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Research Article

Synthesis and Characterization of Aluminium 6061 Alloy-Flyash & Zirconia Metal Matrix Composite

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Abstract

The results of an experimental investigation of effect of reinforcement (Zirconia+ Fly Ash) on mechanical properties of aluminium alloy (Al 6061) composites samples, processed by stir casting method are reported in this paper. Two sets of composites were prepared with fixed percentage of fly ash (10%) & varying percentage of Zirconia (5% & 10%) by weight fraction. The evaluated properties of the samples were tensile strength, hardness and percentage elongation. In the presence of Zirconia and fly ash with aluminium, it was fairly observed that the hardness was increased. Correspondingly, the increase in tensile strength was also observed but elongation of the hybrid metal matrix composites in comparison with unreinforced aluminium was decreased. From the experiment it was observed that the best properties were obtained from the sample containing (Fly ash (10%) + Zirconia (10%)) as compared to the base metal. The characterization of the best obtained sample was done by Scanning electron microscopic machine & image analysis.

Keywords: *Aluminum 6061, Hybrid MMC's, Fly Ash, Zirconia, Stir casting*

Introduction

Composites are one of the most advanced & adaptable engineering materials. A fast progress in the field of material science & technology has given birth to these fascinating & wonderful materials. Composite are heterogeneous in nature. Composite material is composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents. The matrix may be me metallic, ceramic or polymeric in origin T.W. Clyne, P.J. Withers (1993). It gives the composites their shape, surface appearance, environmental tolerance & overall durability. A composite material can provide superior & unique mechanical & physical properties because it combines the most desirable properties of its constituents while suppressing their least desirable properties.

Composite materials have high specific stiffness and strength for weight savings and durability) F.L.Matthews *et al* (1995). They have outstanding wear resistance for longevity and reduced maintenance. High thermal conductivity for rapid heat dissipation Low coefficient of thermal expansion for dimensional stability components and structures made from ceramic reinforced metal by casting or infiltration processes are being used in products for robotics, sporting goods, industrial process equipment, electronics packaging, aerospace, medical instrumentation, and automotive applications.

Choice of Matrix

Al 6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use T.W.Clyne (2001). Commercial grade Aluminium alloy 6061 was obtained from R. Kumar & Co., Chawri Bazaar Delhi which in turn had acquired it from Aditya Birla Group Hindalco, Mumbai.

Aluminum 6061 was chosen because 6061 Aluminium shows: good formability, weldability, high corrosion resistance; the most economical of the heat-treatable aluminium.

Chemical Composition of Aluminium 6061

Table1 Chemical Composition of Aluminium 6061 alloy

Manganese (Mn)	0.15%
Iron (Fe)	0.70%
Copper (Cu)	0.15 - 0.40%
Magnesium (Mg)	0.15%
Silicon (Si)	0.4 - 0.8%
Zinc (Zn)	0.25%
Chromium (Cr)	0.4 - 0.35%
Others (Total)	0.05- 0.15%
Aluminium (Al)	95.8-98.6%

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Comparing the theoretical and practical values of the various properties of base metal i.e. aluminum 6061 alloy which were being calculated at CITCO, Chandigarh

Table 2 Comparison between Theoretical & Practical Values

S.No	Mechanical properties	Theoretical values	Practical values
1	Ultimate tensile test	241MPa	223MPa
2	Yield strength	145MPa	190 MPa
3	Hardness vickers	75	78
4	% Elongation	25%	21.66%

Experimental Procedure

Stir Casting method was used for making the MMC samples. Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) 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 Satyanarayana KG *et al* (2007).

Stir Casting is characterized by the following features:
- Content of dispersed phase is limited (usually not more than 30 vol. %).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous.
- The technology is relatively simple and low cost.

The fixed quantities of fly ash (10Wt. %) & Zirconia (5% &10%) were taken in powder form in suitable crucibles. Then the reinforcements were heated to 450̊ C and maintained at that temperature for about 20 min. M. Mabuchi *et al* (1991). The weighed quantity of Al (6061) alloy was melted in a crucible at 950̊ C. The molten metal was stirred to create a vortex and the weighed quantities of preheated reinforcements were slowly added to the molten alloy. After mixing the melt was poured into a prepared mould for the preparation of specimen. The following figure shows the laboratory setup for the stir casting apparatus.

Fig1 Inside View of Stir Casting Furnace

Fig 2 Stir Casting Appratus

Table 3 Chemical composition of samples

Chemicals	Zirconia(%)	Fly Ash (%)
S-I	5	10
S-II	10	10

Testing of Properties

The Testing of the prepared samples was done from Chandigarh Industrial & Tourism Development Corporation limited (CITCO) . It is a government undertaking institute which is equipped with latest technology, sophisticated and computerized equipment's and machines which are capable of giving results of very high accuracy. The well trained, educated and experienced staff is dedicated to produce results with great precision) P. Shanmughasundaram *et al* (2011).

The following tests were conducted on the base metals and the samples prepared

- Tensile testing done on UTM
- Vickers Hardness Testing
- % Elongation Test

Tensile Behaviour

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uni-axial tension untill failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces F.J. Humphreys (1990).

