Evaluation of Hardness Strength of Aluminium Alloy (AA6061) Reinforced With Silicon Carbide

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Abstract - In the experimentation, AMC specimens were cast by Stir cast method, for different size and percentage of reinforcing material. Standard size Hardness test specimens were prepared and the properties evaluated. The composite materials offers a solution to the challenging problem of, developing materials with high performance capability. Due to the lightness of aluminium, its alloys find a wide range of applications. Silicon carbide (SiC) is known for its hardness and high degree of chemical inertness. In this experimentation, An Aluminium metal matrix composite (AMC) consisting of aluminium alloy (AA6061), reinforced with SiC is considered for evaluation.
Keywords : *High performance, Chemical inertness, AMC, Hardness.*

I. INTRODUCTION

This experimentation aims at materializing a MMC by reinforcing AA6061 alloy with silicon carbide and studying its Hardness properties. The reinforcement is done using stir casting technique[1,2]. With the increasing demands for superior light weight materials, in areas such as aircrafts, space shuttles, deep sea submarines, hypersonic space planes etc, there is a need to develop materials with high performance capabilities. The composites approach offers a systems solution to this challenging problem. The recent advancement in the field of material sciences led to the development of species of materials known as composites. Composites are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components[3,4]. The composites created with metal or a metal alloy as the base, are known as metal matrix composites (MMCs). The aluminium alloy (AA6061) has proved its usefulness in various fields ranging from aircraft construction to common household equipments such as ladders and window frames. Silicon carbide (SiC) is a potential material for structural applications at high temperatures. Also, it has good hardness and high degree of chemical inertness.

1.1 Literature review

AA 6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935[1]. Common applications of AA 6061 are Window frames, Engine cylinder blocks, Pressure vessels, Aircraft fuselage, Aircraft wings, Household wiring, Yacht and boat construction, Automotive wheel spacer assemblies, Aluminium wrapping foils and cans for food and beverages and so on. Composite materials are complex materials whose components differ strongly from each other in the properties. Composite materials can be defined as a macroscopic combination of two or more materials, having a recognizable interface between them. The first focused efforts to develop Metal Matrix Composites originated in the 1950s and early 1960s. The principal motivation was to dramatically extend the structural efficiency of the metallic materials while retaining their advantages. Metal matrix composites typically use abrasive grade ceramic grit. Silicon carbide provides the best strength and stiffness for aluminium alloy matrices, but is slightly more expensive than aluminium oxide. The intrinsic advantage of Metal Matrix Composites developed by reinforcement of the base alloy is the improvement in mechanical properties, strength and stiffness of the so developed composite material. Y.Sahin[7] has investigated aluminium alloy containing various particle sizes of 10% and 20% Silicon Carbide particles prepared by molten metal matrix and squeeze casting method under argon gas. Microscopic examination, hardness, density and porosity measurement have been carried out. The uniform dispersion of particles in the matrix alloy has been observed. The density decreases with increase in particle sizes, but porosity increases considerably with increase in particle size. The present study aims at conducting an experimental analysis of the variation in the hardness properties of AA6061 alloy, reinforced with 5%, 10% and 15% weights of 400, 320 and 200 mesh sizes of silicon carbide powders.

II. METHODOLOGY

distributing the reinforcement material [5,6]. After the addition of requisite SiC powder, stirring was done using motorized stirrer, as shown in Fig 2. Molten metal is poured in to the Die and the Die with solidified MMC is shown in Fig 3 and the casting shown in Fig 4. Standard dimensions [6] of hardness test specimen are shown in Fig 5 and the

III. EXPERIMENT

Procedure followed in stir casting and subsequent evaluation of hardness strength is as follows [7,8].

- The reinforcement particles were weighed as per the experiment's requirement, preheated to 600ºC in a separate electric furnace and added to AA6061 alloy melted to 750°C. The required quantity of alloy is weighed and melted in ceramic crucible and The furnace was totally closed by ceramic wool is used to avoid the escape of heat from the furnace.
- Degassing tablet (hexachloroethane) was added and the slag was removed carefully
- Matrix was kept in the furnace for around four hours and then the AA6061 alloy was ready for stir casting. The silica wool from the main furnace was removed and stirrer setup was brought into its position to stir the melt. 450 RPM was set as the stirrer speed using the speed regulator, the preheated reinforcement material was carefully added. Due to the stirring speed, vortex was formed and it allowed the reinforcement to mix properly throughout the melt. The melt was continuously stirred for 10 minutes and poured into the pre heated finger mould, coated with chalk powder.
- Specimens were cooled and separated from the casting and machined as per the dimensions of standard hardness test specimen to be tested on hardness testing machine.
- Casting is obtained and specimens were prepared for varying weight percentages (5%, 10%, and 15%) and particle size (200 mesh, 320 mesh and 400 mesh) of SiC. A specimen was also cast and machined, corresponding to basic metal without reinforcement and is called "as cast" specimen.
- Each specimen is mounted on the "Hardness testing machines" and BHN, HRB and HV were recorded.

