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INVESTIGATION ON PHYSICAL AND MECHANICAL BEHAVIOUR OF A356 - *x* wt. % SiC/Gr HYBRID COMPOSITES

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The experiments were planned to fabricate an A356 as a matrix material with 3, 6, 9, 12 wt. % of SiC and 3 wt. % of Gr as reinforcements to cast the hybrid composites at optimal process variable conditions using squeeze casting technique. Further T6 heat treated casted samples are prepared for testing as per standard procedure to record the responses like density, porosity, hardness, ultimate tensile strength, and percentage elongation respectively. There is a gradual increment in density because of adding an optimal level of up to 9 wt. % of SiC and 3 wt. % of Gr strengthening particles available in the A356 matrix and the porosity present in the sample diminishes, which in turn increases the hardness.

Key words: A356, silicon carbide, graphite, hybrid composites, mechanical properties.

INTRODUCTION

Aluminium and its alloys contain cast alloy and wrought alloy, which offers a phenomenal wide scope of ability and applicability, with an outstanding combination of benefits that make it the choice of material for various items in a market. [1]. A356 alloy was selected as the most appropriate of other alternatives while it is having a significant component of silicon containing A356 alloy. The cost is low, simple to handle, great castability, weldability, high strength, malleability and very good protection from erosion [2]. The bonding in silicon carbide is very strong in the crystal lattice which is a combination of tetrahedral carbon and atoms of silicon [3]. The graphite is limited to 3 wt. %. By incorporating the graphite wt. % between 3 to 7 wt. % into the aluminium matrix, it reduces the pulling effect of the material with the application of force making the tensile strength weaker and also has a negative effect on Young's modulus of the material [4]. The weight fraction reinforcement should be within 15 wt. % and particle size should be in between 30 – 80 micron to avoid agglomeration in both the cases [5]. Appropriate selection of grain size of around 25 μm of silicon carbide and 44 μm of graphite were included as the strengthening material for reinforcement [6]. The A356 is apted as the matrix material and mixed with SiCp of volume percentage 10 [7]. The hybrid composites fall into one of the classes of materials out of three were natural and inorganic components mixed to form a homogeneous mixture [8]. A356 hybrid composites were fabricated using a liquid metallurgy technique with a uniform mixing of SiCp and Gr particles. The hardness is improved with the gradual addition of SiCp and achieves the most extreme hardness for 9 wt. % [9]. In a matrix alloy with a weight fraction of SiCp, more than 10 percentage diminishes the wettability followed by agglomeration thereby increase the settling tendencies due to cluster formation [10]. The optimal significant process parameter of squeeze pressure can vary between 40 – 150 Mpa, with 650 - 800 °C of melt temperature, 150 – 300 °C die temperature and Stirrer speed of 300 - 400 rpm respectively [11].

From the majority of the literature review, research work is associated with stir cast hybrid composites and furthermore, there was no inside and out research performed by past researchers for this A356/SiC/Gr combination of hybrid composites prepared by squeeze casting route. Subsequently, an attempt is made to examine the impact of SiC on physical properties followed by mechanical properties of graphite reinforced hybrid composite by squeeze casting methods with T6 heat treatment to satisfy the research gap.

EXPERIMENTAL SETUP

Fabrication of hybrid composites

In this investigation work, the five combinations of samples were prepared through a squeeze casting setup and prepared under optimal process parametric conditions. For virgin material, A356 with x wt% SiC 3,6,9,12 is variable and 3 wt% Gr is kept constant. For each casting, 1 kg of A356 aluminium alloy ingot as shown in figure 2 was melted in a furnace. Further, the other four combinations of composites were prepared under the

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following conditions. The two types of reinforcement such as x wt. % SiC and 3 wt. % Gr is preheated separately in a furnace at 300 ˚*C*. Now the preheated particles are gradually transferred into the melt and agitated by means of stirrer arrangement in squeeze casting equipment rotating at a speed of 400 rpm for 5 minutes to form a whirling mass for complete mixing of particles. The equally distributed particles in the molten metals are discharged into the die cavity with utmost care and maintained at a temperature of 225 ˚*C* through a preheated passage to bottom pouring furnace. The force is applied through the punch from a hydraulic power press squeezed at a pressure of 140 Mpa till the liquid metal completely solidifies. After a few minutes, the split die was removed and the casted sample was taken out. Now the casted samples are heat treated in a solution at 540 ˚*C* for a period of 4 hours followed by water quenching at 25 ˚*C*. After that, artificial aging is done continuously for 4 hrs at 155 ˚*C*. Finally, the specimen is kept in cooled air until it approaches room temperature. Further, the heat-treated samples were taken for preparing test specimens. By following ASTM standards the prepared specimen after machining and heat treated were assessed to measure density, porosity, hardness, ultimate tensile strength, and percentage elongation respectively.

