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The Effect of Various Reinforcements on Aluminium Alloy (Al7075) – A Review

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Abstract—*Aluminium is the most predominant and suitable material as a alternate for steel owing to its less weight and that's why is application is spreading enormously. The alloying elements with aluminum contribute to the strength, hardness, corrosion resistant, working temperature to a certain level. Tailored material with Aluminium is possible when it reinforced with many material for various application. These Composite materials are right now the search of materials engineers to all over the world to fit the exact materials for their products. Aluminium alloy Al7075 is the material of interest in aerospace and automotive application because of its flexibility and tailorablity. Here an attempt is made to review various reinforcement involved with Al7075 Alloy and their effect in contributing to the properties of the parent material.*

Keywords: *Metal Matrix Composite (MMC), Reinforcement, process parameters*

I. INTRODUCTION

The aluminum metal matrix composite materials is the combination of two or more constituents in which one is matrix and other is filler materials (reinforcements). Aluminum metal matrix may be laminated, fibers or particulates composites. These materials are usually processed through powder metallurgy route, liquid cast metal technology or by using special manufacturing process. The processing of discontinuous particulate metal matrix material involves two major processes powder metallurgy route and liquid cast metal technology. The powder metallurgy process has its own limitation such as processing cost and size of the components. Therefore only the casting method is to be considered as the most optimum and economical route for processing of aluminum composite materials. Ceramic particulate reinforced Al-alloy composites led to a new generation tailorable engineering materials with improved specific properties. The structure and the properties of these composites are controlled by the type and size of the reinforcement and also the nature of bonding. From the contributions of several researchers, some of the techniques for the development of these composites are stir casting powder metallurgy, spray atomization and co-deposition, plasma spraying and squeeze-casting. Manufacturing of aluminum alloy based casting composite materials via stir casting is one of the prominent and economical route for development and processing of metal matrix composites materials. Properties of these materials depend upon many processing parameters and selection of matrix and reinforcements. The above processes are most important of which, liquid metallurgy technique has been explored much in these days. Therefore the present paper summarizes the studies conducted by several investigators under sections mechanical and tribological behavior. The factors that determine properties of composites are volume fraction, microstructure, homogeneity and isotropy of the system and these are strongly influenced by proportions and properties of the matrix and the reinforcement. Also an overview of stir casting process, process parameter, &preparation of AMC material by using aluminium as matrix form and ceramic materials as reinforcement by varying proportion.

The properties of the Al7075: Elastic Modulus (Gpa) = 70-80, Density (g/cc) =2.81, Poisson's Ratio=0.33, Hardness (HB500) =60, Tensile Strength (T) =220(MPa).

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Zinc (Zn)	Magnesium (Mg)	Copper (Cu)	Iron (Fe)	Silicon (Si)	Manganese (Mn)	Titanium (Ti)	Chromium (Cr)	Aluminium (Al)
5.1-6.1	2.1-2.9	1.2-2	0.5	0.4	0.3	0.2	0.18-0.28	87.1-91.4

II. Casting Processes

A. STIR Casting

In Stir casting route method of composite materials fabrication, 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. The stir casting methodology is relatively simple and low cost. This can usually be prepared by fairly conventional processing equipment and can be carried out on a continuous and semi continuous basis by the use of stirring mechanism.

