EXPERIMENTAL STUDIES ON GREY CAST IRON REINFORCED AA6061 COMPOSITE

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Abstract- Aluminium alloy composites are widely used because of their higher strength, stiffness and good wear resistance. In producing these composites the reinforcing materials used in common have been silicon carbide, aluminum oxide, boron carbide and graphite in the form of particles or whiskers. The ceramic particles reinforced aluminum composites are new generation materials which can be tailored for particular properties for specific application requirements. The particulates reinforced composite have best plastic forming ability than that of whisker or fiber counterpart and hence have emerged as most demanding reinforcements with great cost advantage. The particulate reinforced composites have been proved to be most suitable for heat and wear resistance applications. In the present study microstructure, hardness, tensile and impact properties of AA 6061based composite reinforced with Grey Cast Iron (GCI) is analyzed and presented. The presence of Grey Cast Iron resulted in improving the mechanical properties of their respective composites. The micrographs of the composites studied revealed the uniform distribution of the particles in the matrix system. Comparison of the characteristics study before and after heat treatment was done and it was found that there is an improvement in hardness, tensile strength and impact resistance of the composites as well as AA 6061 alloy after heat treatment.

Index Terms- particulate, metal matrix composites, stir casting, heat treatment

I. INTRODUCTION

Al and its alloys have been extensively used in casted and in wrought form with heat treatment in various applications. Forged parts, sections, extruded parts, sheets, plates, strips and wires are examples for wrought form and casted form are available as sand, pressure and gravity die castings[1].

Practically the most favorable alloys that can be dispersed in cast and wrought aluminium alloys for structural applications are Mg, Si, Mn, Cu, Zn. These dispersoids can be used individually or in combined form. The dispersion of these elements will enhance the properties of plain alloy when added in appropriate percentages. The wrought Al alloys are designated as shown in table 1[2].

Heat treating of Al alloys is normally limited to definite kind of operations used for improving the strength and hardness of Al alloys. Al alloys can be categorized as non- heat treatable and heat treatable alloys as all Al alloys are not suitable for heat treatment.

Wrought and cast forms of alloys can be subjected to Annealing heat treatment. The basic purpose of this treatment would be to enhance the ductility. Generally complete or partial annealing is done for non-heat treatable alloys[3]. Alloys of Al of this kind belong to the system having low solubility in the solid state and are known as precipitation hardeneble alloys[4]. The basic feature of this type of alloys category is that they have temperature dependent equilibrium solid solubility that increase as temperature is raised. Also the other feature is that they retain single phase super saturated solid solution by quenching and precipitation of coherent or partially coherent phase by decomposition of the super saturated solid solution.

Some of the types of these are as under [5]:

- 2XXX series alloys. The presence of Cu and Mg enhances the strength by age hardening.
- 6XXX series alloys. These exhibit high weldability property, high corrosion resistance and resistance to stress corrosion cracks.
- 7XXX series alloys. These can be easily age hardened. There will be decrease in zinc solubility as the temperature is reduced. The resistance to stress corrosion cracking can be enhanced by addition of Cu to Al-Zn-Mg Alloys.

Few of the alloys will not respond to heat treatment as they contain homogeneous solid solution with or without any non-coherent precipitates and exhibit lower strength and higher ductility. These alloys will not have a decrement of solid solubility with reduction in temperature. Also strength can be enhanced only by cold working [6].

There exists even medium strength alloys used for extrusion components that have superior weldabality, resistance to corrosion and resistance to corrosion, corrosion stress cracking.

Al 6061 is a precipitation hardening aluminium alloy, having Mg and Si major elements. This alloy exhibits superior weldability and mechanical characteristics. It is most commonly used alloy for general applications [7].

With the introduction of Mg the Al-Si alloys can be age hardened by the precipitation of Mg_2Si particles. The major Al alloy system is as shown in figure1.

Of the many types of particulate reinforcements, grey cast iron is a type of cast iron that has a graphitic microstructure which can be used as reinforcement for Al alloys. It is most extensively used cast iron based on weight [8]. The age hardening or precipitation hardening is induced by sequential phase

transformation that would lead to homogeneous distribution of nano scale, coherent precipitates in a softer, more ductile matrix [9].

Age hardening process contains basically three stages [10-11] like solution treatment, quenching and aging.

