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ANALYSIS OF ALUMINIUM AL7075 COMPOSITES REINFORCED WITH BORON CARBIDE (B4C)

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***Abstract*:**

Aluminium is a material which has an exclusive advantage of light weight and high thermal conductivity which can be improved by reinforcing aluminium with various composites (viz) zinc, Magnesium and Copper which are the major constituents of Al7075 series. In this zinc is a primary alloying material. This makes this composite strong like steel and with good fatigue strength but has less corrosion resistance than other Aluminium alloys. This property is enhanced by reinforcing with new materials which are stronger and lighter. The individual components remain separate and distinct with finished structure.The matrix material surrounds and support the reinforcement by maintaining the relative position. Some of the important Aluminium matrix composites are Al7075-TiC(Titanium Carbide), Al 7075-B4C(Boron Carbide), and Al 7075-SiC-Al2O3 Silicon carbide, Boron Carbide and Alumina. The above mentioned Aluminium composites are made by stir casting process in which the base material (Aluminium) is heated inside a furnace and in its molten state the various constituent materials are added in specific quantities at specific temperatures accompanied by stirring at a constant speed using stir casting set up for obtaining different Aluminium composites. These composites are of varied properties which are much desired in various applications.

1. Introduction

A Metal Matrix Composite(MMC) is composite material with at least two constituent parts, one being metal and the other material may be different metal or any material such as ceramic or organic compound. The Metal Matrix composites are metals in which particles; fibers are added in various compositions. These MMCs can be made to be light weight along with other properties like high strength, high elastic modulus, high toughness, resistance to impact, low sensitivity to temperature changes, high surface durability, low sensitivity to surface flaws, minimum moisture absorption (corrosion resistance). Generally Aluminium alloys lack in wear resistance which can be improved by reinforcing with various material as composites.

Al7075 is a matrix metal alloy with zinc as the major alloying element. It is a strong alloy with a very good fatigue strength and average machinability but has less resistance to corrosion. The properties of these Al7075 can be enhanced by reinforcing it with various particles like Titanium carbide(TiC), Silicon carbide(SiC), Boron carbide(B4C), Alumina etc.

The chemical composition of various elements of Al7075 composite is elucidated in the following table:

Element	**Chemical Composition (%)**
Zinc	5.1-6.1
Magnesium	2.1-2.9
Copper	1.2-2
Iron	0.5
Silicon	0.4
Manganese	0.3
Chromium	0.18-0.28
Titanium	0.20
Aluminium	Major Composition

1.1. Reinforcing Materials

1.1.1 Titanium carbide(TiC)

The Aluminium Metal Matrix Composite's (AMMC) discussed under this topic contain 2-8% weight of Tic, 3-12% weight of graphite and alumina by 6% weight. A detailed analysis has been carried out in cast condition to ascertain its mechanical and tribological properties

1.1.2 Boron Carbide (B4C)

It is an extremely hard Boron Carbon ceramic; one of the hardest known materials next to Cubic Boron Nitride and Diamond. At 7.5 % weight of B4C, its Vickers hardness, bending strength and compressive strength are 184.30 HV, 813 MPa and 895 Mpa respectively. These samples are tested for hardness, Tensile, compression, Flexural strength and wear behavior.

1.1.3 Carbides and Alumina (Al2O3)

Micron sized Silicon carbides(SiC), Boron carbides(B4C), and Alumina (Al2O3) are added to Al-7075 alloy to get the necessary Aluminium Metal Matrix Composite. This type of composites contains 6-8% of SiC,6-8% of B4C,and 4-8% of Alumina (Aluminium oxide). These elements are added to the Aluminium composites improve their properties which are more desirable for various applications.

2. Experimental procedure

Three different type of Aluminium composites are to be made as individual components which are distinct from each other in many aspects like grain structure, composition, properties, heat treatment etc. Composites are made of matrix and reinforcement. At least one portion of each type is essential to make three different composites. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions.

The aluminium composites are to be reinforced with Titanium Carbide, Boron Carbide, Silicon carbide and Alumina and composites are prepared by stir casting process. This is an efficient process which influences the final micro structure and enhances the mechanical properties of the composites.

2.1 Materials preparation

The three different types of Aluminium composites are to be prepared by “Stir casting” which is an efficient process for the fabrication of Aluminium matrix composites. The 1)Al7075-TiC composite is produced with titanium carbide having 2-10% weight of the total composite. Another Aluminium composite 2)Al7075-B4C composite with 7.5% weight of B4C is also prepared by stir casting. 3) Al7075-SiC-Al2O3-Aluminium composites with considerable amounts of carbide and alumina are also prepared to examine the properties of Aluminium composites under various loads. Some of these stir casted components are heat treated so as to test the properties of the composites before and after heat treatment.

2.2 Specimen testing

The prepared specimens are subjected to various tests to examine their enhanced properties. These tests provides scale to compare the casted specimen with other materials and to bring out the desired properties which may utilized for the betterment of machine elements which are much needed in the Industry. By analyzing the test results, the better AMMC material can be selected among the three specimens.

The types of test conducted are elucidated below:

2.2.1 Hardness

The hardness tests are carried out in the specimen using Vickers Hardness testing machine, to test the micro hardness of each and every specimen. During testing of the specimen, indentations are made on them by applying a specified amount of force. The Hardness number represents the hardness of the material tested which is an important requirement of an machine element.

