The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 8 || Pages || 69-73 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Characterization of the Mechanical Properties of Aluminium Alloys with SiC Dispersants.

C. E. Njoku*, H. Udomon, C. C. Ugwuegbu, J. U. Anaele, U. S. Ikele, U. U. Solomon, C. A. Omocho, J. I. Ekekwe

Metallurgy and Materials, School of Engineering, Federal University of Technology Owerri,Imo State, Nigeria.

ABSTRACT

The mechanical properties of annealed Al-SiC composite were investigated. Various percentages of SiC particles were embedded in Al matrix using stir casting to produce the metal-matrix composite. Annealing of the composites was carried out in a muffle furnace at 340^oC for 2 hours. The annealed samples were then subjected to various mechanical property tests. The results obtained showed that increasing the percent reinforcement increased the tensile strength and hardness but reduced the ductility.

KEYWORDS: *stir casting, metal-matrix composite, annealing, strength, hardness, ductility.*

Date of Submission: 02 Dec 2013 Date of Publication: 30 August 2014

I. INTRODUCTION:

A composite material is a combination of materials differing in composition or form on a macroscale for the purpose of obtaining specific characteristics and properties [1]. Naturally occurring materials can be regarded as composites e.g., bones, wood, etc. In principle, any two materials can be joined to give a composite and they might be mixed in much geometry [2].

Among the constituents of composites are fibres, particulates, sheets, laminae or layers, flakes, fillers and matrixes. The matrix is the body constituent, serving to enclose the composite and give it its bulk form; also it acts as a binder that contains the major structured elements and transfer load between them. The fibres, particulates, sheets, laminae, flakes, and fillers are the structural constituents or reinforcements (which are sometimes called additives). Particulate composites have an additive which is essentially one or two dimensional and macroscopic, and they differ from the fibre and flake types in that they are randomly distributed.

Metal-matrix composite (MMC) is one of the special classes of composites and are usually made with alloys of aluminium, magnesium or titanium and the reinforcement is typically a ceramic in the form of particulate, platelets, whiskers or fibres [1]. The type of reinforcement plays a very important role in the selection of an MMC because it determines virtually every aspect of the finished product including mechanical properties, cost and processing approach. In MMCs, the reinforcements usually used are in the form of particulates and whiskers. Alumina, boron carbide, silicon carbide, titanium carbide and tungsten carbide are the most common particulates. Siliconcarbide particulates are attractive reinforcements because they are used as commercial abrasives with wide availability and very low cost. Also they offer enhancement of strength, stiffness and wear resistance when used at volume percentages ranging from 5-40.

The main aim in particulate composite production is to achieve a homogeneous distribution of the ceramic reinforcements in the matrix. Embedding these particles (e.g. SiC) in the soft matrix (e.g. Al) increases the yield strength, the elastic modulus, the thermal resistance and the hardness of the final product (MMC), but it decreases its thermal expansion. Due to these advantageous attributes, the metal-matrix composite can be properly set up as engine components in the aircraft, automotive and recreational industries or as brake equipment [2].The method of manufacturing MMCs depends on whether or not the liquid metal is involved. Diffusion bonding is mostly used for the solid-state fabrications, while as, for the liquid-state fabrications, infiltration process, compocasting (or simply casting) method can be used [4].

The as-cast castings are relatively brittleand possess poor mechanical properties, so heat treatment of the castings is necessary to make them serviceable [5]. The main objective of the heat treatment (annealing) of aluminium alloy is to homogenize the non-uniform cast structure, relieve induced stresses which were set up during solidification; and also to produce specific properties.

The objective of this study is to determine the effect of various volume fractions of SiC particles on the mechanical properties of annealed aluminium-based composites.

II. EXPERIMENTAL

The silicon carbide with particle size of 600Grit used was obtained from Physical Metallurgy laboratory of the Department of Materials and Metallurgical Engineering FUTO, Owerri. The aluminium ingots used were obtained from Industrial Development Centre (IDC) Owerri, Imo State. The chemical constitutions of the aluminium were given in Table 1.

