compared to aluminum and steel [3]. Along with, composites part can alleviate joints and provide simplicity of any engineering structure. Besides all these properties, the most important advantages of composite are: low thermal expansion, flexible, non-conductive, low maintenance cost, long life cycle, will not dent design flexibility [4]. It is known to all that two or more materials are combined together to make composites, all materials possessing different mechanical and chemical characteristics. It produces an individual material which differs from the properties of parent components when they are combined. However, it is known as the composition of materials. In composites, reinforcement particle is usually the load carrying particle and matrix is the weaker particle. The reinforced particle improves stiffness and strength of products which develops huge structural load carrying capacity. It is noted that it has been a great interest for the researchers and metallurgist to form new materials in material science which could be able to stand with higher performance standers, poses for the path for developing a new material possessing excellent physical, mechanical and chemical characteristics, known as metal composites. Metal composites are combined form of material in which an incessant metallic phase is combined with a discontinuous reinforcement phase. Metal composites have various types of benefits over other types of composites along with that they have high modulus, high strength, low sensitivity to changes in temperature or thermal shock, high toughness, high surface durability, low sensitivity to surface flow, high electrical conductivity, stiffness, wear resistance, strength to wear ratio etc. [5]. Metal composites can easily be a potential candidate to replace conventional materials with these properties. There are number of ways for fabrication of metal composites as categorized according to the temperature of metallic matrix during processing. Accordingly, they can be classified into five categories such as: liquid-phase processes, solid-liquid processes, deposition techniques, in suit process, and two-phase (solid-liquid) processes [5]. Stir casting is a liquid-phase process for fabrication of metal composites among aforementioned categories. In stir casting process, a dispersed phase material is mixed with a molten matrix metal by means of mechanical stirring. It is noted that stir casting is one of the simplest and most economical methods for fabrication of composites material except some technical difficulties. It is worthy to mention that making of composites by stir casting method, fabrication cost can be reduced to about one-third to half and for high volume production; cost can be reduced to about one-tenth compared with other conventional method [6]. This paper shows production of Al-Cu metal composites by stir casting process and development of mechanical properties of metal composites compared with Al and Cu metal respectively.

2. MATERIALS & METHODOLOGY

Matrix and Reinforcement selection is one of most important parts for making metal composites of improved desired characteristics. Al-Cu metal is selected for the matrix phase in this study. Innovative 20-wt% Cu and 30-wt% Cu is used separately as the reinforcement with Aluminum in this study because Al and Cu make a good combination as dispersed phase in final product. A manual setup was made in a renowned workshop located in Chattogram city for stir casting process. Before melting, initially weighted Al bar is placed in the furnace in a pot type crucible. The furnace temperature is increased to around 700℃ and it is kept at this condition about one and a half hour, until Al bar melts completely. Afterward, copper pieces are added to the molten Al at around 820℃ and almost, same temperature is maintained while copper completely melts. 20-wt%-Cu powder which is used as reinforcement is preheated separately around 200℃ about 30 minutes and the 20-wt%-Cu is poured into molten Al-Cu alloy at 750℃ slowly. Stirring operation is done by a stirring rod for uniform distribution of 20-wt%-Cu particles into molten Al-Cu alloy and continued about one minute. Temperature of Al-Cu mixture is maintained around 750℃ for about 30 minutes after stirring. Dies are made of as desired shapes where Al-Cu composites are poured and kept aside before they are completely solidified. Production of 30-wt%-Cu composites is same as 20-wt%-Cu composites; the only difference is that pre-weighted 30% Cu powder is added instead of 20% Cu. Samples are made for hardness, tensile and impact test with required shapes and sizes with 20-wt%-Cu and 30-wt%-Cu separately mixing with Al-Cu alloy. A total of 10 metal composites bar are produced for testing purpose in order to comparing development of mechanical properties that is the main objective of this study.

3. SAMPLE PREPARATION FOR TESTING OF MECHANICAL PROPERTIES

Sample of Al-20-wt%-Cu and Al-30-wt%-Cu composite bar are shaped into different size for performing some experimental investigation. It is noted that samples are shaped into different size as they cope with experimental facilities available in Department of Mechanical Engineering laboratory CUET, Chattogram-4349, Bangladesh. Some mechanical properties of those samples are tested as shown below.

3.1 Density Test

For density measuring purpose, 40 mm×40 mm × 5mm size samples both for Al-20-wt%-Cu and Al-30-wt%-Cu is weighted in a digital weight testing machine. A total of four test data are taken and average values are reported.

3.2 Tensile Test

Samples are tested in universal testing machine in order to perform tensile test. Samples are made with specific size shown in Fig. 1. Four samples are tested and acquired data are reported.

