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Investigation of Mechanical Properties of A356/Al_2O_3/RHA by Stir Casting Method

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Abstract:
Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites possess significantly improved properties high specific strength, specific modulus and good wear resistance compared unreinforced alloy. Among MMC's aluminium composites are predominant in use due to their low weight and high strength. The Key Features of MMC's are specific strength and stiffness, excellent wear resistance, high thermal and electrical conductivity. The present investigations aim at the development of A356 aluminium alloy based Rice Husk Ash (RHA) and Al_2O_3 particulate reinforced hybrid metal matrix composites by stir casting route. Tensile strength and Hardness of the hybrid composites have been evaluated. Significant improvement in the properties was been observed with the addition of reinforcement. Further, properties of heat treated composites were enhanced when compared to as cast composites.

Keywords: *Hybrid composites, A356, Rice Husk Ash, Al_2O_3, Stir casting*

1. Introduction

Materials are the essential part of engineering industry. An engineer needs materials to give shape to his/her concept and design. In general, materials of high strength will have relatively high density. Materials for aerospace, automobile, marine and structural application should have low density but yet strong and hard. Conventional materials will not posses this unusual combination of properties. The mechanical and tribological properties of various materials can be improved by forming new class of materials known as composite. A composite material is defined as a structural material formed artificially by combining two or more materials having dissimilar characteristics. A composite is designed to display a combination of the best characteristics of each of the component materials. Metal Matrix Composites (MMCs) consists of either pure metal or an alloy as the matrix material, while the reinforcement generally a ceramic material. Aluminium is the most popular matrix for the metal matrix composites. The Al alloys are quite attractive due to their low density, capability to be strengthened by precipitation, good corrosion resistance, and high thermal and electrical conductivity. Aluminium Matrix Composites (AMCs) are the class of light weight, high performance materials [1]. The reinforcements in AMCs could be in the form of particulates. In the present investigation RHA and Al_2O_3 particulates are reinforced with A356 alloy matrix which is a high strength alloy mainly used in marine applications.

2. Material Selection

In the present work, the matrix material used for experiment is A356 alloy. The table 1 shows the matrix material chemical composition. The reinforcement materials used are Al_2O_3 and RHA. The average size of the Al_2O_3 particulates is of 100µm and average size of the RHA particulates is of 75µm. Table 2 shows the RHA chemical composition. To enhance the wettability between the matrix and the reinforcements during manufacturing of hybrid composites, wetting agent is required and magnesium was used as a wetting agent here.

Element	Si	Mg	Fe	Ti	Cu	Mn	Zn	Ni	Al
Weight%	6.6	0.45	0.10	0.10	0.05	0.055	0.005	0.005	Bal.

Table 1: A356 Chemical composition

Element	Silica	Graphite	Calcium Oxide	Magnesium Oxide	Potassium Oxide	Ferric Oxide
Wt %	90.23	4.77	1.58	0.53	0.39	0.21

Table 2: The RHA Chemical composition

3. Experimental Study

The rice husk is burned and ash obtained as result is washed thoroughly with water. Washing with water removes all dirt then the resultant material is dried for 24 hours at normal room temperature. The moisture content and organic matter should be removed by heating the cleaned rice husk up to 200°C for 60 min. Then carbonaceous material has been removed by heating it to 600°C for 12h [1]. The ash, thus collected, was used as reinforcement material in the preparation of hybrid composites.

A356 aluminium alloy was charged in the electric furnace and superheated to a temperature of 800°C. RHA and Al_2O_3 particulates were preheated to a temperature of 450°C for 1h to remove moisture and absorbed gases. Degasing of liquid metal was done by hexa-chloro-ethane tablets. Liquid metal temperature was maintained at 750°C with sufficient viscosity. The molten metal was stirred at a speed of 500rpm for 5 - 10min with the help of impeller to create sufficient vortex. The stir speed chosen is high enough to get a sufficient vortex for proper mixing of the ceramic particles with the liquid metal and at the same time it is low enough to avoid the gas and air entrapment in the liquid metal. The preheated particles were introduced laterally in to the vortex of the molten metal. One percent Magnesium was added to increase the wettability of the particles. Stirring speed was maintained at 500rpm for next 10min to ensure the proper mixing. After this stage, the molten mixture was drained in to the mould. To accomplish the uniform solidification of the molten metal the mould was preheated to 200°C for 30min. Thus, particle strengthened hybrid composite materials are formed by adopting the stir casting process and 1%, 2%, 3%, 4% and 5 % by equal weight proportions of RHA and Al_2O_3 are thus used.