(i) TiC

In testing the hardness of the TiC composite, a lower amount of load is applied on the composite for indentation. Diamond indentation is observed. This indentations caused are very small and microscopic measurements are necessary for accurate readings. The uniform distribution of TiC in the composites is also responsible for increasing the hardness of Al7075 in addition to sintering temperature which increases the bonding between matrix-reinforcement particles and makes it stronger.

(ii) B4C

Hardness is tested by applying pressure which has a limited effect on the hardness values of the samples for a given amount B_4C which is thought to be based on the improved densification of the samples due to the casting pressure. On the other hand, B_4C addition significantly improves the hardness of the samples regardless of the casting pressure. Hardness of the Al7075 with B_4C samples was found to be almost 50% greater as compared to pure Al samples.

(iii) SiC and Al2O3

Hardness testing of pure Al7075 and its composites containing SiC and Al2O3 are carried out in similar manner. Indentations are caused by applying forces of definite quantity and the corresponding hardness numbers are determined for each and every sample. The average hardness number are calculated and tabulated.

2.2.2 SEM analysis

SEM stands for scanning electron microscope. It is a type of electron microscope which uses a focused beam of electrons instead of light to produce images of a given sample. It helps researchers to examine much larger variety of specimens under magnifications in the range of 500, 1000, 1500 and 2000 times. It has a large depth of field which allows

over 10 to 1,00,000. It has a higher resolution so that closely placed specimen can be magnified multifold.

The Al7075 composites containing Tic, B4C, SiC, Al2 O3 and Graphite reinforcements in varies percentage are analysed under SEM and their images are obtained at varied magnifications.

2.2.3 Test on Wear property

The Wear test on the Al7075 composites are carried out in Pin –On Disk apparatus. It is table top equipment containing a stationary"Pin" under an applied load in contact with a rotating disk. It is configured with a system control with Tribox software. It is a simplified instrument for conducting Tribological test for all instruments. The pin with a radiused tip is positioned in perpendicular to other flat circular disk. A ball, rigidly held is used as a pin specimen. The pin specimen is pressed against the disk at a specific load by hydraulic or pneumatic loading methods. The pin on disk apparatus can provide a variety of results which are obtained through different testing conditions and operating parameters.The materials are tested in pairs under nominally non-abrasive conditions. The wear test is reported as volume loss in cubic millimeters for the pin and disk separately.

2.3 Results and discussion

The three major tests namely the hardness test, wear test conducted on pin on disc apparatus and finally scanning electron micro scope (SEM) analysis were conducted on the prepared Aluminium metal matrix composite specimen .These above tests were conducted to determine the tribological properties of the prepared samples containing different constituent materials at various compositions.

Aluminium and its alloy based MMC's are the most needed materials for the future automobiles, aviation and other applications. The preparation and experimentation of Al7075 alloys reinforced with varied weight fractions of Boron carbide, Titanium carbide, Silicon carbide and Alumina were successfully done by using powder metallurgy technique. Tribological tests are conducted to determine wear loss, physical properties like density, and mechanical properties such as compression and hardness of the composites are evaluated and SEM analysis is carried out to observe the micro structural uniformity and distribution of reinforcement materials in the metal matrix.

The various conclusions that were arrived from the obtained test results are as follows,

- Al7075 alloy MMC's reinforced with various weight percentages of B4C, TiC, SiC, and Al2O3 (containing 2%, 4%, 6%, 8% by weight of the composites) which are produced by powder metallurgy strategy along with stir casting method for producing the specimen rods, showed some improved properties.
- Hardness test revealed that that with sintering temperature (450C to 600C) and reinforcement containing Tic (2% to 8%), B4C (up to 6%), and graphite (up to 9%) the hardness was higher and it was also increased when compared with the base Al7075 alloy matrix. It can be concluded that the hardness properties got increased after the addition of carbide particles in the matrix.
- Wear test results showed that addition of TiC by 10% in the total weight of the composite has increased wear resistance significantly. Also the wear rate is observed to be very less for the material composition having 11% B4C and 5% graphite and a satisfying wear resistance is obtained for material having a composition of 6% B4C and 9% graphite.
- SEM images of the metal matrix composites containing various reinforcements at various weight percentages are obtained and it is observed that the B4C, SiC, & Al2O3 particles are homogeneously dispersed through the metal matrix of the aluminium composites. From this it can be inferred that the properties of the composites are improved due to the equivalent dispersion of reinforcement particles in the base alloy.
- In the wear test conducted in Aluminium composites containing various reinforcements, the sample containing SiC (upto 8%), B4C (upto 8%), and Al2O3 (upto 4%) is observed to have highest coefficient of friction for a load of 20N and another sample containing SiC (upto 7%), B4C (upto 7%), and Al2O3 (upto 6%) has the highest friction coefficient fo a time period of 360 seconds.
- From all the above test results, the final inference obtained is that the Aluminium MMC containing SiC (upto 8%), B4C (upto 8%), and Al2O3 (upto 4%) has been found to have better hardness, lowest wear rate than Aluminium metal and other Aluminium composites irrespective of the increase in load for a time period of 360 seconds.

2.4 Future scope

- ✓ These composites can find application in places where Aluminium has been exclusively used such as aerospace industries, heat exchangers, Disc brakes, etc.
- ✓ These can be used as replacement for heavy materials such as cast iron(hardness 140-200) in specific parts.

- ✓ This type of Aluminium composites can be used in places which require high strength to weight ratio.
- ✓ Hence, Aluminium metal matrix composites can replace Aluminium owing to its high strength and enhanced properties compared to the Aluminium metal.