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EFFECT OF REINFORCEMENTS ON THE HARDNESS OF A356 HYBRID COMPOSITE-A REVIEW

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Abstract - *Aluminium metal matrix composites and methods of fabrication of hybrid composites are increasing in usage for commercial and industrial applications both under static and dynamic conditions in recent years. Conventional materials are easy to manufacture and machine, whereas hybrid materials require unconventional machining processes that are hard to machine by traditional methods. Aeronautical, military, medical, optoelectronics, and many other industries are replacing conventional aluminium material and employing hybrid aluminium. The blend of constituents determines the properties of hybrid materials. In this study, an attempt is made to review the influence of various reinforcements on the hardness of A356 hybrid composite. Further, the other parameters affecting the hardness of hybrid composite is discussed.*

Key Words: *Aluminium metal matrix composites, hybrid materials, A356 hybrid composite, hardness, Porosity.*

1. INTRODUCTION

The mission for better materials has been proceeded by explorers from the past few decades. The advancement of composites led to different favorable circumstances, for example, lightness of the material, better mechanical properties and so on.

However, the limitation of composites, for example, the high expense of raw materials, difficulty in fabrication, low matrix toughness and so forth still endures. This led to the advancement of composites from primitive to its advanced stage. Hybrid metal matrix composites serve the purpose of combining the advantages of reinforcements based upon the necessity and need of application [1]. Hybrid MMC s consists of two or more reinforcement materials in the base matrix and these yields better stiffness, strength, high strength to weight ratio and other mechanical properties. Hybrid composites have the potential to substitute single reinforced composites due to improved properties. Hybrid aluminum matric composites have been used for the design of a wide range of components for advanced applications. Structural applications in aerospace and automobile industries focus on aluminum alloys due to their excellent properties such as corrosion resistance, lightweight and recyclability [2]. Among the other materials, aluminum A356 alloy is most abundant with excellent specific strength, high thermal conductivity, and reflectivity [3]. A356 belongs to a group of hypo eutectic Al-Si alloy and has a wide field of application in the automotive and avionics industries [4]. It has great elongation, higher strength, and considerably higher ductility than 356.0. Impurities are less and hence having wide application in airframe casting, machine parts, and truck chassis [5].

Hardness is a proportion of the resistance to confined plastic distortion prompted by either mechanical indentation or abrasion. Metals are harder when compared to plastics. Macroscopic hardness is for the most part described by strong intermolecular bonds, yet the conduct of strong materials under force is complex.

The key to understanding the mechanism behind hardness is understanding the metallic microstructure, or the structure and arrangement of the atoms at the atomic level. Most important metallic properties critical to the manufacturing of today's goods are determined by the microstructure of a material [6].

In this paper, an attempt is made to explore the potential of hybrid reinforcements on the hardness of A356 alloy.

2. HARDNESS TEST METHODS

Material Hardness Testing determines a material's strength by estimating its resistance to indentation. Hardness test outcomes can be very helpful when choosing material since the revealed hardness test shows how effectively the material can be machined and how well it will wear. Hardness testing of metals is routinely performed to evaluate the estimation of treatments and coatings. The various test methods are as follows:

(a)The Rockwell Hardness Test is performed on castings, forgings and other large metal samples and tests as it delivers large visible indentation. The indenter can be chosen based on the characteristics of the test material. A minor load is connected to either a diamond cone or a steel ball indenter situated on the test material's surface to build up a zero-reference position. Next, a heavy load is connected for a specific time, leaving the minor load applied upon release. The Rockwell hardness number will be the difference in depth between the zero-reference position and the indent due to the major load.