Table 1Chemical Composition (wt%) of Aluminium

Elem.	Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Ni	V	Pb
%	98.810	0.448	0.193	0.010	0.003	0.490	0.031	0.005	0.001	0.002	0.004	0.002

Four samples of the MMC coded A, B, C, D, with increasing percentages of SiC reinforcements of 0%, 5%, 15%, 25% respectively, were produced by conventional metal casting (with initial manual stirring to ensure proper homogenization of the melt) before mechanical stirring for 20 minutes in the furnace for further homogenization and uniform dispersion of the particulates.

The as-cast specimens were machined according to ASTM specifications and annealed at 340^{o}C for 2 hours, after which they were allowed to cool in air. Both tensile and hardness tests were carried out on the specimens.

III. RESULTS

The results of this study are reported in tables 2-4 and figures 1-3

Table 2 Load and Extension for the specimens

Load ($x10^2$)	Extension (mm)	Load ($x10^2$)	Extension (mm)	Load ($x10^2$)	Extension (mm)	Load ($x10^2$)	Extension (mm)
Specimen A		Specimen B		Specimen C		Specimen D	
6.000	1.000	2.000	1.000	2.000	1.500	1.500	0.500
6.873	1.170	8.000	3.000	4.000	2.500	2.000	0.500
9.000	34.816	12.000	5.000	6.000	3.000	10.000	5.000
16.000	109.664	16.000	7.500	10.000	4.000	14.000	0.375
17.672	115.712	20.000	9.000	12.000	6.500	18.000	8.000
		24.000	11.000	16.000	8.000	22.000	10.000
		24.000	12.000	20.000	9.500	25.000	11.000
		24.000	16.000	23.600	10.720	30.000	13.000
				26.000	12.500		
				26.000	14.000		

Table 3Stress and Strain for the specimens

Specimen A		Specimen B		Specimen C		Specimen D	
Stress (N/mm^2)	Strain ($x10^{-3}$)	Stress (N/mm^2)	Strain ($x10^{-3}$)	Stress (N/mm^2)	Strain ($x10^{-3}$)	Stress (N/mm^2)	Strain ($x10^{-3}$)
30.558	3.034	10.186	3.340	10.186	1.500	7.640	1.517
35.004	3.534	40.744	9.102	20.372	2.500	10.186	6.068
45.837	105.631	61.115	15.170	30.558	3.000	50.930	15.170
81.485	332.718	81.485	22.757	50.929	4.000	71.301	18.200
90.003	400.000	101.859	27.306	61.115	6.500	91.673	24.270
		122.231	33.374	81.487	8.000	112.045	30.340
		122.231	36.408	101.859	9.500	127.324	33.400
		122.231	48.544	122.231	10.720	152.788	39.470
				132.417	37.930		

Table 4: Experimental Results of Mechanical properties of the specimens

Specimens	Reinforcements (%)	Ultimate Tensile Strength (N/mm^2)	Ductility (%El)	Hardness (HRC)
A	0	90.003	40.00	25
B	5	122.231	4.854	28
C	15	132.417	4.247	39
D	25	152.788	3.947	48