• Solution treatment: It is the primary stage in age hardening process. To dissolve the secondary phases and to form uniform solid solution generally the alloy is heated above 5500C.
• Quenching: It is the intermediate stage in age hardening process. Here alloy is rapidly cooled from the higher temperature one phase region to two phase region at atmospheric in order to form supersaturated solid solution.
• Aging: It is the last stage in age hardening process. Here the alloys will retain fine dispersions of small precipitates at the end of this stage.

II. EXPERIMENTAL DETAILS

A.Precipitation hardening/ Age hardening treatment

An aging study was carried out on specimens of plain Al 6061 matrix alloy and Grey Cast Iron (GCI) Al 6061 composite in order to find the time necessary to achieve peak hardness. The aging process involved solution treatment of the sample for 2 h at 550^0C, then quenching in water followed by artificial aging at 160^0C for different aging times.

B.Microstructure Studies

The majority of burrs were eliminated by a belt polisher. The emery is initially used to polish specimens before polishing by disc polisher covered with velvet cloth. The alumina paste is also used during polishing so that mirror surface is obtained at the end of process. The specimens are further cleaned with water and dried using ethanol solution. Dried specimens are further etched with Nital, washed and dried after exposing for optimum duration with etchant. Inverted metallurgical microscope is used to record the microstructure at 200X.

C.Details of Hardness Test

The chemical elements of AA 6061-T6 alloy used in this study is identified by spectral analysis and is given in Table 2.
The specimens then subjected to heat treatment by retaining at 550^0C for 2h followed by quenching in water at room temperature. The samples were artificially aged in the furnace at 100^0C, 150^0C and 200^0C for various time durations.
According to the Al-Mg-Si phase diagram melting of ternary eutectic Mg_2Si-(Al)-(Mg) phase takes place at 558^0C. It is reported that the samples of 6061 Al/SiC composite, with the solution heat-treated at 558^0C, exhibit better strength compared to the samples solution treated at 530^0C after aging treatment [9].
Hardness values are measured at time interval of 30/60 minutes, to determine the peak aging time for that specific temperature. Hardness tests were done by a Brinell hardness tester with steel ball indenter of diameter 5mm and a load of 250 kgf (SAROJ Brinell Hardness Testing Machine, Model:-B/3000/00, Sl# 13/06/08- India). Specimens of diameter 12 mm and length 15 mm are prepared.
Brinell hardness tests were conducted on both AA 6061alloy and composites. The results of test are given in Table 3-5.

D.Details of Tensile Test

The dumb bell shaped tensile test specimens were prepared as per IS: 2102-1989. The gauge length and diameter were 25 mm and 6.4 mm respectively (figure 2(a)). The tensile test was carried out in a tensometer that is computer integrated to generate the on line plot of load-vs-extension. The fractured tensile specimen of AA6061+2% is as shown in figure 2(b).
E. Details of Impact Test
The Charpy test specimens were as per IS: 1499-1959. The total length was 55 mm of square cross section having dimensions 10 mm x10 mm. A U notch of 2mm width and 5mm deep was made at the mid length. Photographs below show the specimens prior and after impact test.

III. RESULTS AND DISCUSSION

F. Microstructural features

Figure 2 shows the optical micrographs of Al6061 alloy, Al 6061+2% CI and Al 6061+4% CI reinforced composites respectively. Micrographs reveal that there is fairly uniform distribution of cast iron particulates throughout the matrix alloy and no porosity is found. Also, it can be observed that there is good bonding between the matrix and the reinforcement particulates resulting in better load transfer from the matrix to reinforced material. There was no agglomeration of reinforcements since sufficient care was taken to prevent agglomeration by preheating the particulates to 2000C for 2 h.

G. Hardness

Figure 5 shows the hardness variation as a function of aging time for unreinforced Al 6061 alloy,AA6061 +2% CI and AA6061+4% GCI composites at 1600C respectively. AA6061+4% composite have achieved peak hardness at lesser duration as compared to bare alloy and composite with 2% GCI reinforcement.
Figure 6 shows the comparison of hardness in as cast and peak aged conditions for a specific quantity of reinforcement. As seen from the plot that peak aged specimens may be in as cast or in composite form exhibited higher hardness compared to the casted counterparts.

H. Tensile Test

As the weight % of the reinforcement increases the UTS value of the material increases in both as cast and

peak aged conditions (Figure 7). Highest tensile strength is seen for composite specimen with 4% GCI. Also irrespective of whether bare alloy or composite, aging treatment brings improvement in UTS.

