FABRICATION AND ANALYSIS OF ALUMINIUM METAL MATRIX COMPOSITE

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Abstract

Because of its key qualities such as high strength, low density, and superior wear resistance compared to any other metal, aluminium metal matrix composites are gaining broad acceptance for vehicle, aircraft, agricultural farm equipment, and many other industrial applications. The current research focuses on the addition of reinforcements to the Aluminum matrix in different quantities, such as graphite, fly ash, silicon carbide, red mud, organic material, and so on. Each reinforced material has a unique feature that enhances the qualities of the base alloy when combined. An attempt has been made to evaluate the various composite combinations and how they impact the characteristics of the various aluminium alloys.

Introduction

A composite material is made up of two components that have distinct physical and chemical characteristics. When they are mixed, they form a material that is specialised to do a certain task, such as becoming stronger, lighter, or more electrically resistant. They may also help with stiffness and strength. They are preferred over conventional materials because they increase the qualities of their basic materials and may be used in a variety of applications.

Composites have been utilised by humans for thousands of years. The Mesopotamians in Iraq constructed the first man-made composites approximately 3400 B.C. Plywood was made by glueing wood strips at varying angles on top of each other in ancient culture. Following this, the Egyptians began to manufacture death masks out of linen or papyrus wet in plaster approximately 2181 B.C. Later, each of these tribes began to use straw to reinforce their goods, such as mud bricks, pottery, and boats.

Literature review

The Al metal matrix composites offer wide range of properties suitable for a large number of engineering applications. Sufficient literatures are available on different aspects of tribology and machining of conventional metals and alloys but limited literature are available for reinforced metal matrix composites.

Aluminum-Silicon (Al--Si) casting alloys are the most versatile of all common foundry cast alloys in the production of pistons for automotive engines. Depending on the Si concentration in weight percent, the Al--Si alloy systems fall into three major categories: hypoeutectic (<12 wt. % Si), eutectic (12-13 wt. % Si) and hypereutectic (14-25 wt. % Si).However, commercial applications for hypereutectic alloys are relatively limited because they are among the most difficult AL alloys to cast and machine due to the high Si contents.

Mahesh et al (2014)

The properties of strength, toughness, stiffness to weight ratio, great formability, strong corrosion resistance, and high machinability must all be addressed. Hybrid Metal Matrix Composites could be able to help with this problem. Hybrid Metal Matrix Composites are a new kind of material that is light in weight, has a high specific strength, is resistant to wear, and has a low coefficient of thermal expansion. Composite materials are widely used in the structural, aerospace, and automotive industries. MMCs are composed of a metallic matrix with hard ceramic or soft reinforcement. Hybrid MMCs are created by reinforcing the matrix alloy with a variety of reinforcements, each with its own set of properties. Hard ceramic reinforcements, such as SiC, might be employed, while soft ceramic reinforcements, such as graphite, could be utilised.

Shrawan Kumar et al (2017)

In recent years, much study has been done on aluminium metal matrix composites, but because of their lightweight, excellent mechanical, and wear qualities, these materials have a wide range of applications. A study of aluminium metal matrix composites is being conducted in this study, with an emphasis on the aluminium alloy Al6061. Stir casting was chosen for the production of aluminium metal matrix composites because it is a low-cost technology that produces a homogenous combination of the composite's ingredients. Al6061 is used as the matrix material, whereas aluminium oxide, silicon carbide, and copper are used as reinforcing materials. Aluminium MMC is widely used in automobile engine components, body pieces, and brake pads, among other applications.

Nithyanandhan.T et al (2020)

The mechanical characteristics and tribological behaviour of aluminium metal reinforced with silicon carbide and graphite is the subject of this article. For reinforcement, different amounts of silicon carbide and graphite were used. The stir casting process is used to manufacture the components. In this research, mechanical qualities such as fatigue, impact, and microstructure are tested, as well as wear tests. According to the findings, increasing the weight % of reinforcement improves mechanical and tribological qualities.

Composite materials

Classification of Composites

There are two classification systems of composite materials.

Based on Matrix

One commonly used classification of composites is based on matrix used based on the base matrix composites can be divided into three main groups:

- Polymer Matrix Composites (PMCs)
- Ceramic Matrix Composites (CMCs)
- Metal Matrix Composites (MMCs)

MATERIAL USED

- Silicon Carbide
- Magnesium
- Aluminium 1060
- Fly Ash

SILICON CARBIDE

- Silicon carbide is an important non-oxide ceramic which has diverse industrial applications.
- In fact, it has exclusive properties such as high hardness and strength, chemical and thermal stability, high melting point, oxidation

resistance, high erosion resistance, etc.

