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Fabrication and Characterization of Direct Recycled Al-Cu-Cullet Metal Composite

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Abstract: A composite is any material which consist of two or more components of different phases and with different and superior than those of any of the original materials. In the present work, Aluminium (Al) composites were fabricated from direct recycle of Aluminium scrap from door and window frames, used copper (Cu) wires and cullet powder (CP) using stir casting method. The processing parameter of these composites were only varied in their holding time during casting process. The composites and the matrix alloy were analysed for mechanical properties as well as for their chemical composition. The mechanical property, hardness, of the composites in addition to some physical properties such as density was found to have enhanced in the product. The fabricated composites were analysed using energy dispersive x-ray spectroscopy (EDX) and results have shown ascertained that the chemical composition of the product comprising all the components while X-ray Diffraction (XRD), results confirmed qualitatively, the chemical structures of the elemental components. The tests results indicated that the Al-Cu-CP metal matrix composites (MMCs) had shown higher degree of hardness along with density than the unreinforced matrix.

Keyword: Composites; Matrix; Microstructures; Reinforcement; Stir casting.

1. Introduction

A composite is any material which comprises components from two and above of dissimilar phases (continues and discontinues phases) and having most of the properties substantially different and superior than those of any of the parent materials [1]. The matrix is commonly made up of one of the following three material types, which are ceramics, metals and polymers. The matrix always forms the major part of the product. The secondary phase, the discontinuous or the dispersed phase is normally implanted in the matrix whereby it strengthens the composites as a whole and improves the mechanical behavior [2]. Reinforcement materials are mostly integrated into the matrix in form of particles, short fibers, continuous fibers or mono filaments [3]. The metal matrix composites (MMCs) are being used for lots of advanced structural and non-structural applications such as in automotive, aircraft, marine, electrical industries and the likes. The MMCs consist of reinforcing materials and metal matrices such as Al, Titanium (Ti) or steel (Fe) to obtain new materials with better mechanical and thermal properties such as higher strength and higher temperature resistance respectively [4]. MMCs are always under investigations for wide range of applications because of these enhanced properties [2]. In the recent times, Al based MMCs have gotten lot of acceptance in all fields of engineering and technology due to their superior strength, lower creep rate, better fatigue resistance, lower coefficients of thermal expansion as compared to monolithic materials [5]. Al is being utilized for different materials in various fields, for example in automotive industries, rail way and architectures, due to its low density, excellent anti-corrosive properties and specific strength [6]. Al plays key roles in the development of MMCs reinforced with a variety of additive materials such as Cu, cullet powder, Aluminium oxide (Al2O3) Titanium carbide (TiC) Boron carbide (B4C) and Silicon

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carbide (SiC) [7]. The overwhelming acceptance of particulate MMCs in engineering applications is being thwarted by procurement of highly expensive component materials. This challenge could be overcome by acquiring those expensive components through relative cheap means which includes recycling of the metallurgical wastes [8]. Recycling can be viewed as a scheme determined on reusing waste in order to maintain the natural resources and energies and at the same time, reducing the effect of pollutants on the environment. Recycling of waste materials also simplifies access to some raw material inventories, reduces cost of production of raw materials and also it alleviates the burden on the environment caused by waste production [9]. Previous investigations revealed metallurgical wastes such as: steel cooling refuse, etching refuse along with Al scrap metal processing waste and glass waste have been considered for the fabrication of MMCs [10]. Al is an environmental friendly material because of its ability to be recycled as well as its numerous applications which substantiate the high requirement of Al production. Al can be reclaimed, refined and recycled for further use at an energy cost that is only 5 per cent of what is required to produce the same quantity of the metal from its ore [11]. In the present work, a composite was fabricated through stir casting from Al scrap reinforced with Cu and CP which were all sourced from waste materials. The composite fabrication is cost effective because all its components since they were considered as waste materials. Properties such as density and hardness were investigated and the chemical composition of the composite was also discussed and presented.

2. Materials and Method

Preparations. The Al scrap was cut into smaller pieces for thorough melting process. The average size of the Al pieces was 31 mm length and 20 mm breadth. The copper wire was cut into smaller pieces with average length of the copper particles was 14 mm. Cullet was crushed to smaller pieces using mortar and pestle. The crushed particles were then milled in the ball mill machine to CP. The CP was then sieved to obtained particles in the range of 63μm – 90 μm. The sieving period was 10minutes with time interval of 5 minutes and amplitude of 0.3 mm.

Casting process. Liquid state technique of manufacturing MMCs, particularly stir casting, is an ensuring method for the fabrication, especially for AMCs, because of its uncomplicatedness and ease of manufacture [12]. Stir casting is a very simple technique and among the inexpensive ones available for manufacturing MMCs [13]. Owing to all these advantages, hence, stir casting technique was used in this research for the composites fabrication. The components for the composite fabrication were weight as; 38.00 g Al, 1.20 g Cu and 0.80 g CP, are equal to 95 %, 3 % and 2 % respectively. The matrix element, Al, was the first to be placed in the furnace and the temperature was raised to 800 °C from room temperature. The temperature was stabilised after 16 minutes. The Al scrap in the furnace has been melted after 22 minutes of heating. Cu chips were then added and stirred thoroughly. Then, the CP was also added and stirred. The mixture was allowed to continue being heated for 30 minutes before it was poured into the mould and allowed to cool.