IV. TABLES AND FIGURES

Table 1: Standard terminology of Al alloy

Alloy Designation	Detail
1XXX	99% Pure Aluminium
2XXX	Cu as major element in alloy
3XXX	Mn as major element in alloy
4XXX	Si as major element in alloy
5XXX	Mg as major element in alloy
6XXX	Mg as major element in alloy
7XXX	Zn as major element in alloy
8XXX	Other alloys

Table 2: Composition of AA 6061 matrix material.

Material	Si	Fe	Cu	Zn	Mg	Cr	Al
Wt%	0.60	0.50	0.23	0.20	0.98	0.23	Rest

Table 3: Hardness values of AA 6061 alloy aged at 160°C for different ageing times.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Aging Time (hours)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5
BHN (aged at 160°C)	57.6	63.3	63.3	69.1	69.1	85.2	55.8	76.8	81.9	77.9	83.2	76.2	82.6	85.7	89.7	**90.4**	87.7	81.9

Table 4: Hardness values of AA 6061+2% CI composites aged at 160°C for different ageing times.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Aging Time (hours)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	**5.5**	6	6.5
BHN (aged at 160°C)	60	71.5	69.1	83.8	89.7	83.2	76.8	82.6	82.6	77.9	91.8	**99.3**	93.6	89

Table 5: Hardness values of AA 6061+4% CI composites aged at 160°C for different ageing times.

Sample No.	1	2	3	4	5	6	7	8	9	10
Aging Time (hours)	0	0.5	1	1.5	2	2.5	3	**3.5**	4	4.5
BHN (aged at 160°C)	62.1	75.1	75.1	80.8	83.1	87.3	98.4	**112.7**	88.4	87.7

Table 6: Hardness values in both as cast and peak aged conditions

Condition	AA6061-BHN	AA6061+2%-BHN	AA6061+4%-BHN
As cast	55	67	72
Peak aged at 160°C	90.4	99.3	112.7

Table 7: Tensile strength in both as cast and peak aged conditions

Condition	AA6061-MPa	AA6061+2%- MPa	AA6061+4%- MPa
As cast	84.2	102.6	110.2
Peak aged at 160°C	137.2	149.5	171.3

Table 8: Impact resistance in both as cast and peak aged conditions

Condition	AA6061-Joules	AA6061+2%- Joules	AA6061+4%- Joules
As cast	26	23	19
Peak aged at 160°C	23	18	13

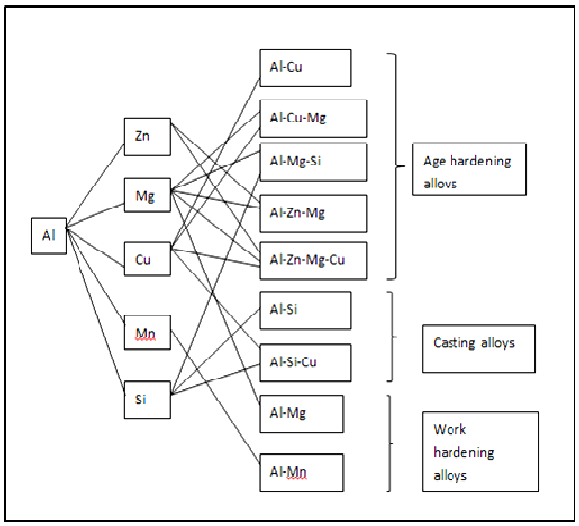
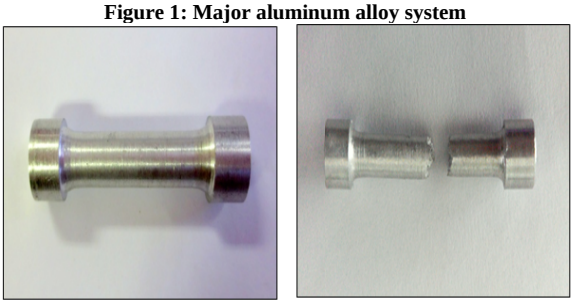


Figure 1: Major aluminum alloy system



(a) (b)

Figure 2: Tensile strength test specimen before and after the tensile strength test.