- All of these qualities make SiC a perfect candidate for high power, high temperature electronic devices as well as abrasion and cutting applications.

Quite a lot of works were reported on SiC synthesis since the manufacturing process initiated by Acheson in 1892.

Silicon Carbide

MAGNESIUM

- lowest density of all metallic constructional materials;
- high specific strength;
- good castability, suitable for high pressure diecasting;
- can be turned: milled at high speed;
- good weldability under controlled atmosphere;
- much improved corrosion resistance using high purity magnesium;
- readily available;

Magnesium

Aluminium 1060

- Aluminium has a unique and unbeatable combination of properties that make it into a versatile, highly usable and attractive construction material.
- Aluminium is light with a density one third that of steel, 2.700 kg/m3.
- Aluminium is strong with a tensile strength of 70 to 700 MPa depending on the alloy and manufacturing process.
- Aluminium has a good formability, a characteristic that is used to the full in extruding. Aluminium can also be cast, drawn and milled.
- Aluminium is very easy to machine.
- Aluminium can be joined using all the normal methods available such as welding, soldering etc.
- A thin layer of oxide is formed in contact withair, which provides very good protection against corrosion even in corrosive environments.
- The thermal and electrical conductivities are very good even when compared with copper.

Aluminium 1060

Fly Ash

- The combustion of powdered coal in thermal power plants produces fly ash.
- The high temperature of burning coal turns the clay minerals present in the coal powder into fused fine particles mainly comprising Aluminium silicate.
- Fly ash produced thus possesses both ceramic and pozzolanic properties.

Fly Ash

METHODOLOGY

Properties of the matrix and the composition of the Conventional monolithic materials have limitations in terms of achievable combinations of strength, stiffness, coefficient of expansion and density. MMC shave emerged as an important class of advanced materials giving engineers the opportunity to tailor the material properties according to their needs. A Metal matrix composite is an engineered combination of two or more materials in which tailored properties are achieved by systematic combination of different constituents. MMC's desirable properties result from the presence of small, high strength ceramic particles, whiskers or fibres uniformly distributed throughout the aluminium alloy matrix.

Aluminum MMC castings are economically competitive with iron and steel castings in many cases. However the presence of these wear resistant particles significantly reduces the machinability of the alloys, making machining costs higher due mainly to increased tool wear. As a result, the application of cast MMCs to components requiring a large amount of secondary machining has been somewhat stifled. Development of these materials is a subject of great interest as they offer attractive combination of physical and mechanical properties, which cannot be obtained in monolithic alloys. Essentially, these materials differ from the conventional engineering materials from the point of homogeneity.

The major advantages of MMCs compared to unreinforced materials are as follows:-

- Higher strength-to-density ratios
- Higher stiffness-to-density ratios
- Better fatigue resistance
- Better elevated temperature properties
- Lower coefficients of thermal expansion
- Improved abrasion and wear resistance
- Improved damping capabilities

MOULDING PROCESS

Moulding is a process for producing simple or complex near net shape castings, maintaining tight tolerances and a high degree of dimensional stability. Moulding is a method for making high quality castings. These qualities of precision can be obtained in a wider range of alloys and with greater flexibility in design than die-casting and at a lower cost than investment casting.

Moulding

The process details

A metal pattern having the desired shape of the casting is heated to 800 – 900^o C. The pattern is sprayed with a solution of a lubricating agent or a release agent containing silicone to prevent the shell from sticking to the pattern. The sand is put in the dump box in sufficient quantity. The pattern is then turned down with its heated face inside the dump box. The dump box is now inverted so that the sand resin mixture falls on the heated metal pattern face. The sand mixture gets heated up and it softens the resin forming a shell on the pattern. Initially the resin becomes sticky. Further additional heat cures it. The dump box is again turned to its original position. The excess sand falls in the dump box leaving a shell on the pattern.

The pattern along with the shell is again kept in the heating oven. This cures the resin in the sand and shell acquires rigidity. On the pattern ejector pins are provided to strip off the shell. After the shells get cooled the two parts are joined properly to form a mould. Fireclay is applied along the edges of the mould to avoid leakage of the molten metal. Shell mould D was used as it had better thickness and had no breakage.

A 1 kg scrap of Aluminium Silicon alloy was charged in a muffle furnace in a clay graphite crucible. The dross floating on the molten alloy was removed by a thin graphite plate. The molten aluminium silicon alloy was poured in the cavity of the shell mould.