3.1. Heat Treatment Procedure

The following steps are involved in heat treatment procedure:

i. Solutionizing
ii. Quenching
iii. stretching/straining
iv. Aging
  a) Single aging step at lower temperature
  b) Double aging step at higher temperature

3.1.1. Solutionizing and Quenching

Solution treatment for 6 Hrs, Soaking temperature of 540°C was adopted followed by oil(SAE30/40) quench at room temperature was carried out.

3.1.2. Stretching/Straining

This is a particular condition where, instantaneously after the heat treatment and quenching, before precipitation starts and the hybrid composite material become harder. One set of prepared samples is permanently deformed by 8 % to 10 % by applying external force (before 5Hrs).

3.1.3. Single Aging

After quenching single aging is at the temperature of 140°C for about 12 Hrs of period is carried out.

3.1.4. Double Aging

The Second step of aging procedure also done for the 12 Hrs of time and at a temperature of 190°C.

4. Results and Discussion

The samples were machined according to the ASTM specifications. The samples were exposed to the solution heat treatment. The resulting A356 hybrid composite material mechanical properties have been investigated.

4.1. Microstructure Analysis

Figures below- shows the microstructure of As- cast A356 composite. Precipitations were evident both along and across grains. Figure-2to 5 shows typical microstructure of the A356 alloy Hybrid Composites containing 4% RHA and 2 % Al2O3. Micrograph clearly reveals minimal micro porosities in the casting. No clustering of reinforcements was observed in the matrix, and the dispersion of RHA and Al2O3 particles is seen to be almost uniform. Figure 4 and 5 shows there is good bonding between matrix material and the reinforcements. Also it is clearly evidenced that the particulates are concentrated in the boundary region which is clearly visible and it indicates good bonding strength. The grain structure in Double aged with strain (Figure 5) is denser than other conditions; hence this gives better mechanical properties. It clearly indicates that no gap is observed between the particle and matrix and between the fiber and the matrix, and reinforcing materials are seen well bonded with the matrix.

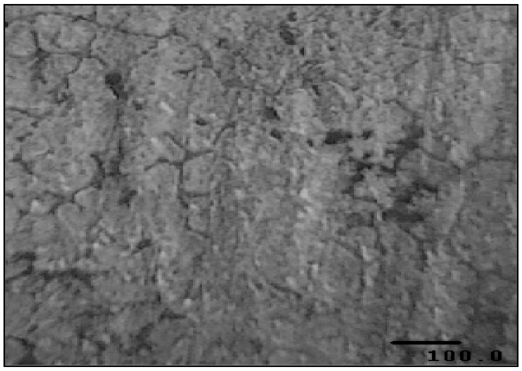

Figure 1: Microstructure of As-cast A356 composite (4% RHA and 4% Al2O3)

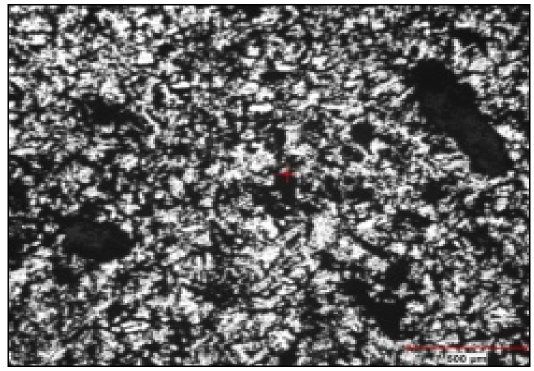

Figure 2: Microstructure of Single aged A356 composite (4%RHA and 4% Al2O3)