(b)The Brinell Hardness Test can be applied to almost any metallic material and is the method most commonly used to test castings and forgings that have a grain structure too coarse for other types of metal hardness testing. During the Brinell Hardness Test, a carbide ball indenter is pressed into the sample with the accurately controlled force for a specific amount of time. When removed, the material has a round indent that is measured to calculate material hardness according to a formula as given below

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

(c)Vickers Hardness Test methods measure small samples or small regions in a sample. They are often used to measure surface or coating hardness on carburized or case-hardened parts, as well as surface conditions such as grinding burns or decarburization. This test can be performed on both the micro and macro hardness scales with a maximum test load of 50 kilograms. This type of hardness test is also performed by applying controlled force for a specific amount of time through an indenter, which in this case is a square-based diamond pyramid. The impression measurement and test load are used in the appropriate formula to calculate the Vickers hardness value. Like Brinell, this method has one scale that covers its entire hardness range.

3. LITERATURE SURVEY

[7] K. Ramu, A. Robin Richard et. Al, incorporated Rice husk ash and fly ash with different weight fractions (0 and 5 %) into aluminium A356 alloy and fabricated using stir casting technique. Vickers microhardness test and compression hardness test done on A356 aluminium alloy and A356/RHA-fly ash hybrid composite revealed that the addition of reinforcements particles improved the hardness of the hybrid, irrespective of the material and higher value of hardness was obtained when the materials aged as shown in table 1 i.e. Maximum hardness was obtained when the material aged. It was found that the compression value of the alloy was decreased due to the agglomeration and the presence of high silica. In conclusion, the A356/5%fly ash and 5% RHA hybrid composite offered higher hardness and compressive strength due to the uniform distribution of reinforcement particles in the melt and having good wettability.

Table -1: Microhardness and compressive values of investigated materials

Material	Microhardness (HV)	Compression strength (N/mm^2)
A356/5%RHA-5%Fly ash	77	462
A356/5%RHA-5%Fly ash(aged)	84	479

[8] Kulkarni & Menghani et. Al, investigated the influence of fly ash and Al2O3 on the mechanical behavior of A356 alloy. Reinforcement was varied from 0 to 12% by weight in steps of 4%. Stir casting was the method of fabrication followed. Microstructure studies reveal that the hybrid composite has a refined grain structure. It was found that the addition of hybrid reinforcements (fly ash and Al2O3) increased the density of the hybrid composite with an increase in reinforcement %. Porosity was found less in hybrid composite when compared to the nonreinforced and fly ash reinforced A356 alloy. Highwood HWMMT-X7 microhardness tester was used to measure the Vickers' hardness with a load of 500g for a time of 10s. The compression test of the cast samples of size 10mm diameter and 9mm length revealed that the compression strength increased with the increase in the percentage of the reinforcements.

Table -2: Microhardness results of the hybrid composite.

Material	Microhardness (HV)	Compressive strength (MPa)
A356	84.66	612.7389
A356-2% fly ash+2% Al2O3	88.33	689.9089
A356-4% fly ash +4% Al2O3	77	716.5605
A356-6% fly ash +6% Al2O3	90	723.5669

The addition of hybrid reinforcements in A356 alloy improves compression strength and microhardness and manufactured composites contain lesser porosity and suitable grain refinement.

[9] B.M viswanatha and M Prasanna et. Al, in their study, used A356 matrix material by varying the reinforcement of SiCp from 0 to 9% in steps of 3wt% and a fixed quantity of 3% graphite. The hybrid composite was fabricated by a two-step mixing (stir casting) method which helped in better particle distribution. Hardness test using Vickers' macro hardness testing system as per ASTM E-92 standard was done. The test results are as shown in Fig 1.