Figure 3: Charpy impact test specimen before and after the impact test

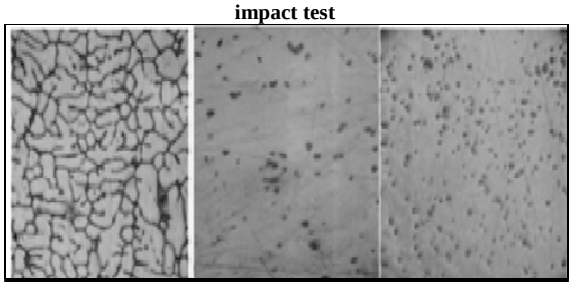


Figure 4: Micrographs in as cast conditions; AA 6061+0% CI (L), AA 6061+2% CI (M) and AA 6061+4% CI(R).

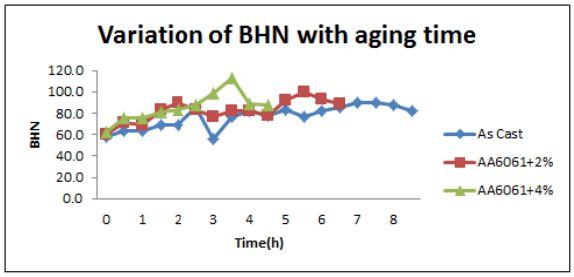


Figure 5: Graph showing variation of hardness values with time during aging.

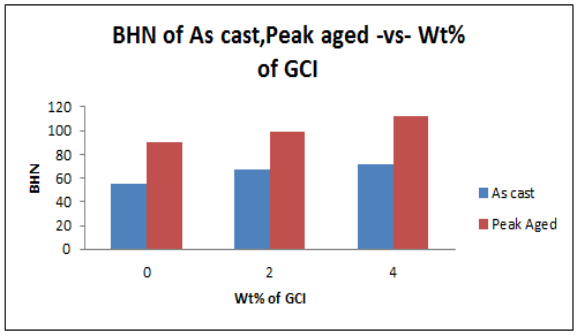


Figure 6: Comparison graph of hardness values in both as cast and peak aged conditions.

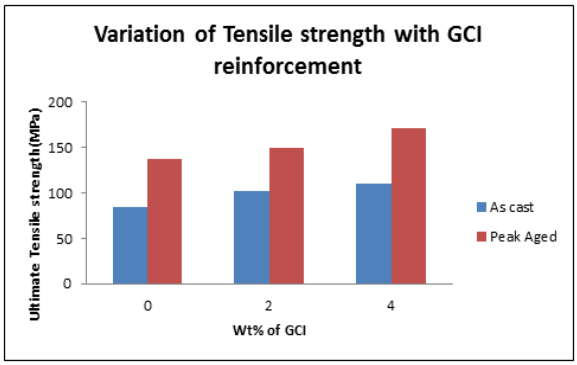


Figure 7: Comparison of UTS values in both as cast and peak aged conditions

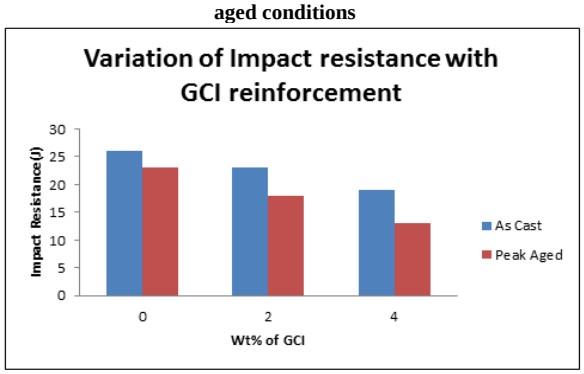


Figure 8: Comparison of impact resistance in both as cast and peak aged conditions

CONCLUSION

The objective of the study is to investigate the mechanical properties of AA6061 alloy and its composites in as cast conditions and after giving heat treatment and also to compare the results of treated and untreated unreinforced AA6061 alloy and composites reinforced with Grey Cast Iron. Microstructure studies, hardness test, tensile test and impact tests were conducted and the following conclusions were drawn:

- Microstructure studies showed uniform distribution of Grey Cast Iron particulates in AA6061 matrix. It is found that there is no agglomeration of reinforcements in the matrix. The microstructure justifies that the stir casting process is one of the simplest and effective casting process for particle reinforced MMC.
- Heat treatment gives positive effect on mechanical properties.
- Hardness is increased for composites in comparison with the respective in as cast condition.
- Tensile and Toughness properties of as cast and composite were found to be improved due to heat treatment.

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