Fabrication & Investigation of Mechanical Properties of AA 6082 Composites with Al_2O_3/SiC/B_4C by Stir Casting

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ABSTRACT

Aluminium alloys are used in advanced applications because their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. However, the scope of these properties can be extended by using aluminium matrix composite materials. These Aluminium matrix composites are used mostly in space ships, aerospace, automotive, nuclear, biotechnology, electronic and sporting goods industries. Aluminium oxide, silicon carbide and boron carbide can be used as reinforcement to improve the properties of aluminium alloy 6082; which has better machinability, excellent corrosion resistant and medium tensile strength. In present work, the main focus is to improve hardness and ultimate tensile strength of AA 6082. For that powers and their mixtures are reinforced with AA 6082 by stir casting process. After the fabrication of Aluminium matrix composites Brinell hardness and Ultimate Tensile Strength tests are performed on fabricated samples. It observed that with the increase in percentages of reinforcement the both mechanical properties hardness and ultimate tensile strength improv

INTRODUCTION

Composite Material

Composites are combination of metals, ceramics, plastics, and other materials. Composites materials are produced by combining two dissimilar materials in to a new material that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength, stiffness, heat resistance, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

The advantages of MMCs over polymer matrix composites are:

- ✓ Higher temperature capability
- ✓ Fire resistance
- ✓ Higher transverse stiffness and strength
- ✓ No moisture absorption
- ✓ Higher electrical and thermal conductivities
- ✓ Better radiation resistance
- ✓ No out gassing

● 1.4 Stir Casting

Stir casting is a liquid state method for fabrication of composite material, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies.

Stir Casting Process Parameters

A. Stirring speed:-
B. Stirring temperature:-
C. Reinforcement preheats temperature:-
D. Stirring time:-
E. Powder Feed Rate:-

Aluminium Alloy 6082

Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys. Alloy 6082 is known as a structural alloy. In plate form, 6082 is the alloy most commonly used for machining. As a relatively new alloy, the higher strength of 6082 has seen it replace 6061 in many applications.

Table 1: Chemical Composition of AA 6082

Element	Percentage
Silicon (Si)	0.75 - 1.20
Magnesium (Mg)	0.65 - 1.50
Manganese (Mn)	0.45 - 1.05
Iron (Fe)	0.50
Chromium (Cr)	0.1
Zinc (Zn)	0.20
Titanium (Ti)	0.10
Aluminium (Al)	Balance

Physical Properties of Aluminium Alloy 6082:

Table 2: Physical Properties of AA 6082

Property Value	
Proof Stress 0.2% (MPa)	60
Tensile Strength (MPa)	130
Shear Strength (MPa)	85
Elongation A5 (%)	27
Hardness (BHN)	40
Density (kg/m3)	2700
Melting Point (°C)	555

Application of AA 6082

- Highly stressed applications Ore skips
- Trusses
- Bridges
- Cranes
- Transport applications
- Beer barrels
- Ore skips

LITERATURE REVIEW

Aluminium matrix composites have drawn immense interest for various applications in making aerospace and automobile components due to their high strength to weight ratio, high stiffness, lower cost, good formability and low coefficient of thermal expansion. Particulate–reinforced Aluminium matrix composites (AMCs) are of particular interest due to their ease of fabrication, lower costs, recyclability and isotropic properties. Overall strength of such particle reinforced AMCs depends on size of the particles, the inter-particle spacing, volume fraction of the particles and the nature of matrix and reinforcement interface [1]. Aluminium alloys have important advantages in relation with other structural alloys, because of their higher specific mechanical strengths and corrosion resistance. When an aluminium alloy is reinforced with ceramic particles, an increase in specific strength and stiffness can be obtained, controlling other interested properties [2]. Mechanical properties are one of the most relevant current fields of research. The events that occur on the surface, such as wear, corrosion or stress concentration create regions prone to crack nucleation, which under static or dynamic loading will eventually lead to most components and structures failures. These result in important losses in repairs or unscheduled maintenance operations [3].