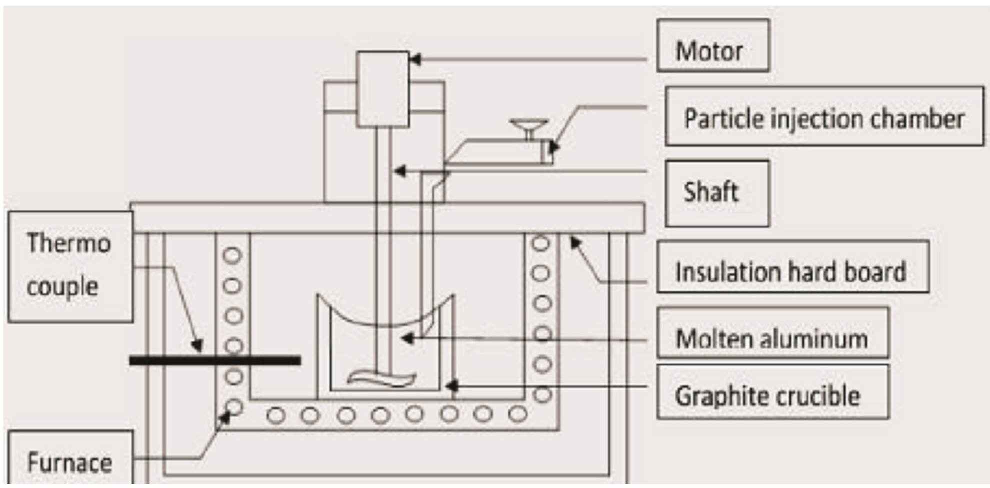

Fig 1 Stir casting setup

B. Compo-Casting

A recent development in stir casting process is a double stir casting or two-step mixing process. In this process, first the matrix material is heated to above its liquidus temperature. The melt is then cooled down to a temperature between the liquidus and solidus points to a semi-solid state. At this point the preheated reinforcement particles are added and mixed. Again the slurry is heated to a fully liquid state and mixed thoroughly. In double stir casting the resulting microstructure has been found to be more uniform as compared with conventional stirring. The potency of this two-step mixing method is mainly due to its ability to break the gas layer around the particle surface which otherwise impedes wetting between the particles and molten metal. Thus the mixing of the particles in the semi-solid state helps to break the gas layer because of the abrasive action due to the high melt viscosity.

C. Squeeze Casting

Squeeze casting is also known as liquid metal forging is a combination of casting and forging process. The molten metal is poured in the bottom half of the preheated die. As the metal starts solidifying the upper half closes the die and applies pressure during the solidification process. The amount of pressure thus applied is significantly less than used in forging, and part of the grade detail can be produced. Coring can be used with this process to form holes and recesses. The porosity is low and mechanical properties are improved. Both the ferrous and non-ferrous materials can be produced using this method.

D. Centrifugal Casting

Centrifugal casting or roto-casting is a casting technique that is typically used to cast thin-walled cylinders. It is used to cast such materials as metal, glass, and concrete. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use. In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured. The molten

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metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away. Casting machines may be either horizontal or vertical-axis. Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings. Most castings are solidified from the outside first. This may be used to encourage directional solidification of the casting, and thus useful metallurgical properties to it. Often the inner and outer layers are discarded and only the intermediary columnar zone is used.

E. Powder Metallurgy

Powder metallurgy is a term covering a wide range of ways in which the materials are components are made from metal powders. Powder metallurgy process can avoid are greatly reduce the need to use metal removal processes, thereby drastically reducing a yield losses in manufacturing and often resulting in lower cost. Power metallurgy is also used to make unique materials impossible to melt or form in other ways.

III. Major Reinforcements

A. Silicon Carbide

Silicon Carbide is also known as Carborundum. Silicon carbide posses high strength, high elastic modulus, high toughness and impact resistance, low sensitivity-to changes in temperature or thermal shock, high surface durability, low sensitivity to surface flaws, high electrical and thermal conductivity, minimum exposure to the potential problem of moisture absorption resulting in environmental degradation, and improved fabric ability with conventional metal working equipment. The effects of the test temperature on the impact behaviour of all materials were not very significant.

B. Boron Carbide

B4C is a robust material having excellent chemical and thermal stability, high hardness (HV=78), and low density (2.52 g/cm3) and it is used for manufacturing bullet proof vests, armor tank etc. Hence, B4C reinforced aluminum matrix composite has gained more attraction with low cost casting route.

C. Fly ASH

Fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products. Fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides is used as reinforcing phase. The major constituents of flyash are SiO2, Al2O3, Fe2O3, and CaO.