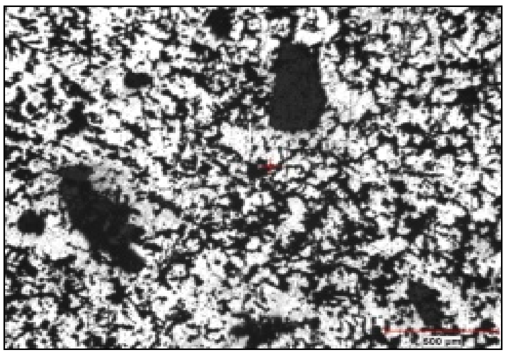

Figure 3: Microstructure of Double aged without strain A356 composite (4%RHA and 4% Al2O3)

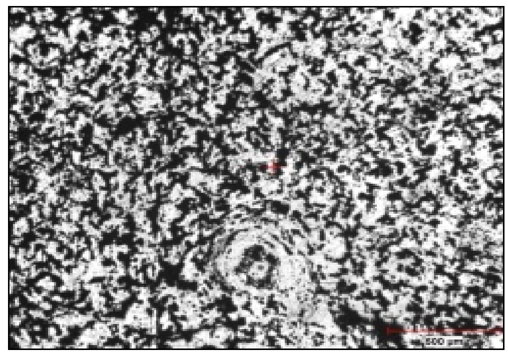

Figure 4: Microstructure of Double aged with strain A356 composite (4%RHA and 4% Al2O3)

4.2. Tensile test

Test specimens were prepared according to (ASTM 8) standards. The heat treated and aged specimen was loaded in Universal Testing Machine until the failure of the specimen occurs. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength was measured. Simultaneous readings of load and elongation are taken at uniform intervals of load. Uniaxial tensile test is conducted on the fabricated specimen to obtain information regarding the behaviour of a given material under gradually increasing stress strain conditions.

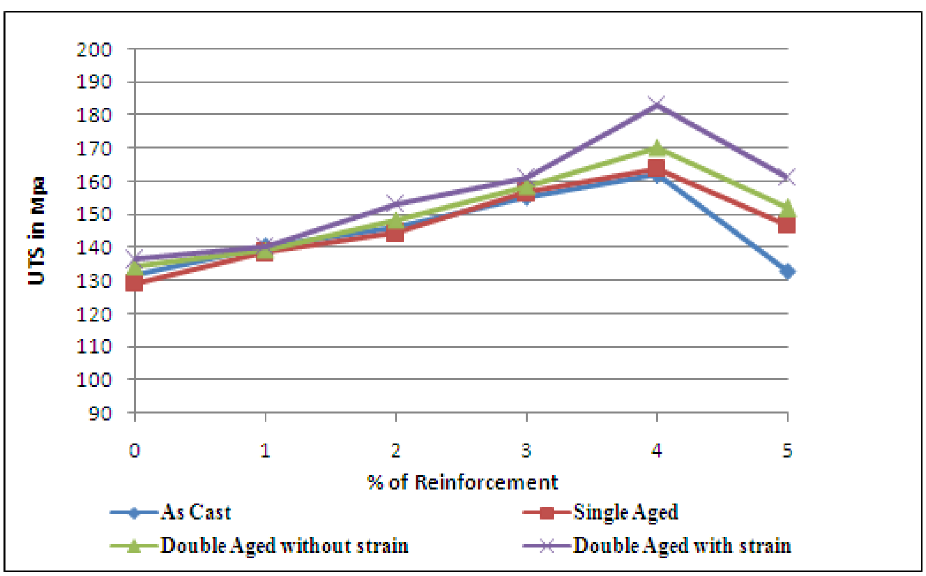

Figure 5: Evaluation of UTS for samples with various RHA and Al_2O_3 Compositions and Aging conditions

From the above Graph1, it is evident that the ultimate tensile strength (UTS) of the composite material is much higher than that of its parent metal. It is also shown that the UTS of the composite material increases with wt% of RHA and Al_2O_3 content. This is because of addition of reinforcement makes the ductile A356 alloy into more strong as silica content increases. And also the heat treatment and aging lead to the formation of intermetallic precipitates. When the specimens are subjected to strain the grains are more uniform and closer and this leads to stabilized material which is seen.