Aluminium matrix composites with Al_2O_3 reinforcements give superior mechanical & physical properties. Their applications in several demanding fields like automobile, aerospace, defence, sports, electronics, bio-medical and other industrial purposes are becoming essential for the last several decades. Various manufacturing processes e.g. stir casting, ultra-sonic assisted casting, compo-casting, powder metallurgy, liquid infiltration are being utilized for the production of the aluminium matrix composites. These composite materials possess improved physical and mechanical properties e.g. lower density, low coefficient of thermal expansion, good corrosion resistance, high tensile strength, high stiffness and high hardness and wear resistance. The choice of Alumina as the reinforcement in Aluminium composite is primarily meant to use the composite as very good electrical insulation (1x1014 to 1x1015Ωcm) , Moderate to extremely high mechanical strength (300 to 630 MPa), Very high compressive strength (2,000 to 4,000 MPa) ,High hardness (15 to 19 GPa), Moderate thermal conductivity (20 to 30 W/mK), High corrosion and wear resistance, Good gliding properties, Low density (3.75 to 3.95 g/cm3)[4].

Aluminium based metal matrix composites have been one of the key research areas in materials processing field in the last few decades. Most of the research work has been dealing with aluminium matrix with Al_2O_3 & SiC reinforcement requiring the light weight in combination of high strength and high stiffness [5]. This is because aluminium is lighter weight which is first requirement in most of the industries. In addition, impressive strength improvement and the thermal expansion coefficient of Al matrix composites can be adjusted by using Alumina in varying proportion. Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%, 9%)**.** [6]. Over the past thirty years Metal Matrix Composites (MMCs) have [7] emerged as an important class of material within the engineering industry. At present, MMCs offer attractive performance or weight-saving alternatives for a wide range of applications within the sport industry, from Formula 1 racing components to golf club shafts. This paper briefly reviews the advantages of MMCs, and presents a study of the effects of additional treatments (heat and surface) which produce beneficial characteristics in monolithic and alloy materials, but whose effects become more complex when applied to composites.

The material used for this study was 2124 Al alloy matrix, reinforced with particulate silicon carbide having a mean particle size of around 3μm treatment. The influence of machining parameters [8] such as cutting forces and surface roughness on the mach inability of LM6/ SiC metal matrix composites at different weight fraction of SiC discussed in this paper. It is observed that the depth of cut and the cutting speed at constant feed rate affects the surface roughness and the cutting forces during dry turning operation of cast MMCs. It is also observed that higher weight percentage of SiC reinforcement imparts a higher surface roughness and needs high cutting forces. This experimental analysis and test results on the mach inability of Al/SiC-MMC will provide essential guidelines to the manufacturers. A detailed study [9] on the processing of Al-metal matrix composites cites with the reinforcement of different particulates such as SiC, TiN and TiO_2 was carried out. The results of the present studies show that the Al based composites prepared through various techniques exhibits excellent mechanical, physical and tribological properties and could emerge as promising materials for defence, aerospace and other engineering applications.

With concern [10] increasing over environmental issues, reduction in automobile weight has become more important and has been proved to be effective for improving fuel efficiency. Metal Matrix Composites (MMC) is expected to be useful to cope with these problems. The authors have developed a new aluminium engine block which has the cylinder bore surface structure reinforced with short hybrid fibres of alumina and carbon. The development of aluminium metal matrix composites (Al-MMC) brake rotor and pad was discussed [11].The improvement in fuel consumption rate requires a reduction in vehicle weight. In this study, we developed aluminium metal matrix composites break rotor and pads, which have equivalent braking effects and wear resistance to those of the conventional cast iron rotor, by optimization of the quantities and the particle diameter ratio of hard particles used for the rotor and the pad. Metal matrix composites [12] offer considerable potential for widespread application in most aerospace fields. The potential for the use of these materials in civil aircraft is largely dependent on costs and currently these are too high. However, by the use of appropriate design and manufacturing technology this intrinsic high cost can be overcome to unlock their poten.