Fig. 1: Samples for tensile test

3.3 Hardness Test

40 mm × 40 mm× 5 mm size specimens as shown in Fig. 2, are made for hardness test. Hardness tests are carried out in a standard Brinell hardness testing machine with an equivalent constant load of 9.81 KN (1000kg). Ball diameter of the Brinell hardness testing machine is 10 mm. After testing, indention diameters are listed and used for hardness comparison between Al-20-wt%-Cu and Al-30-wt%-Cu composites. Four data is taken from the Brinell hardness testing machine.

Fig. 2: Samples for hardness test.

3.4 Impact Testing

Impact testing is carried out to determine the behavior of samples at higher deformation speed. Samples are made of the specific size as shown in Fig. 3.

Fig. 3: Samples for impact test.

4. RESULTS AND DISCUSSIONS

Figure 4 shows density variation of Al-20-wt%-Cu and Al-30-wt%-Cu metal composites. It is noted that Al-20-wt%-Cu composites show 4.84% lower density than Al-30-wt%-Cu composites. It is worthy to mention that Al-30-wt%-Cu shows greater density because of higher level of mixture of reinforcement particles. It is concluded that composites with higher reinforcement mixture always show greater density variations.

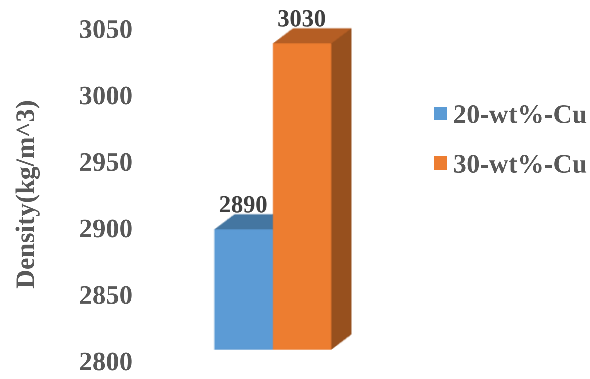

Fig. 4: Density variation of Al-20-wt%-Cu and Al-30-wt%-Cu metal composites.

Figure 5 shows stress vs. strain graph for Al-20-wt%-Cu Composites. It is noticeable that yield stress is obtained as 70.74MPa for Al-20-wt%-Cu composites whereas 91.96 MPa for Al-30-wt%-Cu composites as shown in Fig. 6. It is worthy to mention that yield strength is increased with more addition of Cu with Al.

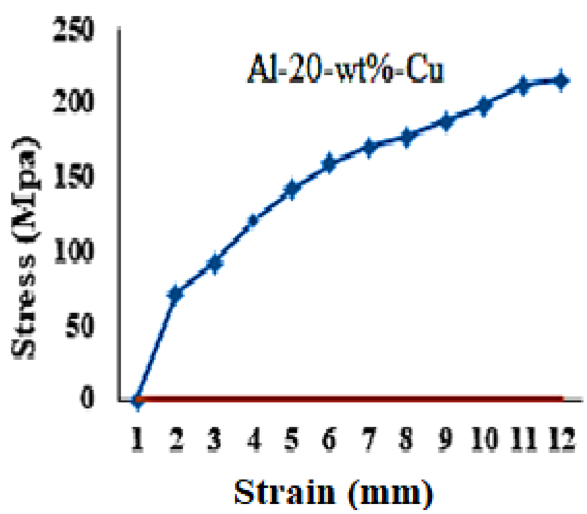

Fig. 5: Schematic representation of stress vs. strain graph for Al-20-wt%-Cu Composites bar

In addition, Fig. 7 shows the comparison of mechanical properties between the composites with different copper content. Al-20-wt%-Cu composite show 10.74% lower strength and 17.8% lower strain than Al-30-wt%-Cu composite.

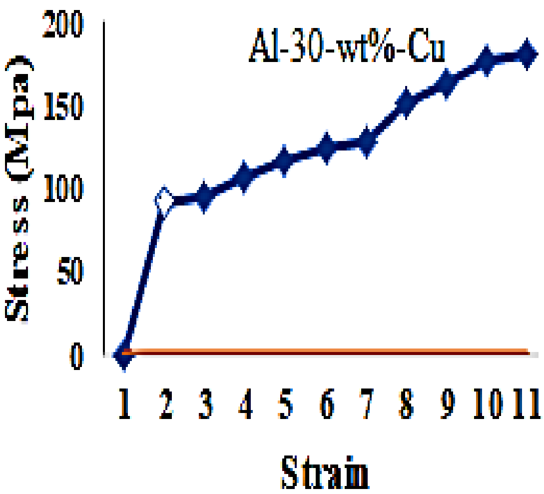

Fig. 6: Schematic representation of stress vs. strain curve for Al-30-wt%-Cu Composites bar.

