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# Strengthened Granite Particles on Al6082 Alloy for Lightweight Structural Applications

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## **Abstract**

**Objectives**: An experimental effort is undertaken to enhance the mechanical properties of composite reinforced granite particles with Al6082 composition in contrast to previous research for lightweight structural applications. Methods : The stir casting process is used to develop the composite for the test samples. S1 sample contains 99.5 wt.% of Al6082 raw material and 0.5 wt.% of granite particles; S2 sample contains 99.0 wt.% of Al6082 raw material and 1.0 wt.% of granite particles; S3 sample contains 100 wt.% of Al6082 raw material and 0.0 wt.% of granite particles. The elemental content and particle size of granite particles were ascertained by means of SEM and EDS analysis. Findings: Tensile test was carried out for S1 & S2 samples. S1 test sample shown better results as compared to S2 sample. The microhardness of test specimen was measured at various locations for S1, S2 and S3 samples. S3 sample performed better as compared to S1 and S2 samples. Further, this microhardness value increased from S1 sample to S2 sample at two locations and the third location showed an equal value. The microstructure examination was also carried out by Using SEM analysis. The average tensile strength (UTS) of the S1 sample is 91 MPa, while the S2 sample's UTS is 50 MPa. The S1 sample can withstand a high load because of its elemental composition percentage, according to the UTS test. The average results of the microhardness test were 118 HV for the S1 sample, 133 HV for the S2 sample, and 143 HV for the S3 sample. It is suggested that this granite particle-reinforced material can be used as a lightweight structural engineering application based on previous research and this experimental investigation. Novelty: By using the granite particles as reinforced material the mechanical properties of the composite improved as compared to the existing available results with different reinforced materials.

**Keywords:** Granite particles (GP); Al6082 alloy; Stir casting; Ultimate tensile strength; Microhardness; SEM & EDS Analysis

#### 1 Introduction

Metal matrix composites plays an important role in the automobile and aerospace applications due to its excellent mechanical properties. The addition of reinforcement particles increases the mechanical properties. The wt.% of silicon carbide varied with 0 to 4 as reinforced material in Al6061 alloy. The 25.6% of tensile strength, 25% of hardness and 12% of compressive strength of the composite samples increased while increasing the weight fraction of the reinforced material as compared to Al6061 alloy<sup>(1)</sup>. The granite particles (wt.% of 2% and 4%) reinforcement have done with A356 alloy. The CoF of granite particle reinforced A356 alloy decreased with increasing the wt.% of reinforcement particles. The ploughing component of friction reduces with increasing material hardness, lowering the coefficient of friction<sup>(2)</sup>.

The microhardness of the hybrid AMC increased as compared to the base alloy. When 2.5 wt.% of  $CeO_2$ , a rare earth element, was added to an  $Al_2O_3$  + SiC mixture, the base alloy's micro hardness value increased by 17.02%. Hardness increased by just 13.70% when compared to non-rare earth element (alloy + 15% weight-%  $(Al_2O_3)$  + SiC) mixture). After the rare earth element was successfully included, the base alloy's Rockwell hardness increased by 33.80% (3). The reinforcement of  $B_4C$  with aluminum matrix composite increases the tensile strength and hardness of the composite sample (4).

The reinforcement of SiC (wt.% of 5, 7.5 & 10) with Al matrix composite performed better hardness values as compared to the Al alloy sample. When compared to supplied aluminum, the highest increase in microhardness of synthesized composites is 60% at 7.5 wt.% of Sic (5). With the incorporation of red mud particles, the microhardness, yield strength, and ultimate tensile strength of both as cast and heat-treated composites are enhanced, while the impact strength is diminished (6). The component information of quartz, feldspar and mica in granite were studied. The mechanical properties of mica are more definite because it has low mechanical qualities (7). The epoxy granite composite performed high value of compressive strength at fine particle size (8).

