Comparative Analysis on Mechanical Properties of Al 6061 and Al 7075 Cross Matrix Composites

R. Balaji, J. V. Muruga Lal Jeyan, A. Basithrahman, Talasila Estheru Rani, and S. Abirami

Abstract Aluminum alloy 6061 and aluminum alloy 7075 (or simply denoted as Al 6061 and Al 7075, respectively) are widely used in the field of aviation, automobiles, and marine due to their exceptional properties such as good strength, lightweight, and better corrosion. In this paper, Al 6061 and Al 7075 are used as base materials for reinforcement to further enhance their mechanical properties. Alumina, silicon carbide, boron carbide, and titanium oxide are used as reinforcement particles. The cross matrix composites of Al 6061 and Al 7075 are produced by the widely used stir casting method. The different weight percentages of reinforcement particles are used to prepare different composition of cross composites. The resultant composites are heat-treated in T6 condition and machined in the suitable dimension for testing. The mechanical characterization was carried out by performing hardness, tensile, and impact tests, and their results have been presented. Moreover, the comparison of mechanical properties of alloys Al 6061 and Al 7075 is also given; specifically, the tensile stress and impact value of Al 6061 are shown to be increased when the reinforcement particles are added comparing to Al 7075 cross composites.

Keywords Cross matrix composites · Aluminum alloys · Stir casting · Mechanical properties · And heat treatment

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C. Prakash et al. (eds.), *Advances in Metrology and Measurement of Engineering Surfaces* , Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-15-5151-2_3

1 Introduction

The use of the aluminum alloys in various industries because of its lightweight, and strength. In the virtual, role of hard ceramic in industry is quit high, but the soft matrix alloy, generally aluminum, improves the mechanical properties of the materials and increases the performance of the composites [1]. Aluminum alloy is used in various industries in line for to its good mechanical properties, and it can be able to withstand different atmospheric conditions without getting cored. But, it displays substandard tribological possessions in extensive application [2, 3]. To increase the brittleness of the aluminum-based materials, we were having plenty of ways, but reinforcing the materials could be the best option among all, reinforcements such as SiC and Al_2O_3 ceramic particles [4]. Many methods normally used to prepare the composites like powder metallurgy [5], but all are not simplest one; complicity range is higher. Stir casting [6] is one of the easiest way to manufacture the composites economically. Squeeze casting [7] is are often used rarely. Comparing to all the above-listed methods, stir casting is way better and simplest one for fabricating particulate reinforced composites [8]. Pre-aging is one of the best ways to increase the tensile properties of the material at various retrogression temperatures; in addition, it will increase the electrical resistivity and hardness of the AA7075 aluminum alloy [9]. The hardness of aged AA7075 alloy increases [10]. Boron carbide reinforced with aluminum alloys at 10% of its weight to increase the hardness and wear resistance. AA 7075 produces higher wear resistance comparing to AA 6061 alloy. The AA 7075/B_4C/graphite cross matrix attains better results [11]. Superior mechanical and tribological properties increased by reinforcing Sic with Alloys [12]. There is an increment in the mechanical and thermal properties using this substance of the materials. The wear resistance of the Al 7075-SiC-b4c composites is improved by aggregating the SiC ceramic particles. The coefficient of friction is indirectly proportional to the volume content of reinforcements [13]. Comparative analysis of the mechanical behavior of cold-worked and annealed 7075 aluminum alloy. In above 265 °C temperature, the rearrangement of the molecules inside the sample specimens at the same time yield and tensile strength gradually decreased [14]. Reinforcement of alloys with Sic increases the tensile strength and lowers the ductility of the alloys [15]. The propagation of 0–8 wt% of the Al_2O_3 and 5 wt% of graphite particles in AA7075 will increase the behavior of the material with various loads. Due to the reinforcement, ultimate strength of the materials increases. The mechanical strength is improved by toting Al_2O_3 particle and sinking due to toting of graphite particle [16].

In this work, the two different types of cross composites were produced by stir casting method using Al 6061 and Al 7075 aluminum alloys. Three different compositions of the cross composites are produced by using reinforcement particles. The comparative results of mechanical properties of two cross composites are analyzed.

Table 1 Composition of Al 6061

Element	Si	Fe	Cu	Mn	Mg
Weight (%)	0.514	0.23	0.161	0.071	0.96
Element	Ni	Zn	Ti	Cr	Al
Weight (%)	0.010	0.015	0.031	0.103	Bal.

Table 2 Composition of Al 7075

Element	Si	Fe	Cu	Mn	Mg
Weight (%)	0.219	0.219	1.582	0.043	2.036
Element	Ni	Zn	Ti	Cr	Al
Weight (%)	0.037	5.403	0.045	0.205	Bal.