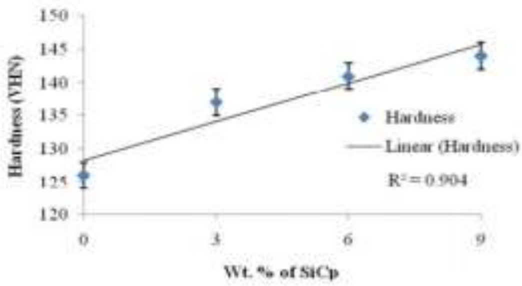

Fig 1 Variation of hardness with an increase in SiCp

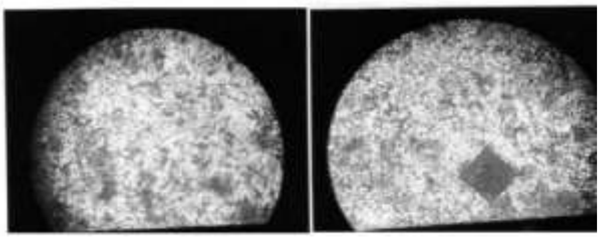

Fig 2 HMC (a)before indentation (b) after indentation

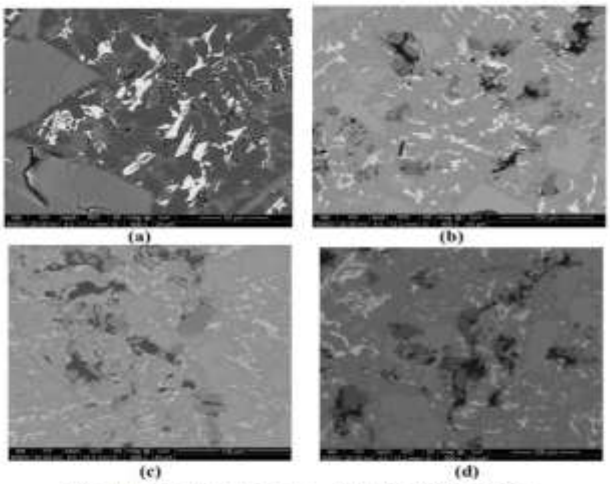

Fig. 3. SEM of (a) A356 alloy. (b) A356-3%Gr-3%SiC$_p$. (c) A356-3%Gr- 6%SiC$_p$. (d) A356-3%Gr-9%SiC$_p$.

The hardness of the specimen increases with increase in SiC and decrease in the hardness were observed with reinforcement of Gr. Inclusion of both SiC and Gr will not yield as good result when compared with SiC alone.

[10] Ajay Kumar, D. Vengatesh et. Al, followed a stir casting route in the fabrication of A356 aluminium matrix with graphite, boron carbide and fly ash as the hybrid reinforcements. Four sets of alloy samples as described in the table were prepared. Bulk hardness measurements were carried out using a standard Brinell hardness test. The load applied was 750kgs and indenture was a steel ball of 5mm diameter. It was concluded that the hardness of the composite material increased with an increase in the weight percentage of fly ash content in the composite. This is due to the strengthening of A356 alloy matrix by the fly ash particles.

Table -3: Hardness test results

Sample	Hardness (BHN)
A356+5%graphite+5%B4C	54.0
A356 +5% graphite+5%B4C+5% fly ash	58.5
A356+5% graphite+5%B4C+10% fly ash	50.5
A356+5% Graphite+5%B4C+15%Fly ash	60.9

[11] Shreekant Jadhav, Atul Aradhye et. Al, in their study, incorporated coconut shell ash particles and groundnut shell ash to A356 matrix. Rockwell hardness test was used to determine the hardness values of the hybrid reinforcements. Rockwell hardness test of A356 hybrid ash reinforced composite is as shown in the table [4]

Table -4: Hardness readings of all the synthesized composite materials.

Sample No	Composition	Trial 1	Trial 2	Trial 3	Average
		S1	S2	S3	$\frac{(S1+S2+S3)}{3}$
1	A356	55	58	55.4	56.13
2	A356+4%CSA+0% GSA	59	61	62.9	60.96
3	A356+3%CSA+1% GSA	64	65	65.2	64.73
4	A356+2%CSA+2% GSA	68	71	70	69.66
5	A356+1%CSA+3% GSA	81	79.6	82	80.86
6	A356+0%CSA+4% GSA	76.3	76	75.6	75.96

The hardness of the synthesized material increases with the addition of a hybrid composition of groundnut shell ash up to 3% and coconut shell ash up to 1% by weight as shown in fig. [4].