4.3. Hardness test

Hardness test was carried out using Brinell hardness tester. Test specimens of 20 mm thickness were machined from as-cast, single aged and double aged with strain and without strain of various compositions mentioned. Steel ball of 2.5 mm diameter and 60 Kgf load was used. The test was carried out at three different locations and the average value was taken as the hardness of the composite specimens. The results are shown as below.

From the below Figures it is evident that the hardness of the composite material is much higher than that of its parent metal. It is also shown that the hardness of the composite material increases with wt% of RHA and Al_2O_3content. This is because of addition of reinforcement makes the ductile A356 alloy into more brittle and hard as silica content increases. And also the heat treatment and aging lead to the formation of intermetallic precipitates. In double aging the amount of precipitate and the size of the precipitates are favorable. When the specimens are subjected to strain the grains are more uniform and closer and this leads to enhanced hardness which is seen in the above graphs.

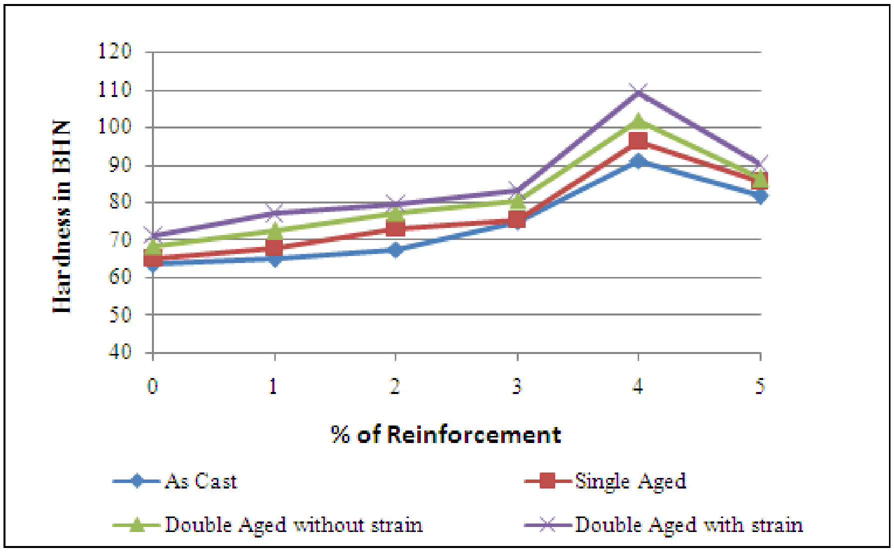

Figure 6: Evaluation of Hardness for samples with various RHA and Al_2O_3 Compositions and Aging conditions

5. Conclusion

The A356 based Hybrid composites were successfully produced by stir casting method with different weight percentage of RHA and Al_2O_3 particulate reinforcements with A356 as matrix material. Within purview of the study following conclusions have been drawn.

- By making use of stir casting method, RHA and Al_2O_3 particulates can be successfully introduced in the A356 matrix alloy material to fabricate hybrid composite materials.
- From the microstructure analysis, it is noticeable that reinforcement in the fabricated composite material is distributed inadequately even manner.
- The grain structure of the specimens which are treated with Double aging with strain have denser structure when compared to other samples, because of nucleation of precipitates and the reinforcement material is well bonded with the matrix material.
- When the percentage of RHA and Al_2O_3 increases in the composite, the UTS of that of composite also increases. UTS is significantly affected by the heat treatment procedure and aging procedure and results obtained for specimens which undergo double aging with strain has peak values.
- If the reinforcement content in the composite increases, then the hardness of the specimens also increases. Peak values have been shown up for Hardness of material and specimens after double aging with strain and they are noticeably affected by the Heat treatment and aging procedures.
- However, beyond four percentages of reinforcement, loss of reinforcements has started taking place due to floatation of the reinforcements in particular RHA. Further, it was difficult to stir and mix them in the molten metal uniformly due to increase in volume.
- The outcomes obtained clearly demonstrate that the double aged with strain specimens shown improved tensile strength and hardness in comparison with the single aging and as cast specimens.

6. Acknowledgement
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