FABRICATION

Steps of Fabrication
Melting of AA 6082

Melting point of Aluminium Alloy 6082 is 550ºC. In present work, first of the graphite crucible heated to 600ºC for 10minutes. and work pieces of AA 6082 putted in the heated graphite crucible. Further it heated to 700ºC for completely melt the AA 6082. It takes near about 20minutes.

Figure 1: Melting of Aluminium Alloy 6082

Pre-Heating of Reinforcements

The various reinforcements Al_2O_3, SiC, B_4C and their mixtures are pre-heated for 1 hour to remove the moisture and unwanted gases at 500ºC in muffle furnace.

Stirring

After the melting of alloy the pre-heated reinforcements are added into alloy and melted together for 5 minutes.
Further the liquid mixture of alloy and reinforcement stirred by stirrer rotating at 300rpm for 12 minutes in graphite crucible.

Casting

The stirred liquid metal matrix composite further poured into to sand moulds of 20mm diameter and 1 foot of length as shown in figure 5.2.

Figure 2: Pouring of Liquid MMC

Cooling

After 15 minutes of pouring of liquid composite the solid composite is removed from the sand mould and followed by air cooling.

Figure 3: Casted Metal Matrix Composites

RESULTS & DISCUSSIONS

Mechanical Testing
Hardness Test

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Some material such as metal, are harder than others. In present work, IS 1500(Part-1)-2013 Brinell hardness test method is used to find out the hardness of fabricated composites. In this method aluminium alloy composites are tested using 250Kg test force and a 5mm carbide ball.

Figure 4: Samples after Hardness Test

The following table represents the result of hardness in HBW

OF above sampals;

Table 3: Hardness of Tested Samples

Sample	Composition	Hardness(BHN)
0	Pure AA6082	40
1	AA+7%Al_2O_3	42
2	AA+14%Al_2O_3	46
3	AA+7%SiC	49
4	AA+14%SiC	51
5	AA+7%B_4C	50
6	AA+14%B_4C	54
7	AA+7%Al_2O_3+7%SiC	45
8	AA+7%Al_2O_3+14%SiC	46
9	AA+7%Al_2O_3+7%B_4C	46
10	AA+7%Al_2O_3+7%B_4C	48
11	AA+7%B_4C+7%SiC	50
12	AA+7%B_4C+14%SiC	53

Ultimate Tensile Strength Test

Ultimate tensile strength (UTS) often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. The UTS is usually found by performing a tensile test and recording the engineering stress versus strain curve. The highest point on the stress-strain curve is the UTS. In present work, IS 1608-2005 Universal Testing Method is used to find out UTS in MPa.

Figure 5: Samples after Ultimate Tensile Strength Test

The following table represents the results of Ultimate Tensile Strength of all samples:

Table 4: UTS of Tested Samples

Sample	Composition	UTS(MPa)
0	Pure AA6082	130
1	AA+7%Al_2O_3	133.8
2	AA+14%Al_2O_3	135.4
3	AA+7%SiC	138.7
4	AA+14%SiC	145.6
5	AA+7%B_4C	144.5
6	AA+14%B_4C	153.2
7	AA+7%Al_2O_3+7%SiC	136.0
8	AA+7%Al_2O_3+14%SiC	140.4
9	AA+7%Al_2O_3+7%B_4C	143.6
10	AA+7%Al_2O_3+7%B_4C	145.5
11	AA+7%B_4C+7%SiC	142.7
12	AA+7%B_4C+14%SiC	146.2

Analysis of Results
Effect of Percentages of Powders on Hardness
For all of the reinforcement power it is analysed that with the increase in the percentage of powder the hardness of metal matrix composites increases.