There is an increase in the hardness of composite materials with an increase in the percentage of groundnut shell ash and with a decrease in the percentage of coconut shell ash percentage.

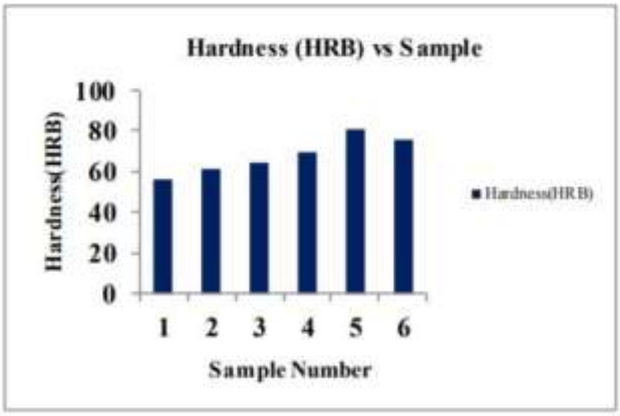

Fig -4 Variation in the hardness of A356 and hybrid ash reinforced composite

[12] Akshay Kumar & Sameer Mehta, investigated the influence of silicon carbide and alumina in cast A356 alloy matrix. Stir casting technique by varying weight percentage of SiC+ Al2O3 particles to the molten metal was followed.

Materials	BHN
A356	61.2
A356+1%SiC+1% Al2O3	71.6
A356+2%SiC+2% Al2O3	73.6
A356+3%SiC+3% Al2O3	83.7

Table 5: Brinell hardness testing result

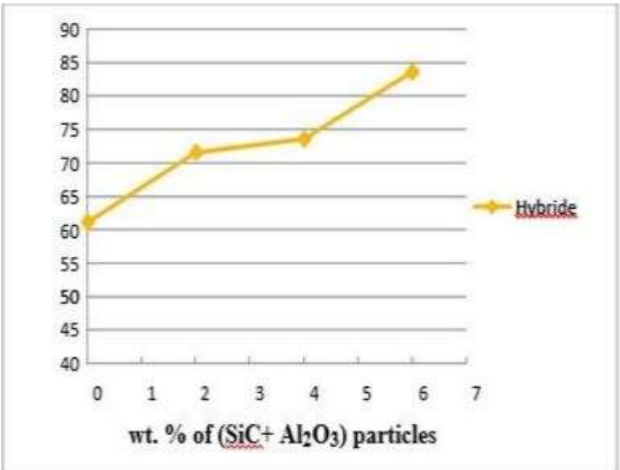

Fig -5 Variation of Brinell hardness of A356 alloy and its composites with wt. % variation of (SiC+ Al2O3)

The hardness of the composite increases with the addition of wt. % variation of SiC, Al2O3, and hybrid (SiC+ Al2O3) particles in the matrix. However, in the case of composites reinforced with 6 wt. % SiC and 4 wt. % Al2O3 there was a reduction in hardness due to porosity.

4. CONCLUSIONS

The review provides several conclusions regarding the influence of various reinforcements on the hardness of the A356 hybrid composite.

- The microstructures of the HAMCs fabricated by stir casting route are stable with uniform distribution of reinforcing particles.
- Higher hardness is obtained when the material is aged
- Agglomeration of silica during stir casting leads to a decrease in the hardness of the hybrid composite.
- The density of the composites increases with an increase in reinforcements.
- In addition to reinforcements such as graphite, coconut shell ash decreases the hardness of the composite.
- Fly ash is found to be the economical reinforcement which when added to the HMC provides higher hardness value.
- Hybrid reinforcements such as SiC &Al2O3 leads to the increase in porosity of the composite, thereby reducing its hardness.
- Hardness is inversely proportional to the porosity
- Vickers hardness test provides accurate results as compared to other hardness tests.

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