2 Experimental Procedure

2.1 Material Composition

TiO_2, Al_2O_3, B_4C, and SiC are cast off as the strengthening particles, and Al 6061 and Al 7075 are used as base material. The composition of Al 6061 and Al 7075 is shown in Tables 1 and 2. Al 6061 and Al 7075 are used because they have virtuous mechanical properties and reveal good wettability. The most collective alloys of aluminum for broad purpose practice.

2.2 Preparation of Composites

Widely used casting technique to manufacture a cross metal matrix composites is stir casting technique because of its uniform reinforcement distribution. The metal matrix which has the uniform distribution will increase the quality of the materials. In this comparative study, the base material was Al 6061 and Al 7075 followed by the reinforcement particles Al_2O_3, SiC, TiO_2, and B_4C. For this comparative analysis, initially Al 6061 was taken followed by Al 7075. In the first casting process, reinforcement particles were Al_2O_3, SiC, and B_4C. For each casting, the reinforcement particles added at the equal amount to validate the result. Graphite crucible electric furnace is used here to heat the aluminum alloys at high temperature. The heat treatment was carried out for one hour in the electric furnaces with the temperature of 650°–800° which is high comparing to the melting temperature. To eliminate dusty particles, preheating is conducted at the temperature range of 450–550 °C. Semisolid molten material was cast off using mechanical stirrer. At the operating speed of 550 to 1100 rpm, the mild steel mechanical stirrer is used for stirring. Preheated reinforcement materials are slowly added during the vortex materialization stage. Magnesium alloy of 1% is added to molten alloy in the second cross composite. Stirring speed is increased after adding the reinforcement, and the duration is maintained 5 min. The casting materials are obtained after preheated mold in a solid form. Using the base materials with different has been manufactures.

3 Compositions

The two types of cross composites with different type of compositions are shown in the table with compositions code. In the first cross composite Al 6061 is used as a base material, and B_4C, Al_2O_3, and SiC are cast off as reinforcement particles. The Al_2O_3 reinforcement weight proportion is varied, and B_4C and SiC weight percentages are maintained as constant (Table 3).

Al_2O_3, B_4C, and TiO_2 were casted as strengthening particles in the second cross composite Al 7075 weight are varied and the rest of the composition is kept constant.

Table shows the composition code of the different composition of cross metal matrix composites (Table 4).

3.1 Heat Treatment Process

The heat treatment process for cast and composite bars was carried out. Muffles were used to heat-treat the materials at T6 condition to an accuracy of ±1 °C for 8 h at 529 °C, followed by water quenching and then aged at 159 °C for 8 h. The casted materials are machined after heat treatment process for testing process with necessary dimension.

Table 3 Composition code of Al 6061

S. No.	Composition	Code
1	Al 6061-3%Al_2O_3-5%B_4C-5%SiC	A-1
2	Al 6061-6%Al_2O_3-5%B_4C-5%SiC	A-2
3	Al 6061-9%Al_2O_3-5%B_4C-5%SiC	A-3

Table 4 Composition code of Al 7075

S. No.	Composition	Code
1	Al 7075-3%Al_2O_3-5%B_4C-5%TiO_2	B-1
2	Al 7075-6%Al_2O_3-5%B_4C-5%TiO_2	B-2
3	Al 7075-9%Al_2O_3-5%B_4C-5%TiO_2	B-3

4 Mechanical Characterization

Experimentations were conducted on the material to find out the mechanical properties of the materials like hardness, impact test, and tensile test for various nodes. Mechanical properties were measured for the reinforced material and test procedures discussed in the following sections.

4.1 Hardness Test

Hardness of the specimen was tested, and the results have been computed using Brinell hardness test. All the test specimen size is maintained as per the ASTM E-18 standard size. The specimen has undergone hardness test with the load of 100 kgf for five different position, and the average is taken as the hardness value of the material. The ball intender dimension is 1/16 throughout the test.

4.2 Impact Test

Using Charpoy impact testing machine, impact test was done. The test specimens were made using casting process, and the material was machined as per ASTM E-23 standard size. Square cross sections of size (10 mm × 10 mm × 55 mm) with single V-notches are calculated for research. The dimensions of V-notches as per the literature review are 45° and 2 mm depth which will be more effective. The effect of roughness factor was indomitable when fracture takes place.

4.3 Tensile Test

For tensile test, 100 mm length and 12 mm diameter specimen has been taken as per AETME-08 standard. With universal testing machine (TUE-C1000), the mechanical properties has been validated and tabulated below.