The research gap identified is that the usage of granite particles as a reinforcement material is very less in the researcher's study for lightweight structural applications. Granite has satisfactory thermal and mechanical properties. It is a naturally occurring refractory and building material. Here an attempt is made to use the granite particles as a reinforcement material with Al6082 alloy. In this paper granite particles (wt.% of 0.5 and 1.0) reinforced with Al6082 alloy prepared to study the mechanical properties and microstructure of the composite samples.

The composite material (Al6082+granite particles) prepared by using stir casting process. The Ultra Furnace-1000 stir casting setup is used for the experimental work. Initially the die is preheated with 300 °C. The furnace temperature maintained with 850 °C, stirring speed followed with 700 RPM and stir holding time is 5-7 minutes and also the pouring time is maintained for 2 minutes. The stir casted sample machined for the tensile test as per required ASTM standards. As the specimen geometry influences the mechanical properties <sup>(9)</sup>, the composite with a stirrer speed of 700 RPM had a greater result as compared to 600 RPM <sup>(10)</sup>.

## 2 Methodology

The experimental methods have been followed in the process of conducting the research work. Preparation of test samples, the elemental composition of the raw material (Al6082) and granite particles and samples S1, S2, and S3 are all included. The machining specifications required by the analysis of the testing results were applied to the stir-casted composite sample. The tensile, and microhardness tests were the objectives of the experimental effort. The workflow for creating composite samples of Al6082 and granite particles and conducting experimental research is shown in Figure 1.

### 2.1 Preparation of Test Samples

Stir casting is a conventional and cost-effective method for producing composite materials. The experimental setup is an Ultra furnace-1000, manufactured in Korea and constructed in India. The requirements adhered to in order to maintain an  $850^{\circ}$ C furnace temperature, a 500g capacity, stirring at a regular speed of 600 RPM, 5 minutes for stirring time, 2 minutes time for pouring, and  $300^{\circ}$ C for preheating the die are all employed in this experiment.

Using stir casting, it is possible to create intricate and expansive forms. This investigation identified Al6082 as a matrix material. The percentage breakdown of granite and Al6082 particles is shown in Table 1. Tables 2, 3, 4 and 5 is a list of the constituent elements that make up Al6082.

The specimens had to be machined into the shape of a spherical pin with a diameter of 8 mm and a length of 40 mm as per ASTM G 99-17.

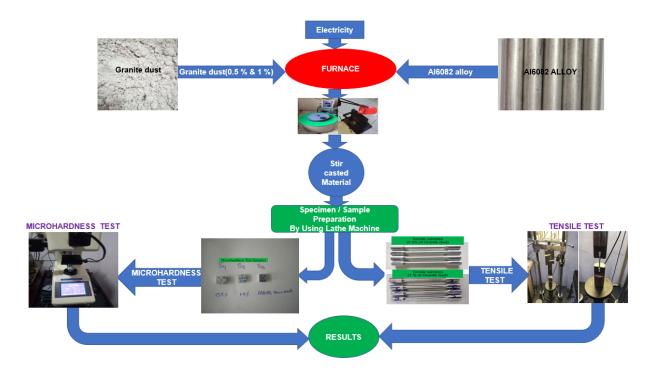


Fig 1. Flowchart for experimental investigation

Table 1. Percentages of the matrix's composition and reinforcement

Sample No.	Al6082 [Wt. %]	Granite particles [Wt. %]
S1	99.5	0.5
S2	99.0	1.0
S3	100	0.0

Table 2. Composition of the chemical components of granite particles

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Element	Si	Al	Fe	Ca	Mg	Na	K	O	Total
Weight [%]	32.08	7.56	3.12	1.87	0.97	3.01	3.99	47.41	100

Table 3. The S1 sample's chemical composition

Element	Si	Al	Fe	Ca	Mg	Na	K	О	Total
Weight [%]	0.35	97.28	0.00	0.00	0.57	0.08	0.08	1.63	100

Table 4. Chemical composition of S2 sample

Element	Si	Al	Fe	Ca	Mg	Na	K	O	Total
Weight [ %]	0.45	98.13	0.03	0.10	0.39	0.00	0.08	0.82	100

Table 5. S3 sample's chemical composition

Element	Si	Al	Fe	Ca	Mg	Na	K	О	Total
Weight [%]	0.52	95.0	0.24	0.00	0.35	0.17	0.01	3.70	100

### 2.2 Composition of Elements

EDS analysis has been used to examine the elemental composition of the granite particles (Figure 2), S1, S2, and S3 samples (Figures 3, 4 and 5). SEM analysis has been used to determine the particle size. Figure 6 illustrates the average particle size of  $70-80 \mu m$  in granite particles.