It is due to the fact that, with enhancement of higher reinforcement particles, strength is gradually increased for Al-30-wt%-Cu composites with the cost of strain. In addition, increasing copper content for Al-30-wt%-Cu composites formation of the composites increases, resulting which guides to the formation of continuous layer between metal matrix and the copper particles. Hence, it can be easily concluded that strength of metal composites is combination of alloy formation, reinforcement and good interface. Wu et al. [7] reported that reinforcement enhances strengthening but formability of the matrix reduces gradually; resulting in a lower level of strain. Poor strain values for both Al-20-wt%-Cu and Al-30-wt%-Cu composites may be because of the reason that reinforcement content is higher. As though, Al-30-wt%-Cu composite's strain is greater than Al-20-wt%-Cu composite, both values are poor because of the fact that both are metals. Fig. 8 shows a greater hardness property for Al-30-wt%-Cu than Al-20-wt%-Cu composites. It is noted that 4.6% higher hardness properties for Al-30-wt%-Cu composites compared with Al-20-wt%-Cu. It is mentioned that presence of higher copper content causes increasing hardness property in Al-30-wt%-Cu composite. Unlike the mechanical behavior in tensile properties, Fig. 9 shows better hardness properties as a whole. Fig. 10 shows how tensile strength, strain and hardness contributing to composites as a part of the whole. In addition, Fig. 10 shows how tensile strength, strain and hardness are differed from each other.

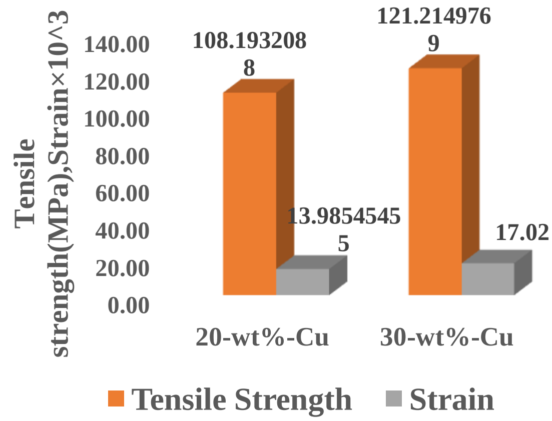

Fig. 7: Comparison of tensile strength, strain of Al-20-wt%-Cu and Al-30-wt%-Cu composite bar.

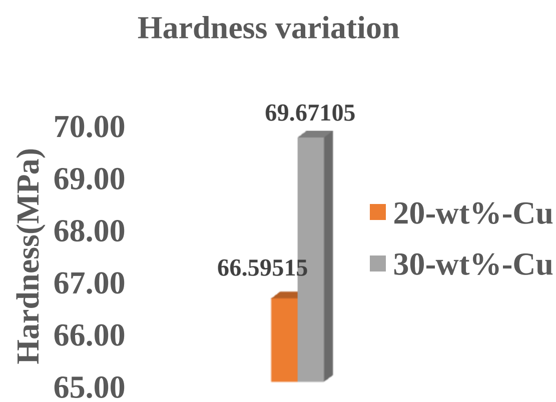

Fig. 8: Comparison of hardness between Al-20-wt%-Cu and Al-30-wt%-Cu composite bar.

The Charpy impact testing machine has free fall angle α=67.5°, length of the hammer, R=0.345m, mass of the hammer, W=2.5 kg. After impact angle, β=62° for Al-20-wt%-Cu and β=60.5° for Al-30-wt%-Cu composites is measured. Absorbed energy for Al-20-wt%-Cu composites is obtained as E=0.73j whereas E=0.93j for Al-30-wt%-Cu composites which is 27.4% higher compared with Al-20-wt%-Cu composites. It is worthy to mention that better tensile strength, hardness properties of Al-30-wt%-Cu composite causes greater energy absorption capability. In addition, presence of enhanced copper content increases energy absorption capability in Al-30-wt%-Cu composites. Fig. 11 and Fig. 12 show the comparison in energy absorption.

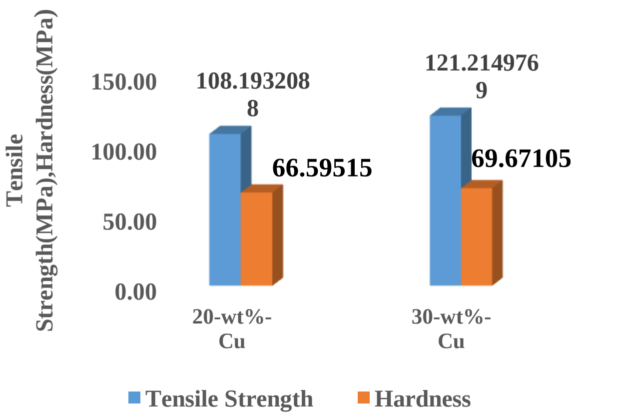

Fig. 9: Comparison of tensile strength and hardness between Al-20-wt%-Cu and Al-30-wt%-Cu composite.