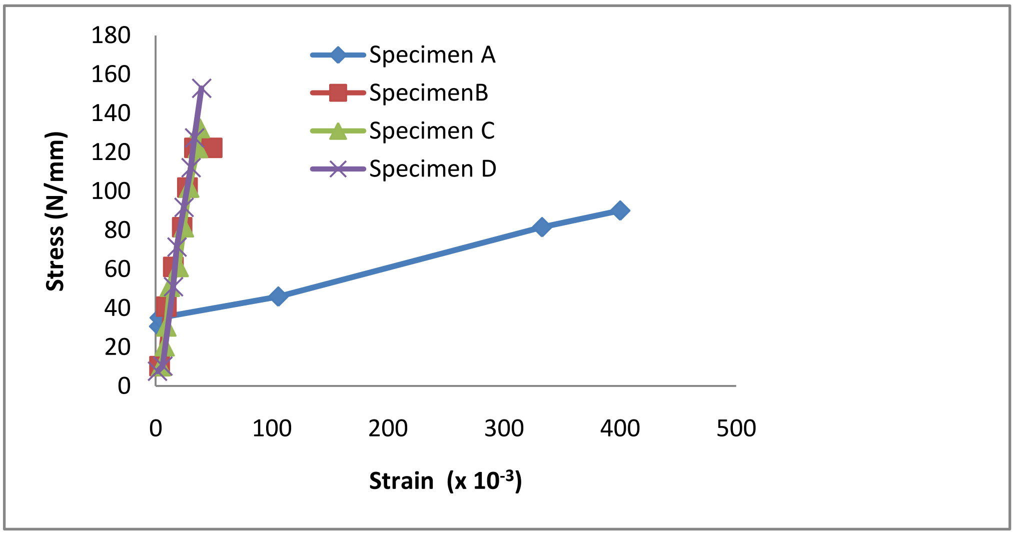

Fig.1 Stress against strain for various specimens

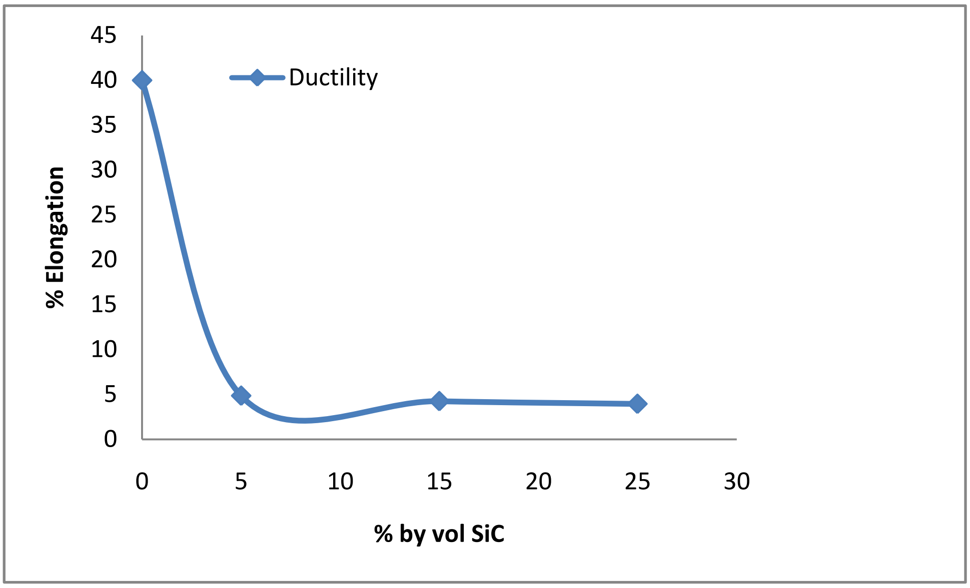

Fig.2 Effect of reinforcement on ductility

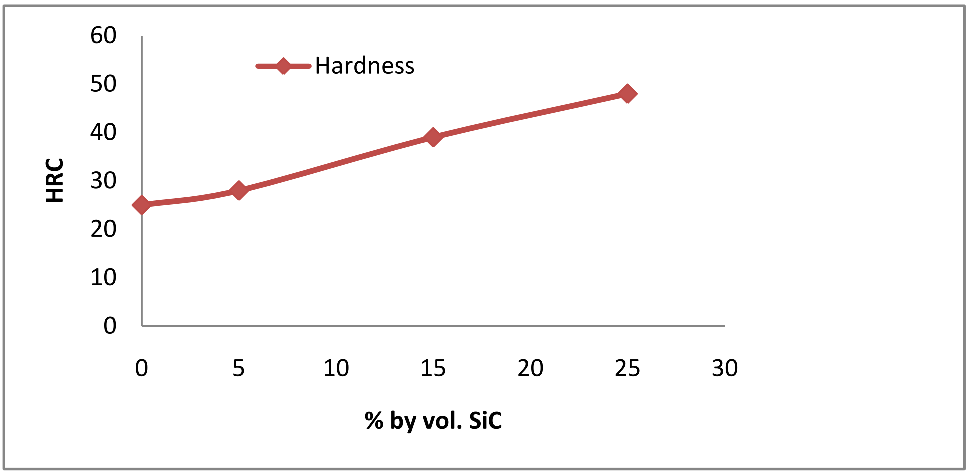

Fig.3 Effect of reinforcement on hardness

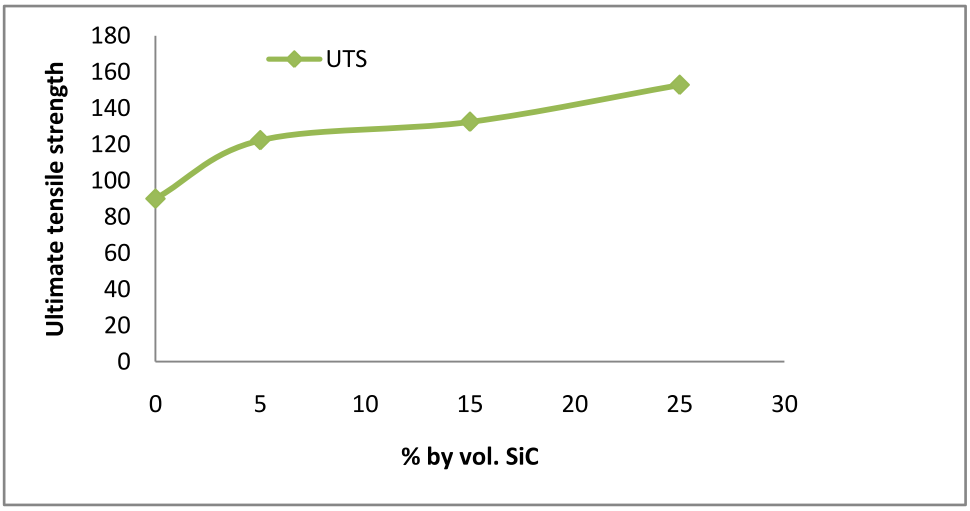

Fig.4 Effect of reinforcement on tensile strength

IV. DISCUSSION

From Figure 4, the ultimate tensile strengths of the specimens A,B,C, and D with the following reinforcements 0%, 5%, 15%, 25% has the corresponding values; 90.0025, 122.2308, 132.4170, and 152.7880 N/mm^2 respectively. It implied that there was an increase in the ultimate tensile strength as the reinforcement was increased. This is because the tensile strength of the reinforcement being greater than that of the matrix caused the reinforcement to carry more load (see Table 2), thus increasing the ultimate tensile strength of the composite. Also the stiffness was increased as the reinforcement increased.Figure 3, illustrates the effect of reinforcement as compared to the hardness of the material. The hardness increased as the reinforcement increased because the SiC particles acted as obstacles to the movement of dislocation when stress is applied.

There was a drastic drop in ductility as the reinforcement increased, as shown in Figure 2.The reinforcement resulted in the composite being more brittle, implying that the amount of deformation the material can withstand without breaking is reduced.

V. CONCLUSION

From the foregoing discussions, stir casting is potentially the cheapest method of production of metal-matrix composites (MMCs), especially in situations where only moderate improvements over the non-reinforced alloy are required.Again, MMCs in aluminium alloys containing 5-25% of SiC particulates are seen offer substantial improvements in the mechanical properties of fabricates.

ACKNOWLEDGEMENT

The authors are grateful to the different bodies that provided the samples and also Federal University of Technology, Owerri that provided the facilities.

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