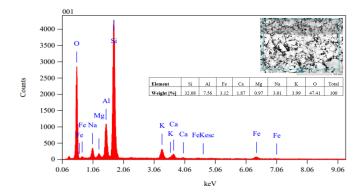


Fig 2. EDS analysis of granite particles

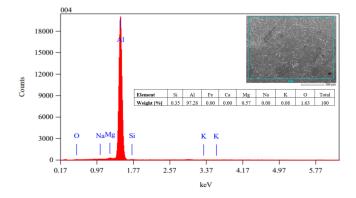


Fig 3. EDS analysis of S1 sample

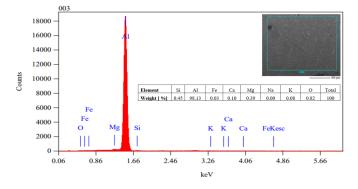


Fig 4. EDS analysis of S2 sample

Tables 2 and 3 describe the elemental composition of the S1 sample and granite particles using energy dispersive spectroscopy (EDS) analysis. The EDS analysis for the S2 and S3 samples is shown in Tables 4 and 5. The presence of SiC and Mg particles within the Al alloy and granite particle is also guaranteed by the EDS result.

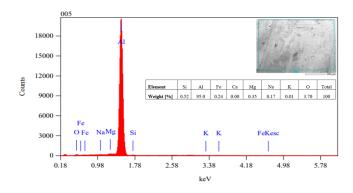


Fig 5. EDS analysis of S3 sample (Al6082 raw material)

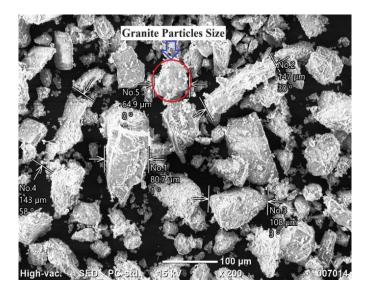


Fig 6. SEM image of granite particles with different particles size

Increased Si content reduces the melting temperature and increases the fluidity of the material composition. Moreover, the addition of Mg increases the composition's hardness. Al-Si alloys have an excellent mechanical property with high strength-to-weight ratio. The Mg percentage increases compressive strength of the composition or specimen. The composite's thermal conductivity increases as the proportion of granite particles in its elemental weight increase (9). Granite particle's calcium and magnesium content increases specimen hardness (10). Silicone is exceptionally resilient and retains its shape and pliability under extreme conditions, making it an ideal material for use in crucial applications.

#### 3 Results and Discussion

The other researchers developed a good composites material. The usage of granite particles is rare in the development of composite materials. Here the novelty of the work shows that an attempt is made to use the granite particles (GP) with Al6082 alloy to provide a better strength for lightweight applications.

The experimental results brought with tensile test, microhardness and SEM analysis. As compared to the available existing results the present work shown a better result due to the wt.% of Si by using granite particles. The tensile strength (UTS) of S1 sample shows 91MPa (avg.), as compared to S2 sample 50 MPa (avg.). From the UTS test the S1 sample can bear high load due to its elemental composition percentage. The microhardness test revealed with the average values of 118HV for S1 sample, 133 HV for S2 sample and 143 HV for S3 sample.

#### 3.1 Tensile Test

Using computerized universal testing equipment, tensile tests at a strain rate of 1mm/min are conducted to determine the ultimate tensile strength of the material being tested for tensile strength. The following UTM specifications were maintained during tensile test. Maximum capacity: 7 tonnes; precision: 10N; smallest displacement count: 0.1 mm; cross head speed: 0.5, 1.0, 1.5 mm/min; software: Auto instruments. On each of the three samples, a tensile test was conducted for the composite of S1 and S2 samples.