Density. The fabricated composites were weight in air, in water and after soaking in a fluid. A digital density meter was used to determine the density of the solid composites, using Mettler Toledo's Density Kits, made in Switzerland (SNR 1129330986). The values for the density of the samples were obtained directly from the machine. The machine used distilled water as its fluid in determining the density of the samples. Each of the samples was first weighted on the machine as a dry sample, then it would be suspended in a fluid. The weights of the samples in the fluid were recorded. The values for density of the samples were only recorded when the weight of samples in fluid are stable and did not change for 15 minutes.

Hardness Test. The essence of MMC technology is to enhance the behaviour and properties of engineering materials for the desired applications. Among the properties worth improving for its vital role in MMC technology is hardness. Vickers hardness test was conducted for both the MMCs fabricated and also for the unreinforced matrix using load weight of 10 kgf throughout the test. The corresponding values of the tests were calculated by the machine and recorded as such. At least three indentations on each sample were made and then the average value of each was taken as the hardness number of that particular sample.

3. Results and Discussions

Density. A1l the samples are composites with the same and equal composition of: 95 % Al, 3% Cu and 2 % cullet. The mean density of the test samples was found to be 2.5269 g/cm³ which is very similar to that of the control sample, 2.5145 g/cm³. There is no much difference between the average densities of the fabricated composites and the unreinforced matrix, which is the control sample. As such, the reinforcement has not made any significant difference in the material.

Hardness. The hardness test was conducted using Vickers hardness tester. The results for the tests were very similar for the test MMCs and the unreinforced matrix which served as the control. The hardness values for 3 MMCs samples were 38.8 HV, 36.2 HV and 36.5 HV. The average hardness values for the fabricated MMCs was 37.2 HV while that of the unreinforced matrix was calculated as 29.3 HV which is lower than the mean value of the reinforced composites. Thus, the fabricated MMCs have an improved hardness property.

Chemical composition. Results from EDX analysis have qualitatively confirmed the presence of the elemental components (Al, Cu and Si) in the test composites, as revealed in Fig. 1. However, Cu and Si were so little in the product to the extent that they only appear very slightly on the graph. The graph also showed some amount of carbon, C. This was partly due to contamination of the product by the graphite crucible used in the melting process while the presence of oxygen was as a result of oxidation during the casting period. Below are the evidences for the presence of all component elements present in the composite.

XRD characterization. The X-ray diffraction (XRD) spectrum of the MMC sample is shown in **Fig. 2.** Only peaks corresponding to compounds comprising the component elements (Al, Cu and Si) were observed in the composite. The XRD pattern confirmed the presence of Al matrix and Cu and Si particulates in the composite.

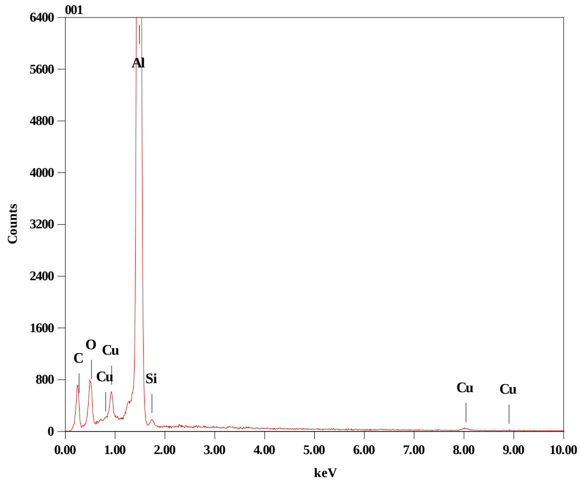

Fig. 1: Chemical representation of the fabricated composites via EDX analysis

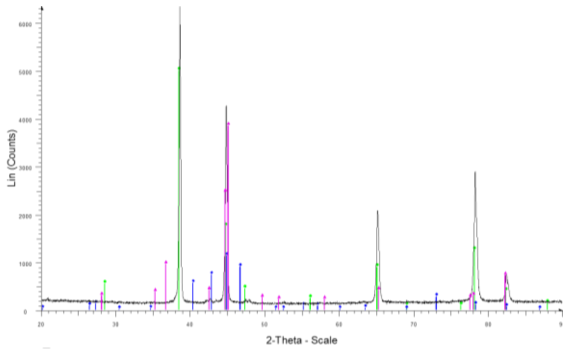

Fig. 2. XRD pattern for the composite.

4. Conclusion

The composites fabricated from recycled materials, Al scrap, Cu wire and CP via stir casting method which has proved to be a success. Thus, after the experimental investigations the following points were obtained:

1. The hardness of the fabricated MMCs has been enhanced as their values were higher than those of the unreinforced matrix.

2. The density of the MMC is similar with the unreinforced matrix, thus, the Cu and CP have no effect on the density of the product.

3. There is chemical evidence of the existence of all the components in the sample analysed.

4. The process is environmentally friendly as there was no any emission to the environment was observed neither any toxic by-product was obtained.

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