Testing of specimens

Archimedes' principle was used to measure the experimental density. The theoretical specimen density is calculated by rule of mixture. Percentage porosity (P) is calculated by;

$$P = [1 - \frac{\text{p Experimental}}{\text{p Theoretical}}] \text{ x } 100 \ \% \qquad (1)$$

The different polished square specimens of size 15 x 15 x 10 mm, as displayed in Figure 1 are taken to compute the hardness test. A load of 250 kg is applied for 15 seconds through the diamond indenter using Vickers hardness testing equipment. The hardness value is measured at the various spot of the area of the specimen and its average value is noted.

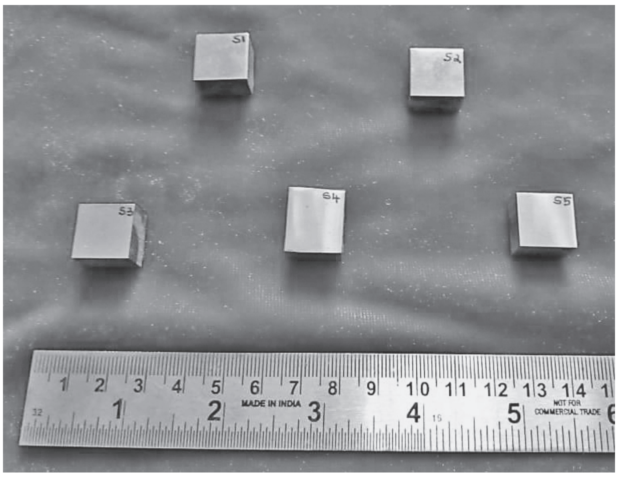

Figure 1 Density, Porosity & Hardness Test

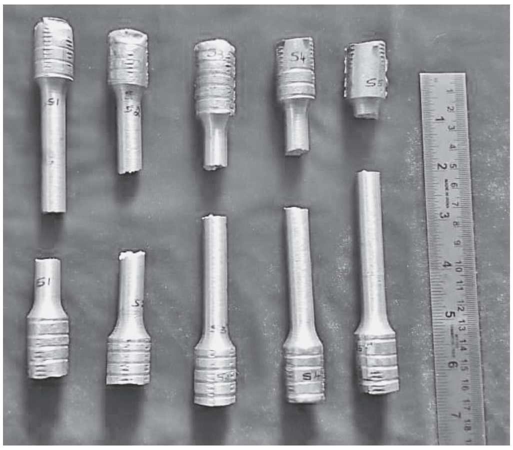

Figure 2 Tensile strength & % elongation test

The prepared samples are machined for the ultimate tensile test as displayed in Figure 2, according to the ASTM E8M-04 series.

The machined sample specimen is held in the universal testing machine (Instron 3380 series) of capacity 100 *KN* for measuring the ultimate tensile strength and specimen % elongation. Table 1 shows all the responses were recorded accurately for the five combination samples.

Table 1 **Recording of the responses for casted samples**

Stir cum squeeze cast samples	Experimental density / g/cm^3	Theoretical density / g/cm^3	Percentage porosity	Hardness / HV	Tensile strength \ MPa	Elongation / %
S1	2,95	2,98	0,67	85,1	260	3,26
S2	3,23	3,25	0,62	89,5	290	3,13
S3	3,54	3,56	0,56	92,5	310	2,9
S4	3,8	3,82	0,52	96,4	335	2,78
S5	3,64	3,66	0,55	94,2	328	2,82

*S1: Virgin A356, S2: A356 / 3 wt. % SiC / 3 wt. % Gr,
S3: A356/ 6 wt. % SiC/ 3 wt. % Gr, S4: A356/ 9 wt. % SiC/ 3 wt. % Gr,
S5: A356/ 12wt. % SiC/ 3 wt. % Gr

RESULT AND DISCUSSION

Density of casted specimen

As theoretical density of SiC particles 3,21g/cm^3 are higher than Gr particles 2,266 g/cm^3 and A356 alloy 2,975 g/cm^3, the cumulative theoretical density of composites is improved in A356 with 3,6,9, wt. % SiC with 3 wt. % Graphite composites and deprived A356 with 12 wt. % SiC and with 3 wt. % Graphite composites based on rule of mixtures method. The experimental density of hybrid composites is lower than the theoretical density and is measured by Archimedes' principle. Figure 3, displays the addition of a lower wt. % of A356 with up to 9 wt. % SiC and 3 wt. % Gr particles distribute evenly due to progressive addition in the high fluidity liquid metal and proper stirring method. The higher weight percentage of A356 with 12 wt. % SiC and 3 wt. % Gr particles form poor bonding due to cluster formation and agglomeration in the liquid melt.