The maximum ultimate strength can be achieved with decreasing weight percentage of granite particles. The S1 sample has superior ultimate breaking load, ultimate stress, displacement, and elongation compared to the S2 sample. Experimental tensile test demonstrates that tensile strength of sample S1 increases in comparison to sample S2. The analysis of the tensile test reveals that the specimens have inconsistent properties. The Figure 7 indicates the experimental set up for a tensile test. Figure 8 displays the tensile test outcomes for samples.



Fig 7. Tensile test configuration

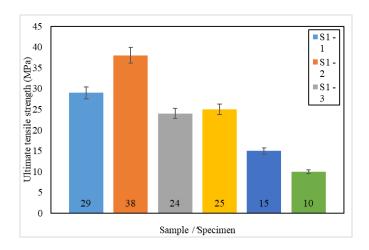


Fig 8. Tensile test results for S1-1 to S2-3 sample

The n-HMMC (sample prepared with AA7075-5wt %SiC-3wt %RHA-1wt %CES) presented a 24.4 % improvement in UTS as compared to the base alloy (AA7075)<sup>(11)</sup>. The M2 composite ((AA6061, 2 wt.% GP) and Z1 (AA7075, 2 wt.% SiC)) performed a precise 0.82 % increase in tensile strength. Comparing the Z1 composite to its Z2 equivalent, there is an astounding 50.1% increase in hardness and a 22.2% increase in tensile strength. M1 (AA6061, 5 wt.% GP) and Z2 (AA7075, 2 wt.% SiC, 2 wt.% GP) composites performed fewer mechanical properties as compared to M2 composite<sup>(12)</sup>.

It is observed that the S1 sample performed a high tensile strength for sample 1 it is 29 MPa, for sample 2 it is 38 MPa and for sample 3 it is 24 MPa. For S2 sample the results performed for sample 1 it is 25 MPa, for sample 2 it is 15 MPa and for sample 3 it is 10 MPa. Here the elemental composition plays a major role to influence the ultimate tensile strength and hardness.

#### 3.2 Microhardness Test

The material's hardness can also indicate its strength. S1, S2, and S3 samples were subjected to microhardness tests (Figure 9) with a load of 0.5 kg at three different locations. Figure 10 displays the microhardness results for samples S1, S2, and S3. For a sample with an overall diameter of 8 mm, the first location is specified as 2 mm, the second location as 4 mm, and the third location as 6 mm. Microhardness test is carried out for the composite of S1, S2 and S3 samples at which each sample with three equal distances of locations. At location 1; S3 sample has higher hardness value compared to the composite S1. It shows greater result as compared to S2. At location 2; S3 sample has higher hardness values and compared to the composites S1 shows greater result as compared to S2. At location 3; S3 sample has higher hardness values. Compared to the S1 sample S2 & S3 shows equal values due to the granite particles reinforcement variation at a location. The present work produced higher hardness values. It shows that the formation of grain structure and chemical composition is playing a major role in increasing the hardness value of the composite.



Fig 9. The microhardness test set up

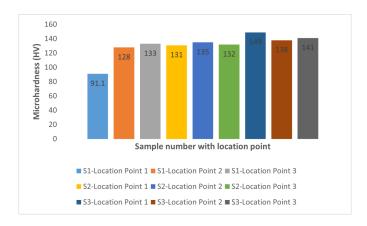


Fig 10. The microhardness values for S1, S2 & S3 samples at three different equal locations

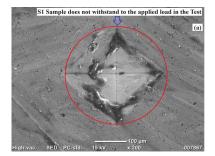
The sample prepared with AA7075-5wt %SiC-3wt %RHA-1wt %CES (n-HMMC) shows maximum hardness (RH = 81.2), 32.83%, 29.23%, and 14.9% higher than the base alloy (AA7075), MMC (AA7075-5wt %SiC), and s-HMMC (AA7075-5wt