Fig 3 Universal Testing Machine

Mechanical Properties Observation

Table 4 Tensile Testing Result of each Specimen

Samples	S-I	S-II
Area of Specimen	222	255.6
Tensile Strength(Composite) N/mm^2 (Mpa)	252	278
Tensile Strength(BaseMetal) N/mm^2 (Mpa)	233	233
%Elongation	1.23	2.34

Hardness

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material The Vickers hardness test method, also referred to as a microhardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a few grams to one or several kilograms, although "Macro" Vickers loads can range up to 30 kg or more. T. Lim (1992).The Microhardness methods are used to test on metals, ceramics, composites - almost any type of material. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH). The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not a pressure.

Table 5 Vickers Hardness Testing Result of each Specimen

Samples	HV	HV	HV	HV	HV
	-1	-2	-3	(AVG)	Base Metal
S-I	82	85	84	83	78
S-II	94	96	95	94	78

Scanning Electron Microscope Apparatus

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, and (in environmental SEM) in wet conditions.

The most common mode of detection is by secondary electrons emitted by atoms excited by the electron beam. The number of secondary electrons is a function of the angle between the surface and the beam. On a flat surface, the plume of secondary electrons is mostly contained by the sample, but on a tilted surface, the plume is partially exposed and more electrons are emitted. By scanning the sample and detecting the secondary electrons, an image displaying the tilt of the surface is created.

Fig.5 Hitachi VP-SEM S-3400N scanning electron microscope (SEM)

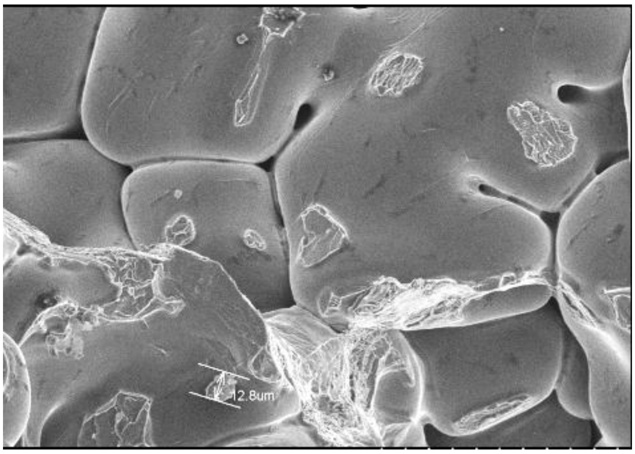

Fig.6 Microstructure of Aluminum, Flyash and zirconia melt casted

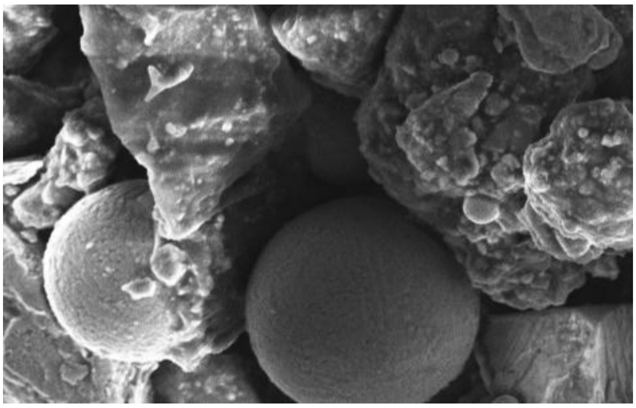

Fig 7. Spherical dark particles as Zirconia,rest Flyash whereas shiny layer is aluminum

Conclusion

Results presented in this paper reveal the effect of the reinforcement on Mechanical properties of Al6061 alloy Composites which were fabricated by the stir casting method. Mechanical properties such as hardness and ultimate tensile strength were improved, when compared with the unreinforced alloy. Composite containing10 wt. % ZrO_2 fabricated at 950˚C showed the maximum value of the hardness and ultimate tensile strength in comparison with other specimens which could be attributed to the presence of ZrO_2particles, dislocations density increasing and their pile-ups behind the uniformly distributed ZrO_2 particles. T. Matsunaga *et al* (2002)Thus, it can be concluded that the optimum fabrication conditions of the composite processing was provided with 10wt% ZrO_2 & 10% FlyAsh.

Aluminum alloy 6061 had measured tensile strength of 233 MPA which was increased to maximum of 278 MPA having the increase in the range of 11-20%.

Secondly, hardness value of 78 was increased to maximum of 94 and with the range of 6-15% increase with the addition of different weight % of Zirconia & fixed % of flyash.

Thirdly, Aluminum alloy 6061 had the measurable elongation of 21.66% which was considerably reduced to minimum of 85% to maximum of 90% due to the addition of ceramic material.

Scope of the Future Work

The study can be extended by the addition of other materials with aluminium 6061. Wear and corrosion studies can also be carried out.

Also it would be interesting to note the results of MMC that would be prepared with other methods e.g. ball milling, with the same %wt. of the particulate other than stir casting technique.

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