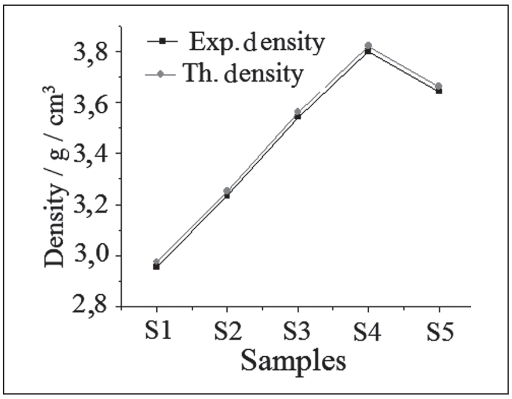

Figure 3 The density of the casted specimen

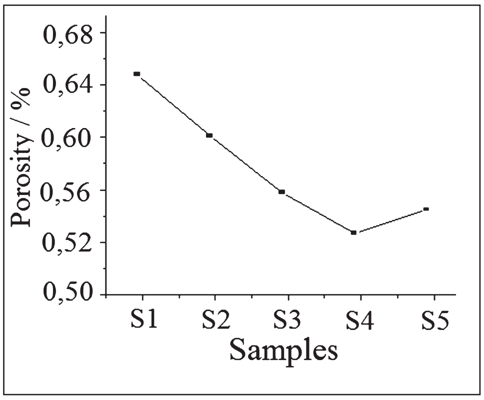

Figure 4 The porosity of casted specimen

Porosity of casted specimen

The value of porosity is decreased in A356 with 3,6,9, wt. % SiC with 3 wt. % Gr composites and increases with 12 wt. % SiC with 3 wt. % Gr composites with the A356 matrix material. From Figure 4, the addition of a lower weight percentage of A356 with upto 9 wt. % SiC with 3 wt. % Gr particles distributes evenly, due to continuous addition in the high fluidity liquid metal and proper stirring method. The higher weight percentage of A356 with 12 wt. % SiC, 3 wt. % Gr particles forms poor bonding due to conglomerate formation and agglomeration in the molten metal increases the porosity and with homogeneous mixtures, the porosity is gradually reduced.

Hardness of casted specimen

The composite hardness is increased by including silicon carbide particles though it weakens the machining property of the composite and furthermore, graphite maintains the minimum level of porosity. The high squeeze pressure results in good interfacial bonding, low porosity, absent of the cluster, equal reinforcement distribution and fine grains, ultimately improve the hardness of the materials in Figure 5

Accumulation of silicon carbide blended with graphite particles in A356 alloy exhibits higher strength and improved abrasive properties in the composites. The graphite particle behaves like a dry or solid lubricant in the matrix material and furthermore improves the machining property of the material is mixed along with silicon carbide in A356 alloy. On the other hand, the addition of graphite particles produces weak van der Waals force, which makes the bond between the aluminium and graphite weak, so that it improves the machinability of the hybrid composites.

Ultimate tensile strength of the casted specimen

Figure 6 displays the hybrid sample subjected to tensile strength tends to increase the maximum for A356, 9 wt. % SiC,3 wt. % Gr combination. Then again by in-

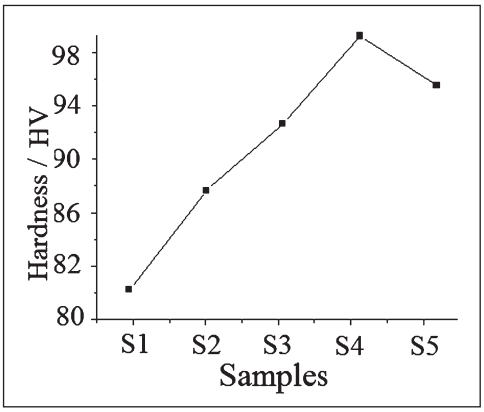

Figure 5 The hardness of the casted specimen

creasing SiC of 12 wt. % and 3 wt. % of Gr, the tensile strength tends to diminish due to additional weight percentage occupied in matrix alloy leads to microvoids, poor bonding, and cluster formation. A356, 9 wt. % SiC, 3 wt. % Gr combination gives the greatest rigidity of the composite. Hence the maximum strength depends upon the type and weight percentage of reinforcement. When a load is applied on the liquid melt, the matrix material pushes the reinforcement particles as a result of deformation, which leads to Piling up by dislocation. This limits the plastic deformation on the matrix giving high strength to the hybrid composite material. In the way that the strong internal stress between 9 wt. % of SiC, 3 wt. % Gr particles within the A356 matrix, it resists the load applied on the material, results in higher ultimate tensile strength.