IV. RESULTS AND DISCUSSIONS.

The hardness test was done, in order to determine the Rockwell Hardness number (HRB), the Brinell Hardness Number (BHN) and the Vickers Hardness

An electric furnace with stirring mechanism, shown in Fig1, is used for melting the base metal and uniformly machined specimen in Fig 6. An "as cast" specimen was also obtained for strength comparison. Rockwell hardness, Brinell hardness and Vickers hardness, for as cast and MMC with different % of reinforcing material and different particle size were determined.

number (HV) for each of the specimen created for the different sizes and weight percentages of the reinforcement. Fig 7 shows the tested Hardness specimen and Fig 8 the corresponding indentations.

4.1 Rockwell Hardness Test

The Rockwell hardness test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload [9].The chief advantage of Rockwell hardness is its ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques. The determination of the Rockwell hardness of a material involves the application of a minor load followed by a major load. Release the major load and the Dial indicator gives the Rockwell hardness number (HRB). Results are shown in table-1 and the corresponding graph in Fig 9. As expected, the hardness of the material is seen to improve with the increasing reinforcement weight percentages. Particle size has not much effect on hardness and 320 mesh size gives slightly better results.

4.2 Brinell Hardness Test

The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece[10]. The value of the Brinell Hardness Number (BHN) is obtained by performing calculations using the following formula:

$$BHN = \frac{2P}{(\pi D(D - \sqrt{(D^2 - d^2)})}$$

Where P = Load applied, D = Diameter of indenter, d = Diameter of indentation

The load used was 60kgf for a duration of 30 seconds. The readings and calculations are shown in table 1.These readings have been substantiated by the following graph shown in Fig 10.

For 400 mesh particle size, the BHN values are seen to increase with the increasing reinforcement amounts. This indicates an increase in hardness with the increase in weight percentages.

For 320 mesh particle size, the BHN values remain almost same for the first two reinforcement amounts and an increase is shown in the third reinforcement amount.

For 200 mesh particle size, the value show an increasing trend with increase in the weight percentages of the reinforcement. The BHN value for 5% reinforcement drops below that of as cast which supports the results obtained in the Rockwell hardness tests.

4.3 Vickers Hardness Test

The Vickers test method is similar to the Brinell hardness testing method. The principle in this test is that a defined shaped indenter is pressed into the material. The indenting force is applied for a certain decided amount of time[11]. The resulting indentation diagonals are measured and recorded. The hardness number is calculated by dividing the force by the surface area of the indentation.

As mentioned previously, the principle of the Vickers test is similar to the Brinell test, but the Vickers test is performed with different forces and indenters. The square-base pyramidal diamond indenter is forced under a predetermined load ranging from 1 to 129kgf into the material to be tested. After the forces have attained static or equilibrium conditions, further penetration cease, the force remains applied for a specific time (10 to 15s for normal test times) and is then removed.

The resulting unrecovered indentation diagonals are measured and averaged to give the value in millimeter. These length measurements are used to calculate the Vickers hardness number (HV).

The test was performed according to ASTM E92-82 [28]. The Vickers Hardness Number (HV) is obtained by the following formula.

$$HV = \frac{2P\ sin(\frac{136}{2})}{d^2} = \frac{1.8544\ P}{d^2}$$

Where, P is the indentation load in kgf and d is the mean diagonal of indentation in mm. The Vickers indenter has included face angles 136˚.The load applied was 5kgf for a duration of 10 seconds.

The data obtained from the above hardness test results have been given in Table1 and the corresponding graphs in Fig 11. Generally considered as the most accurate among the three tests performed, this test also supports results obtained from the previous two tests, thereby confirming the increase in hardness of the composite. The graph shows that the hardness value is increasing with the increase in reinforcement amount which is the same as that obtained from the previous two tests. The graph for 200 mesh size shows that the 5% reinforcement has reduced hardness value which was the same obtained in the previous two tests. This may be attributed to non-uniform distribution of the reinforcement in the metal matrix during stirring and casting.