5 Result and Discussion

5.1 Hardness Test

The testing shows the hardness values of the cross metal matrix composites and that has been tabulated. The hardness test was carried out on Brinell hardness testing

Table 5 Hardness value of cross composites

S. No	Loads (kgf)	Code	Hardness of Al 6061
1	100	A-1	92
2	100	A-2	95.7
3	100	A-3	95.3
S. No	Loads (kgf)	Code	Hardness of Al 7075
1	100	B-1	91
2	100	B-2	102.3
3	100	B-3	105.3

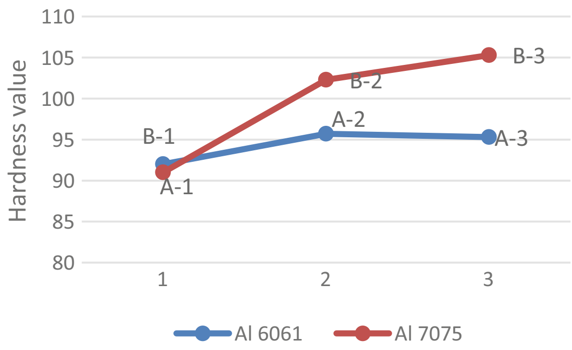

Fig. 1 Hardness value of Al 6061 and Al 7075 cross matrix composites

machine as per ASTM standard. The casted cross composites are machined for required dimension. 100 kgf load is applied to the specimen at three different places. The average values of the hardness are taken as hardness value of the cross metal matrix composites (Table 5).

From the table, it is shown that the hardness value of the Al 7075 cross matrix composites has higher hardness value compared to Al 6061 cross metal matrix composites. For all three different compositions of the cross composites, Al 7075 has high hardness value (Fig. 1).

5.2 *Impact Test*

Table shows the impact factor value of the Al 6061 and Al 7075 cross metal matrix composites. The impact test was carried out on Charpoy impact test machine as per ASTM standard. The casted composites are machined for required dimension (Table 6).

From the table, it is shown that the Al 6061 cross composite have higher impact factor value compared to Al 7075 cross composites. For all three different compositions of the cross composite Al 6061, cross matrix composites have higher impact value (Fig. 2).

Table 6 Impact value of cross composites

S. No	Code	Impact value of Al 6061
1	A-1	4
3	A-3	2
S. No	Code	Impact value of Al 7075
1	B-1	2
2	B-2	4
3	B-3	2

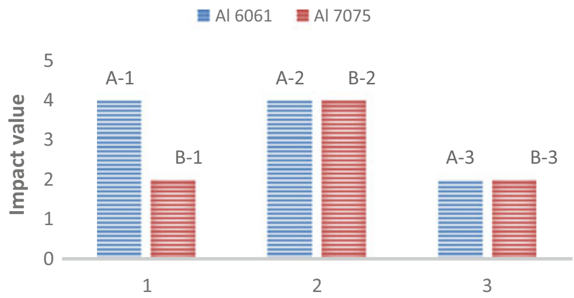

Fig. 2 Impact factor value of Al 6061 and Al 7075 cross matrix composites

5.3 *Tensile Test*

Table shows the tensile value of the Al 6061 and Al 7075 composites. The tensile test was carried out on universal testing machine as per ASTM standard. The casted composite was machined for required dimension. From the test, mechanical properties of the materials are measured (Table 7).

From the table, it is shown that the tensile stress value of the Al 6061 cross metal matrix composite has higher value compared to Al 7075 cross metal matrix composite. For all three different compositions of the composite Al 6061 have higher tensile strength (Fig. 3).

Table 7 Impact value of cross composites

S. No	Code	Peak load	Ultimate stress	Yield stress	% of Elongation
1	A-1	2.905	58	50	14.50
2	A-2	13.04	259	200	17.0
3	A-3	10.805	215	165	13.6
4	B-1	8.81	175	140	16
5	B-2	3.57	71	56	13
6	B-3	3.575	71	55	12

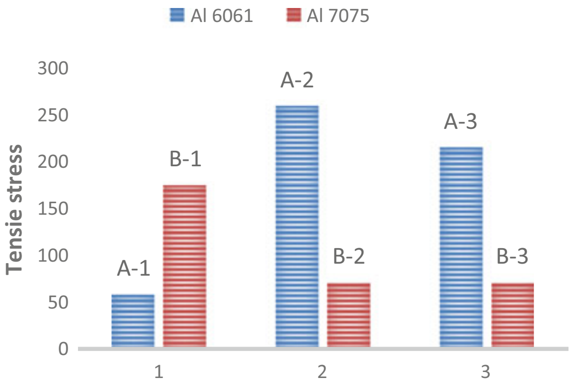

Fig. 3 Tensile stress value of the Al 6061 and Al 7075 cross metal matrix composites

6 Conclusions

In this work, the stir casting method is used to produce the cross composites with ceramic particles in different weigh percentage. Mechanical properties of alloys after reinforcing with ceramic particles have been increased. The other method of increasing mechanical properties is preheating of molds that help to reduce the porosity. Three different compositions of cross composites are produced and machined as per ASTM standard. The cross composites are heat-treated into T-6 condition successfully. The Al 7075 cross matrix composites have higher hardness value compared to Al 6061 cross metal matrix composites. Al 6061 cross matrix composites have higher impact factor value and tensile stress, yield stress, and % of elongation compared to Al 7075 cross metal matrix composite.

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