

Mechanical Behavior and Analysis of Metal Matrix Composite (Al+Sic+Ti)

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Abstract: Aluminum matrix composites (AMC's) reinforced with Silicon Carbide (Sic), Titanium (Ti) particles are being used for high performance applications such as Automotive, Aerospace, Military and Electrical Industries, because of their improved physical and Mechanical properties. Mechanical properties such as Hardness, Impact Strength, and Wear were carried out for different conditions. In the present study a modest attempt has been made to develop aluminum 6063 based silicon carbide (Sic) and titanium (Ti) particulate metal matrix composites (MMC), with an objective to develop a conventional low cost method of producing MMCs. Stir casting techniques used for fabrication of MMC's and the specimen were prepared to carry out the mechanical and NDT test. The results reveal that the Metal Matrix Composite (MMC'S) containing 15% of Silicon Carbide and 10% of titanium reinforcement was shown more improvement in Mechanical properties.

Keywords: Stir Casting Furnace, Metal Matrix Composite, Mechanical Property, NDT

I. Introduction

A composite material is basically a combination of two or more materials, each of which retains its own distinctive properties. Multiphase metals are composite materials on a micro scale, but generally the term composite is applied to materials that are created by mechanically bonding two or more different materials together. The resulting material has characteristics that are not characteristic of the components in isolation. The concept of composite materials is ancient. An example is adding straw to mud for building stronger mud walls. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix; and a dispersed, noncontinuous, phase called the reinforcement. Some other examples of basic composites include concrete (cement mixed with sand and aggregate), reinforced concrete (steel bar in concrete), and fiberglass (glass strands in a resin matrix). The matrix is basically a homogeneous and monolithic material in which a fiber system of a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, serves to transfer load, and provides finish, texture, color, durability and functionality. Composites meeting the criteria of having mechanical bonding can also be produced on a micro scale. For example, when tungsten carbide powder is mixed with cobalt powder, and then pressed and sintered together, the tungsten carbide retains its identity. The resulting material has a soft cobalt matrix with tough tungsten carbide particles inside. This material is used to produce carbide drill bits and is called a metal-matrix composite. A metal matrix composite is a type of metal that is reinforced with another material to improve strength, wear or some other characteristics.

The fundamental design concept of composites is that the bulk phase accepts the load over a large surface area, and transfers it to the reinforcement material, which can carry a greater load. The significance here lies in that there are numerous matrix materials and as many fiber types, which can be combined in countless ways to produce just the desired properties. These materials were first developed for use in the aerospace industry because for certain application they have a higher stiffness to weight or strength-to-weight ratio than metals. This means metal parts can be replaced with lighter weight parts manufactured from advanced composites. Generally, carbon-epoxy composites are two thirds the weight of aluminum, and two and a half times as stiff. Composites are resistant to fatigue damage and harsh environments, and are repairable.

Titanium reinforced with silicon carbide fibers is under development as skin material for the National Aerospace Plane. Stainless steels, tool steels, and Inconel are among the matrix materials reinforced with titanium carbide particles and fabricated into draw-rings and other high-temperature, corrosion-resistant components. In this work, aluminum 6063 along with silicon carbide and titanium is reinforced and formed into a metal matrix composite.

II. Literature Review

EXPERIMENTAL INVESTIGATION AND MECHANICAL BEHAVIOR OF A356.1 ALUMINIUM ALLOY MATRIX COMPOSITE REINFORCED WITH SILICON CARBIDE

[1] PUNEETH.H.M

In this context, A356.1 Aluminium alloy was reinforced with varying weight percentages of 0, 5.0, 10.0 and 15.0 Silicon Carbide, through Stir Casting Technique. The composites were characterized by Scanning Electron Microscope. Mechanical properties such as Hardness, Impact Strength, and Wear were carried out for different conditions. The results reveal that the Metal Matrix Composite containing 15 weight percentage of Silicon Carbide reinforcement was shown more improvement in Mechanical properties

SILICON CARBIDE REINFORCED ALUMINUM METAL MATRIX COMPOSITES FOR AEROSPACE APPLICATION

[2] SURIYANARAYANAN.K

This paper considers the potential of use Al-SiC metal matrix composite (MMC) with particular reference to the aerospace industry. Initially, the required properties are identified, after which, the work explores pure aluminium and its importance in the industry along with its limitations. Using these limitations, MMC's were recommended as a possible replacement for aluminium and it is seen that the exact set of properties depend on certain factors. Therefore these factors such as reactivity at the interface, volume fraction of the reinforcing material, type of the reinforcing material and distribution of the reinforcing material are reviewed using the existing literature. Using the information available, the paper advocates the use of Al-SiC MMC in the fuselage skins of high performance aircrafts. However, it must be noted that the recommendations are purely based on the data available and the author's interpretation of it although every effort has been made to be as logical as possible.