Later on the shell mould was broken to remove the casting. The use of safety goggles, gloves, shoes is a must to avoid any accident.

Milling Machine process

Electric Induction Furnance

The induction heating power supply sends alternating current through the induction coil, which generates a magnetic field. Induction furnaces work on the principle of a transformer. An alternative electromagnetic field induces eddy currents in the metal which converts the electric energy to heat without any physical contact between the induction coil and the work piece. A schematic diagram of induction furnace is shown in figure. The furnace contains a crucible surrounded by a water cooled copper coil. The coil is called primary coil to which a high frequency current is supplied. By induction secondary currents, called eddy currents are produced in the crucible. High temperature can be obtained by this method. Induction furnaces are of two types: cored furnace and coreless furnace. Cored furnaces are used almost exclusively as holding furnaces. In cored furnace the electromagnetic field heats the metal between two coils. Coreless furnaces heat the metal via an external primary coil.

Typical Composition of Al 1060 (weight %)

Element	Weight in %
Al	93.50
Cu	4.4
Mg	1.5
Mn	0.6

This matrix was chosen since it provides excellent combination of strength and damage tolerance at high strength applications like structural components and high strength weldments. It also has a high heat dissipation capacity due to its high thermal conductivity.

IMPACT TESTING MACHINE

CHARPY TEST

The charpy test piece rests on alloy steel support anvils, fitted on the base of the machine rigidly held in position by Allen screws. End stopper is provided for quickly and accurately locating the test piece centrally between the supports.

CHARPY TEST			
S.NO.	TOTAL ENERGY	ABSORBED ENERGY	RASIDUAL ENERGY = TOTAL ENERGY - ABSORBED ENERGY
1	300	35	265
2	300	31	269
3	300	27	273
4	300	25	275
5	300	22	277
6	300	20	280

IZOD TEST

The Izod test is clamped vertically in Izod support fitted on the base of the machine. The support is provided with a machined vertical groove to suit the test piece size. The front clamp piece and the Allen screw enable clamping of the test piece in correct height with the help of Izod setting gauge supplied.

I-ZOD TEST			
S. NO	TOTAL ENERGY	ABSORBED ENERGY	RESIDUAL ENERGY= TOTAL-ABSORBED
1	164	56	108
2	164	52	112
3	164	42	122
4	164	32	132
5	164	27	137
6	164	22	142

UNIVERSAL TESTING MACHINE

This consist of a hydraulic cylinder motor with chain and sprocket drive and a table coupled with the ram of the hydraulic cylinder, mounted on to a robust base. The cylinder and the ram are individually lapped to eliminate friction. the upper cross head is rigidly fixed to the table by two straight columns the lower cross head is connected to two screwed columns which are driven by a motor , axial loading of the ram is ensured by relieving the cylinder and ram of the any possible side loading by the provision of ball seating Tension test is conducted by gripping the test specimen between the upper lower cross-head s compression traverse , bending shear and hardness tests are conducted between the lower cross-head and the table. The lower cross head can be raised or lower rapidly by the operating the screwed columns thus, facilitating ease of fixing of the test specimens.

S.NO	**DIAMETER(D)**	**LENGTH(L)**	**LOAD (KN)=P**	**ELONGATION=P.L/A.E AREA= πD2/4**
1	20mm	90mm	32	0.201mm
2	20mm	83mm	30	0.176mm
3	20mm	100mm	28	0.152mm
4	20mm	100mm	25	0.143mm
5	20mm	100mm	23	0.133mm
6	20mm	100mm	20	0.126mm

Rockwell cum Brinell hardness testing machine

ROCKWELL CUM BRINELL HARDNESS TESTER				
S.NO	HARDNESS	MATERIAL	LOAD APPLIED(KGF)	INDENTOR
1	(79+78+78.5)/3=78.5	ALUMINIUM	100	BALL
2	(88+89+87)/3=88	ALUMINIUM	100	BALL
3	(82+86+85)/3=84.3	ALUMINIUM	100	BALL
4	(87+86+83)/385.3	ALUMINIUM	100	BALL
5	(86+89+87)/3=87.3	ALUMINIUM	100	BALL
6	(79.5+80+79.5)/3=79.6	ALUMINIUM	100	BALL

CONCLUSION

The relevant materials and the selection criteria have been collected and identified. The composite metal is fabricated, hot rolled and the analysis of the fabricated composite with edged cracks is studied and the outcome will be the solution for different applications of the composite material in the field of aerospace and automotive industries.

Final composite Material

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