%SiC-3wt %RHA)  $^{(11)}$ . From the study of Al7050 and Al7075 the optimal hardness value of 141.22 BHN achieved with the reinforcement of 12% of granite and 6 % of SiC particles  $^{(13)}$ . The hardness value of base alloy performed (Aluminium 7075) 51 VHN, Al7075+3%Sic+5% Al<sub>2</sub>O<sub>3</sub> performed the hardness value of 66 VHN, Al7075+6%Sic+5% Al<sub>2</sub>O<sub>3</sub> revealed the hardness value of 73 VHN and Al7075+9%Sic+5% Al<sub>2</sub>O<sub>3</sub> achieved 98 VHN  $^{(14)}$ . Due to the refined grain structure with distinct interfaces, the hybrid composite revealed a significant increase of 15.74% in macro hardness and 16.33% in microhardness as compared to the base material  $^{(15)}$ . The M2 composite ((AA6061, 2 wt.% GP) and Z1 (AA7075, 2 wt.% SiC)) demonstrates a significant 14.97% increase in hardness  $^{(12)}$ .

It is noticed that the S1 and S2 composite shows a competitive result with 118 HV and 133 HV as compared to the previous research results. The S2 sample shows good microhardness result due to the presence of Fe and Ca with 0.03% and 0.1%. Due to the elemental composition variances the hardness value improved for S2 sample.

#### 3.3 SEM Analysis

The SEM analysis has been carried out on microhardness tested samples. Figure 11 (a, b, c) depicts the microhardness test of the samples subjected to SEM analysis that yield positive results. The coarser grain size and uniform dispersion identified in the optical and SEM micrographs of the specimens of stir casted Al6061 base alloy and reinforced cerium oxide and graphene nanoplatelets <sup>(16)</sup>. The SEM micrograph for microhardness test samples revealed that the S1 sample has shown more indentation as compared to the S2 sample due to the wt.% of GP and the varying elemental composition of each sample. The MMC (AA7075-5wt %SiC) and s-HMMC's (AA7075-5wt %SiC-3wt %RHA) reinforcing particle distribution is rather homogeneous, as revealed by SEM examination. However, because of mixing problems and an increase in ceramic content, larger agglomerates are seen in the n-HMMC (AA7075-5wt %SiC-3wt %RHA-1wt %CES). These agglomerates are a possible location for stress concentration, which could weaken the material's impact strength and ductility <sup>(11)</sup>.





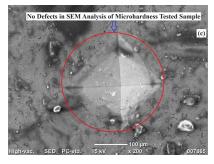


Fig 11. (a, b, c) SEM image of microhardness test samples

### 4 Conclusion

In the existing research, Al7075 and Al6082 is frequently used as a base material. The study on reinforcement of granite particles is rare hence, the attempt is made to enhance the elemental composition, tensile strength, and hardness of the composite (Al6082+granite particles with 0.5%, 1.0 %).

• The average tensile strength (UTS) of the S1 sample is 91 MPa, while the S2 sample's UTS is 50 MPa. The S1 sample can withstand a high load because of its elemental composition percentage, according to the UTS test.

- The average hardness value of sample at three equal locations performed 118 HV for S1 sample and 133 HV for S2 sample. It is observed that the wt.% of GP.
- On the basis of experimental observation, following inferences are drawn from previous work. Tensile test of the S1 sample delivered greater results as compared to S2 sample due to less wt.% of granite particle, Si and Al content is minimum in S1 sample as compared to S2 sample.
- According to the microhardness test results, the S3 sample delivered greater results for each of the three equal locations.
- Further, S1 sample performed with a satisfied result as compared to S2 sample due to high Mg content.
- Microstructure examination reveals that S1 sample showed better results as compared to S2 sample due to the absence of Fe and Ca.
- The reinforcement of granite particles with Al6082 alloy enhances the mechanical strength and hardness due to high Si, Ca and less Mg content of the stir casted Al6082 / granite samples.
- It is concluded that the combination of Al6082 and granite particles also useful for the lightweight applications as compared to the available existing results of other combination of the materials.

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