ALUMINUM SILICON CARBIDE AND ALUMINUM GRAPHITE PARTICULATE COMPOSITES

[3] DUNIA ABDUL SAHEB

Metal Matrix Composites (MMCs) have been used in several applications in aerospace and automotive industries. Although several technical challenges exist with casting technology. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite. Experiments have been conducted by varying weight fraction of SiC, graphite and alumina (5%, 10%, 15%, 20%, 25%, and 30%), while graphite weight fraction 2%, 4%, 6%, 8% and 10% keep all other parameters constant. The results indicated that the 'developed method' is quite successful to obtain uniform dispersion of reinforcement in the matrix. An increasing of hardness and with increase in weight percentage of ceramic materials has been observed. The best results (maximum hardness) have been obtained at 25 % weight fraction of SiC and at 4% weight fraction of graphite.

ALUMINIUM METAL MATRIX COMPOSITES - A REVIEW

[4] VIJAYA RAMNATH.C

Aluminum matrix composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the stiffness, specific strength, wear, creep and fatigue properties compared to the conventional engineering materials. This paper presents the overview of the effect of addition on different reinforcements in aluminium alloy highlighting their merits and demerits. Effect of different reinforcement on AMCs on the mechanical properties like tensile strength, strain, hardness, wear and fatigue is also discussed in details.

HYBRID ALUMINIUM METAL MATRIX COMPOSITE REINFORCED WITH Sic and Tib₂

[5] JOHNY JAMES.

In this research work an effort has been made to prepare hybrid aluminum metal matrix composite to study its machining and mechanical properties. The hardness test shows addition of reinforcement Sic and TiB₂ increases hardness value. Wear test analysis proved that the addition of TiB₂ increased the wear resistance behavior of composite. Reinforcement is the most influential parameter which affects surface quality. In this paper, analysis of metal matrix composite with their mechanical properties and behavioral approach has been studied and it is required for many applications.

III. Material Selection and Methodology

In this work, Al 6063 was chosen as the matrix metal and 15 % silicon carbide (SiC) powder and 10 % of titanium alloy powder. The reason for choosing Aluminium 6063 as the matrix metal is because of its excellent properties like good corrosion resistance, medium fatigue strength, very good weldability and convincing machinability.

The metal matrix composite used in the present work was carried out by the stir casting method. Al-Si-Ti alloys in the form of ingots were used.

The cleaned metal ingots were melted to the desired super heating temperature of 750 °C in graphite crucibles under a cover of flux in order to minimize the oxidation of the molten metal.

A three-phase electrical resistance furnace with temperature controlling device was used for melting. For each melting 300 - 400 g of alloy was used.

The super heated molten metal was degassed at a temperature of 780 °C. SiC particulates, preheated to around 500 °C were then added to the molten metal and stirred continuously by a mechanical stirrer at 720 °C.

The stirring time was between 5 to 8 minutes. During stirring, Titanium was added in small quantities to increase the hardness of SiC particles.

The melt, with the reinforced particulates, was poured into the dried, coated, cylindrical permanent metallic moulds 80 mm in diameter and 175 mm high.

The pouring temperature was maintained at 680 °C. The same molten metal SiC particle mixture was poured into strip. The melt was allowed to solidify in the moulds. For the purpose of comparison, the base alloy was cast under similar processing conditions and the melting was carried in a tilting electric furnace in a range of 760 ± 100 °C. The cast composites are sometime further extruded to reduce porosity, refine the microstructure, and distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcement particles during the melting and casting processes.

The finally distribution of the particles in the solid depends on material properties and parameter such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification

The distribution of the particles in the molten matrix depends on the geometry of the mechanical string, string parameters, and placement of the mechanical string in the melt, melting temperature, and characteristics of the particles added.

IV. Mechanical Testing

Mechanical testing reveals the properties of a material when force is applied dynamically or statically. A mechanical test shows whether a material or part is suitable for its intended application by measuring properties such as elasticity, tensile strength, elongation, hardness, fracture toughness, impact resistance, stress rupture and the fatigue limit.

4.1 TYPES OF MECHANICAL TESTING

- Hardness testing
- Tensile testing
- Compression testing

4.2 HARDNESS TEST

The measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Methods include: Rockwell standard testing, Rockwell superficial testing, Knoop & Vickers micro hardness testing, and Brinell hardness testing.