Al_2O_3

Hardness of the pure aluminium alloy 6082 is 40 BHN. As the Al_2O_3 powder is added in AA 6082 the hardness increases with increase in percentage of Al_2O_3

CONCLUSION

The following conclusions may be drawn from present work:

- From the study it is concluded that we can easily fabricate the Aluminium Alloy 6082 composites with Al_2O_3, SiC and B_4C powders by stir casting process at low fabrication cost.
- With the increase in percentage of aluminium oxide power in composition; the mechanical properties such as hardness and ultimate tensile strength increases at a decent rate.
- Both the carbides silicon carbide and boron carbide also improved the mechanical properties; with raise in percentage of both reinforcements the hardness and tensile strength improved.
- The mixtures of these powders improve the mechanical properties in same sense.
- Finer the size of the reinforcement results into the better improvement in the mechanical properties as in case of boron carbide.
- Stir casting process parameters has major role over the mechanical properties of metal matrix composites.
- Preheating of mould might reduces the porosity and better improved the mechanical properties.

SCOPE OF FUTURE WORK

- Other Metal Matrix Composites can be fabricated and tested by using stir casting methods.
- More improvement can be made in mechanical properties of composites by changing the percentage of reinforcements and stir casting process parameters.

REFERENCES

Rupa Dasgupta, Humaira Meenai, "SiC particulate dispersed compositesof an Al–Zn–Mg–Cu alloy: Property comparison with parent alloy", Materials Characterization, 54, 2011, 438-445.

[1] P. P. Lean, L. Gil, A. Urena, Dissimilar welds between unreinforced AA6082 and AA6092/SiC/25p composite by pulsed-MIG arc welding using unreinforced filler alloys, Journal of Materials Processing Technology 143–144 (2008) 846–850

[2] J. Gandra, D. Pereira, R. M. Miranda, R. J. C. Silva, P. Vilaça, Deposition of AA6082-T6 over AA2024-T3 by friction surfacing - Mechanical and wear characterization, Surface & Coatings Technology 223 (2014) 32–40

[3] Mohd Dan.ish, Dr. M. Arif Siddique, "Microstructural & Morphological Evolutions of Al-Al2O3 Powder Composite during Ball Milling", International Journal of Engineering Research & Technology, Vol.1, No.10,2015

[4] M. Jayamathi, S. Seshan, S. V. Kailas, K. Kumar and T. S. Srivatsan, "Influence of Reinforcement on Microstructure and Mechanical Response of a Magnesium Alloy,"Cur-rent Science, Vol. 87, No. 9, 2009, pp. 1218-1231.

[5] K.K. Alaneme, M. O. Bodunrin, "Corrosion Behaviour of Alumina reinforced Aluminium (6063) metal matrix composite",Journal of Minerals & Materials Characterisation &Engineering, Vol.10, no.12, pp 1153-1165,2011.

[6] R. M. Hathaway, P.K. Rohatgi, N. Sobczak, J. Sobczak, "Ferrous composites: A review" , Oshkosh truck corporation, oshkosh, wisconsin, University of Wisconsin –Milwaukee, Milwaukee, Wisconsin, USA, Foundry research institute, Cracow, Poland.

[7] D. Bacon, J. Moffatt, L. Edwards and M.E. Fitzpatrick, "Metal Matrix Composites: In the driving seat", Dept of Materials Engineering, The Open University, Walton Hall, Milton Keynes MK7 6AA A. D. Tarrant Aerospace Metal Composites Limited, REA Road, Farnborough, Hampshire GU14 6XE

[8] Rabindra Behera, S. Kayal, N.R. Mohanta, G. Sutradhard a, "Study on machinability of Aluminium Silicon Carbide Metal Matrix Composites", Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.10, pp.923-939, 2015.

[9] K. Venkateswarlu , A. K. Ray, S. K. Chaudhury and L. C. Pathak, "Development of aluminium based metal matrix composites", National metallurgical laboratory, Jamshedpur - 831007, India.