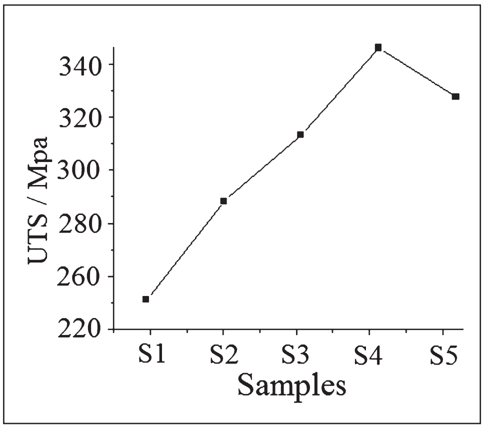

Figure 6 The ultimate tensile strength of the casted specimen

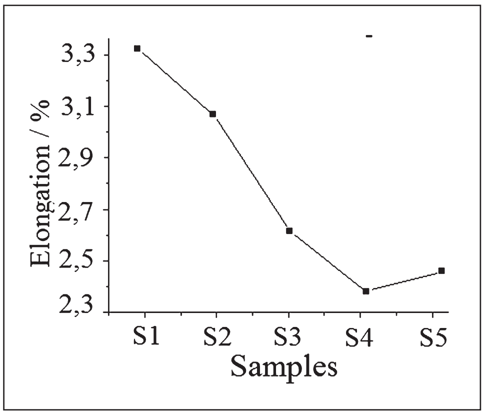

Figure 7 Percentage elongation of the casted specimen

Percentage elongation of the casted specimen

The relation between percentage elongation and varying x wt. % of SiCp with a fixed 3 wt. % of graphite is shown in figure 7. The accumulation of reinforcement in the matrix material minimizes the percentage of elongation. SiC is brittle in nature and Gr which acts as a solid lubricant. By the addition of 3 wt. %, 6wt %, 9wt. % and 12wt. % of SiC with fixed 3 wt. % of graphite in the matrix, the ductility of the hybrid composite reduces up to 9 wt. % Sic,3 wt. % Gr particles in the matrix.

The A356 alloy with the optimal amount of 9 wt. % SiC, 3 wt. % Gr reinforcements repels the flowability of aluminium metal matrix hybrid composite results in brittleness, which improves the hardness and strength thereby reducing the percentage elongation. Also, The distribution of molten metal in the porous area is reduced causing a reduction in wettability thereby mass of molten material is accumulated as a cluster causing an increase in agglomeration results in an increase in settling tendencies with SiC content greater than 9 wt. % SiC, 3 wt. % Gr causes an increase in elongation value.

CONCLUSION

The following denouements were recorded

- Between the matrix and reinforcements, good dispersion and quality were achieved using an optimal 9 wt. % SiC 3 wt. % Gr particles with A356 alloy in stir cum squeeze casting route.
- The density increases due to reinforcement addition up to 9 wt. % SiC, 3 wt. % Gr with A356 alloy and a further decrease in density due to the addition of reinforcements, around 77 % nominal improvement over virgin alloy.
- Interfacial porosity is low which decreases up to 9 wt. % SiC and 3 wt. % Gr with A356 alloy and increases with the further addition of particles in the matrix. With a high squeeze pressure of 140 MPa plays a lead role in density and porosity on the hybrid composites. Due to the elimination of porosity, there is a 78 % improvement over virgin alloy.
- The presence of particle addition up to 9 wt% SiC 3 wt. % Gr with A356 alloy makes a strong interfacial bonding in the lattice material, combined with high squeeze pressure improves the hardness by 88 %, tensile strength by 78 % and 85 % reduction in percentage elongation on hybrid composites.
- Further addition of above 9 wt. % SiC and 3 wt. % Gr with A356 alloy reduces the value of hardness, tensile strength and higher value of % elongation of the hybrid composites due to cluster formation and agglomeration.
- On the whole optimal combination of squeeze cast composite of 9 wt. % SiC, 3 wt. % Gr with A356 alloy shows unique properties than other combinations, so it is suitable for automobile and aerospace applications.

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Note: The responsible translator for the English language is Mrs.M.Caroline Dass, Sri Krishna College of Engineering and Technology, India.