Table 1: Hardness test

S.NO	MATERIAL	INDENTER	LOAD	SCALE	RESULT
1	Al+SiC+Ti Alloys	Diamond cone	150	C	78 HRC
2	Al+SiC+Ti Alloys	Ball	150	B	21 HRB

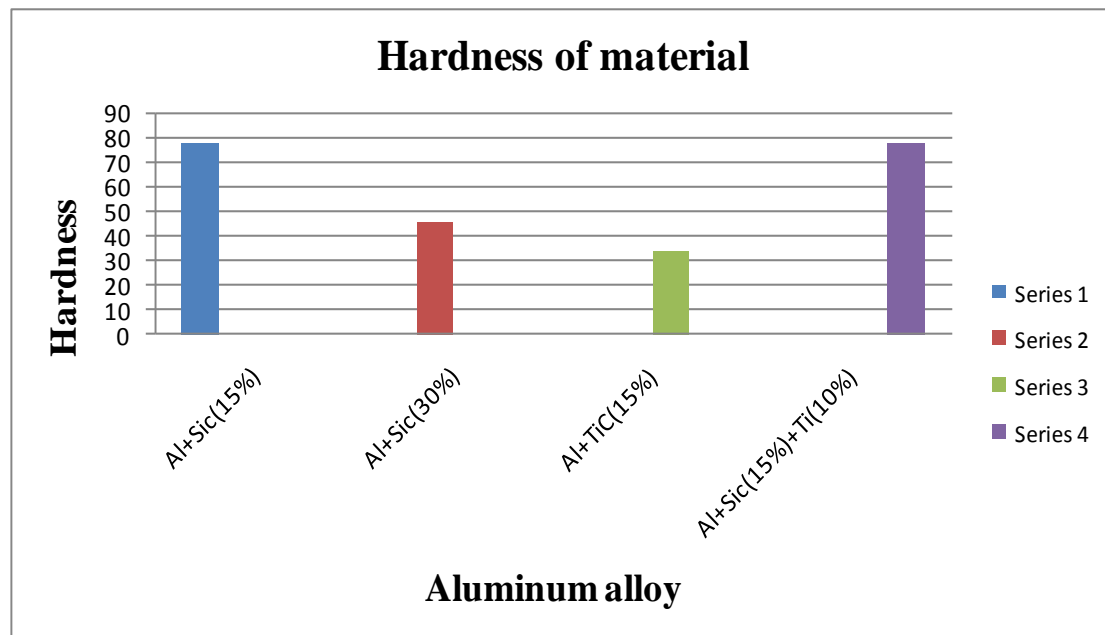


Figure 1: Hardness of material

4.3 COMPRESSION TEST

A compression test is any test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, “squashed”, crushed, or flattened. The test sample is generally placed in between two plates that distribute the applied load across the entire surface area of two opposite faces of the test sample and then the plates are pushed together by a universal test machine causing the sample to flatten. A compressed sample is usually shortened in the direction of the applied forces and expands in the direction perpendicular to the force. A compression test is essentially the opposite of the more common tension test.

Table 2: Compression test

S.NO	SPECIMEN	CROSS SECTIONAL AREA (mm ²)	LOAD (N)	ULTIMATE STRESS (N/mm ²)
1	Al+SiC+Ti	40×25	208	50.44
2	Al+SiC+Ti	50×25	388	79.05

4.4 IMPACT TEST

The charpy test, izod test and other impact testing determines material toughness or impact strength in the presence of a flaw or notch and fast loading conditions. This destructive test involves fracturing a notched specimen and measuring the amount of energy absorbed by the material during fracture.

The izod test, charpy and impact test entail striking notched specimens with a swinging weight or pendulum at a series of temperatures to show the relationship of ductile to brittle transition in absorbed energy. Several machined bar specimens, 1cm x 1cm x 5.5cm with a 2mm deep notch at the middle of a specified flat surface, are required to perform the charpy test. The charpy V-notch test is very common and requires a specimen with a V-shaped notch. The standard izod impact test specimen for ASTM is 64 x 12.7 x 3.2 mm.