V. CONCLUSIONS

The hardness of the materials also showed a steady increase with the increase in the weight percentages of reinforcements for a certain particle size of the reinforcement. The Rockwell hardness test results suggest that the maximum hardness was obtained by the reinforcement of the metal alloy matrix with 400 mesh size silicon carbide in a weight percentage of 15%.The Brinell hardness test results infer that the maximum hardness was obtained by the combination of the metal alloy matrix with 15% weight percentage of 400 mesh size silicon carbide. The Vickers hardness test result, the most accurate among the three hardness tests, also implies the same results. The maximum Vickers hardness number was obtained for the specimen which was made of the metal alloy matrix reinforced with 15% weight percentage of 400 mesh size silicon carbide which indicated maximum hardness for the same.

VI. ACKNOWLEDGEMENT

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Fig 1 Stir casting set up


Fig 2 Stirring by motorized stirrer


Fig 3 Die with solidified MMC


Fig 4 Cast specimen of MMC

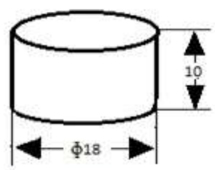

Fig 5 Specifications of hardness specimen


Fig 6 Machined hardness specimen


Fig 7. Tested hardness specimen


Fig.8 Indentation of Rockwell, Brinell and Vickers hardness test respectively

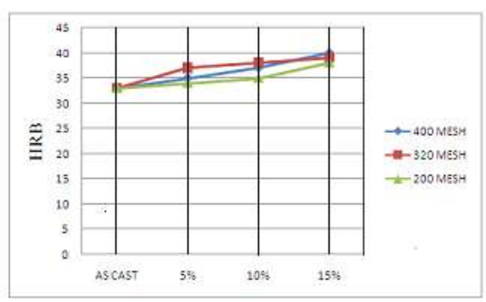

Fig 9 Rockwell hardness number v/s % SiC

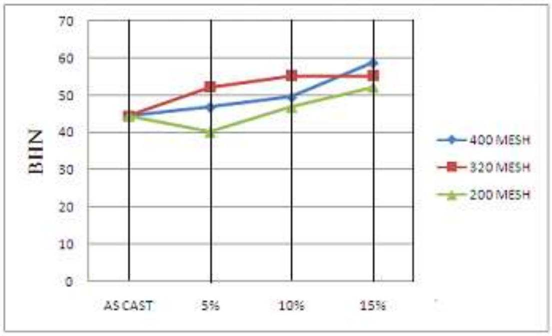

Fig 10 Brinell hardness number v/s % SiC

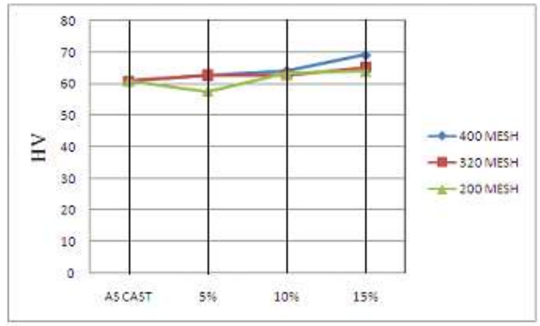

Fig 11 Vickers hardness number v/s % SiC

Table 1 Hardness test results

MATERIAL	% WEIGHT	HRB	BRINELL HARDNESS TEST		VICKERS HARDNESS TEST	
			AVERAGE (3 TRIALS) DIA OF INDENTATION mm	BHN	AVERAGE (3 TRIALS) DIA OF INDENTATION mm	HV
AS CAST	-----	33	1.3	44.426	0.390	60.96
400 MESH	5	35	1.267	46.810	0.385	62.662
	10	37	1.233	49.471	0.380	64.211
	15	40	1.133	58.7	0.366	69.217
320 MESH	5	37	1.2	52.273	0.384	62.771
	10	38	1.2	55.273	0.380	62.880
	15	39	1.167	55.317	0.377	65.236
200 MESH	5	34	1.366	40.12	0,401	57.56
	10	35	1.266	46.83	0.382	63.208
	15	38	1.2	52.273	0.380	64.011