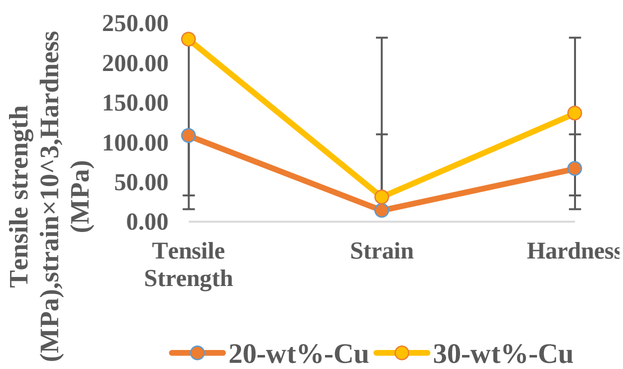

Fig. 10: Contribution and deviation of tensile strength, strain and hardness

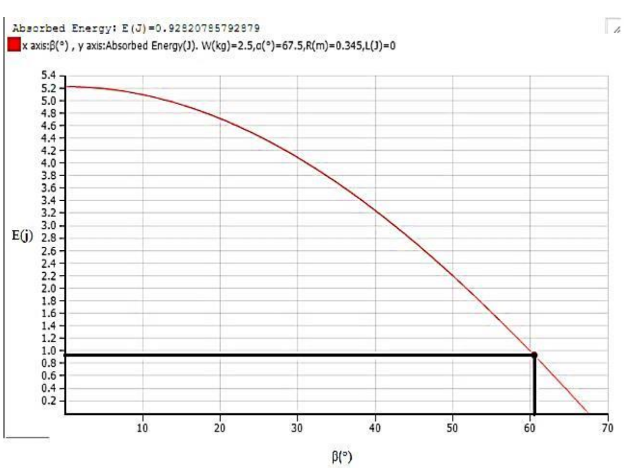

Fig. 11: Energy absorption by Al-30-wt%-Cu composite bar.

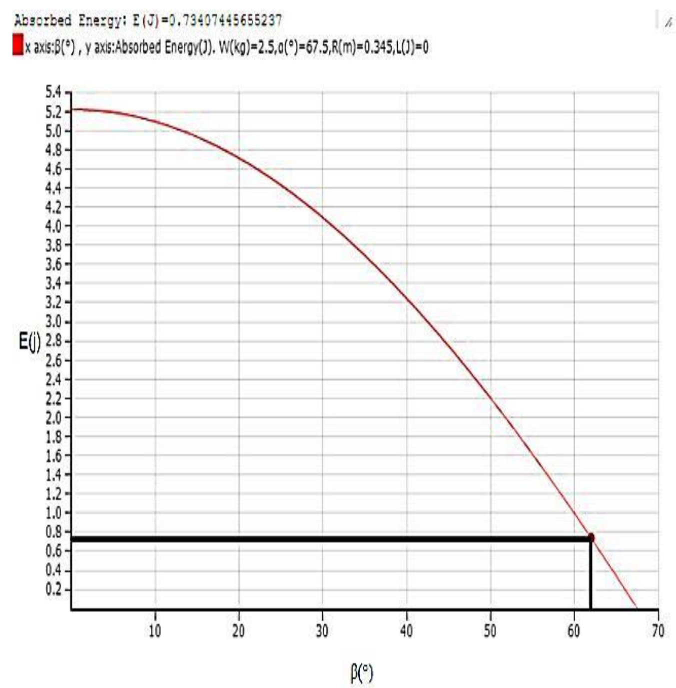

Fig. 12: Energy absorption by Al-30-wt%-Cu composite bar.

5. CONCLUSIONS

This paper represents production of Al-Cu metal composites bar using stir casting method. Stir casting technology is cost economic and easy process for mass production of metal composites. Density of metal composites increases for higher concentration of reinforcement. In addition, tensile strength, yield strength, hardness, energy absorption capability simultaneously increases with increasing reinforcement element. Along with that higher reinforcement composites show better strain behaviour than lower reinforcement composite. This type of metal composite is being used in various fields of mechanical engineering as well as electrical engineering for its high strength and stiffness property. Metal composites can be used as smart materials for automotive section, nano-technology, micro-system engineering, controlling and automation for its mechanical properties such as light weight, high strength, wear resistance, high damping capacity and high energy absorption capability.

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