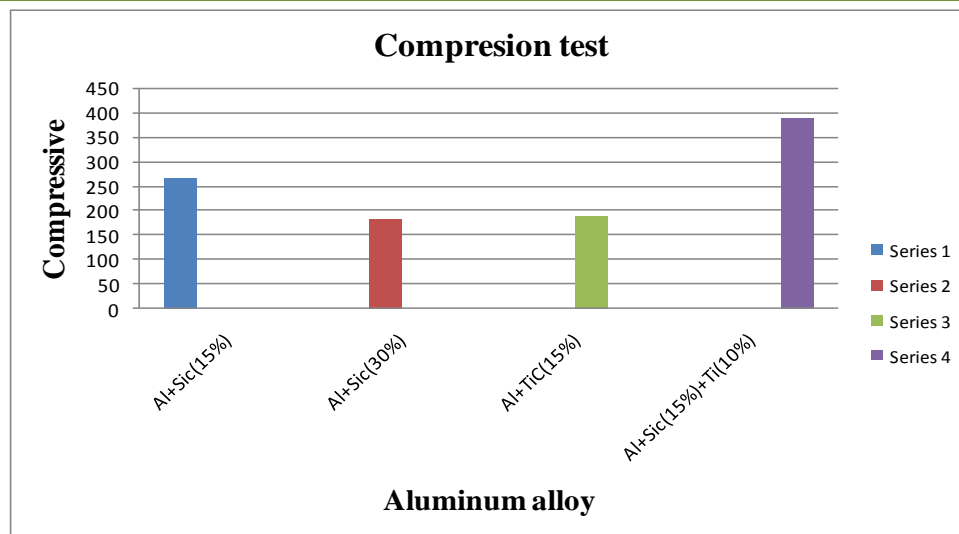


Figure 2: Compression test

Table 3: Charpy test

S.NO	MATERIAL	ENERGY ABSORBED FRICTION		CROSS SECTIONAL AREA	IMPACT STRENGTH
Unit		A(J)	B(J)	mm ²	J/mm ²
1	Al+Ti+SiC Alloys	0	150	50	3.00

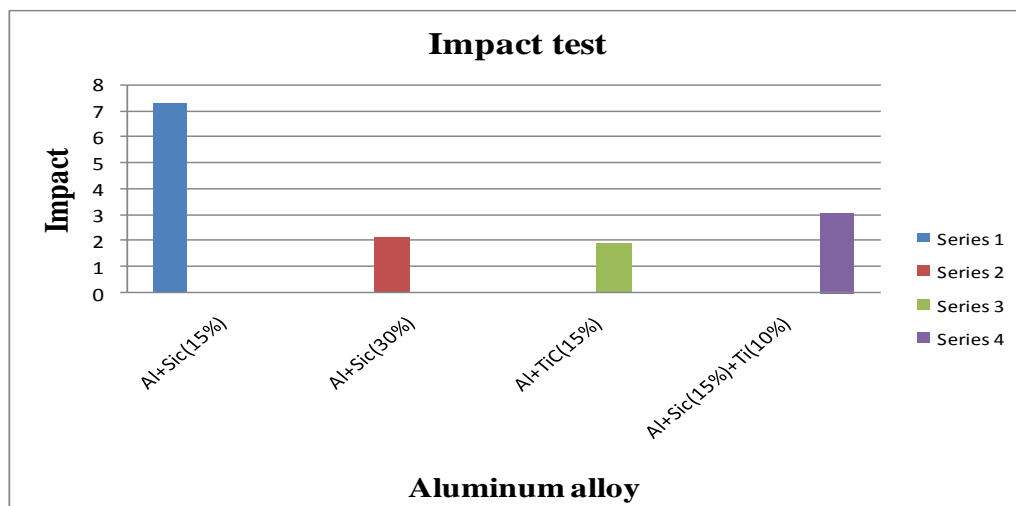


Figure 3: Impact test

V. Non Destructive Testing

Nondestructive testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. Nondestructive evaluation (NDE) is a term that is often used interchangeably with NDT. However, technically, NDE is used to describe measurements that are more quantitative in nature.

In destructive testing, or Destructive Physical Analysis (DPA) tests are carried out to the specimens' failure, in order to understand a specimen's performance or material behavior under different loads.

5.1 METHODS OF NDT

- Visual
- Liquid Penetrant

5.2 VISUAL INSPECTION

- Most basic and common inspection method.
- Tools include fiberoptic, borescopes, magnifying glasses and mirrors.

5.3 LIQUID PENETRANT TESTING

- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen. Visual inspection is the final step in the process.
- The Penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

Table 4: Liquid Penetrant Test details

Penetrant	Penetrant	Visible	yes	Fluorescent			
	Pentrant system	Water washable	–	Post emulsify	-	Solvent removable	Yes
	Brand name	Magnaflux		Solvent			
Remover	Remover	Solvent cleaner		Emulsifier		Yes	
	Brand name	Magnaflux					
Developer	Developer	Wet type		Aqueous	-	Non Aqueous	Yes
	Brand name	Magnaflux					
Test parameter	Light density	1000 flux		Temp:30°C			
	Dwell time	15 min		Developing time:10min			

Table 5: Result

Defect	Mechanical	Mechanical	Mechanical
Distance	2	22	50

VI. Conclusion

- The processing of stir casting route is done with Sic and Ti powder mixed with Aluminum molten metal to produce the Al+Sic+Ti composite in different proportions.
- The mechanical properties of Al+Sic+Ti composites such as Hardness, Compressive strength and Impact strength are studied.
- The Hardness and Compressive properties of MMCs improved with addition of reinforcement particles. Maximum Hardness was achieved when A6063Aluminium alloy was reinforced with 10Wt % of Ti particle content.
- Based on the comparative analysis of mechanical properties, it shows that the formed MMC's are best suitable for tensile and compressive applications.
- It is light weight; compare with other composites Impact is normal.

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