D. Carbon Nano Tubes

Carbon nanotubes are allotropes of carbon with a cylindrical nano structure. Nano tubes have been constructed with length-to-diameter ratio upto 132000000:1, significantly larger than for any other material. Single walled and multi-walled carbon nanotubes have elastic modulus of up to 1TPa, and yield strengths as high as 50GPa .The addition of carbon nanotubes (CNT) into various materials as a reinforcing fibre is a topic of much recent interest. In addition to good chemical and thermal stability, CNT's demonstrate high yield strength and elastic modulus values.

E. Titanium Carbide

Titanium carbide is an extremely hard refractory ceramic material, similar to tungsten carbide .It has the appearance of black powder with the sodium chloride crystal structure. Titanium carbide is high elastic modulus, extreme hardness and temperature resistant properties, TiC ceramic particles are often used as reinforcement within the aluminum matrix. TiC is also relatively inexpensive an exhibits good wetting characteristics in molten aluminum.

F. Aluminium Oxide

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al2O3. Corundum is the most common naturally occurring crystalline form of aluminium oxide. Rubies and Sapphires are gem-quality forms of corundum.

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Aluminium oxide is an electrical insulator but has a relatively high thermal conductivity for a ceramic material. Aluminium oxide is insoluble in water. Aluminum oxide is responsible for the resistance of metallic aluminium to weathering.

G. Silver Nano Particles

Metal nanoparticles are commonly used for surface modification in fiber reinforced polymer composities because of their large specific surface area and electronic, magnatic, other related properties. Nano particles of silver of between I nm and 100 nm in size. While frequently described as being silver some are composed of a large percentage of silver oxides due to their large ration of surface-to-bulk silver atoms.

H. Hybrid Reinforcements

In order to obtain better properties two or more reinforcements are mixed with the base metal in liqiudius state. Depending upon the necessary property, different reinforcements at different composition are alloyed with the base metal.

IV. Effects of Reinforcement

A. Silicon Carbide

[1] Investigated that a significant reduction was observed in the tensile properties of the composites, Stiffness-wise, the monolithic and the n-SiCp reinforced Al composites were found to be similar. However, the addition of 1% vol of n-SiCp drastically reduced the strength and ductility of the composites. This trend continued with an increase in the volume fraction of n-SiCp. The substantial drop in the strength of the composites was found to be caused by the reduced artificial aging of the composites, which was linked to reactivity of Mg with O and its segregation at the grain boundaries and the SiC-Al interface. With the increase in reinforcement ratio, tensile strength, hardness and density of Al MMC material increased, but impact toughness decreased.

Investigation [1] conducted on a study of the high cycle fatigue and investigated the fracture behaviour of 7034/SiC/15p- UA and 7034/SiC/15p-PA metal matrix composites. The modulus, strength and the ductility of the two composite microstructures decreased with an increase in temperature. Experimentally it is found that with addition of Al- SiC reinforcement particles, the composite exhibited lower wear rate compared to Al-Al2O3 composites. Analysed the influence of stirring speed and stirring time on distribution of particles in SiC AMC. The study was about high silicon content aluminium with 10% SiC synthesized using different stirring speeds and stirring times. The analysis revealed that at lower stirring speed and time, the particle clustering was more at some places, by increasing them the distribution resulted better and also it had its effect on hardness of the composite. Uniform hardness values were achieved at 600 rpm with 10 min stirring. investigated about the tool wear and its mechanism for cutting SiC reinforcement which result in shows that the major damage mechanism is abrasive wear on tool flank edge for conventional tools and brittle failure for high hardness tools in the cutting the composites. The major factors affecting tool life are volume fraction of SiC and its size in the composite.

B. Boron Carbide

Aluminium alloys exhibit poor tribological characteristics and restrict their applications which include pistons, cylinder liners in car engines, automotive brake rotors, bearing surfaces, tank tracks, marine drums which is dictated by the surface property. Wear resistant (i.e.) surface metal matrix composite can be obtained by incorporating boron carbide reinforcement. Boron Carbide particulate reinforced [2] aluminium composites possess a unique combination of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy system. A limited research work has been reported on AMCs reinforced with B 4C due to higher raw material cost and poor wetting. Investigations revealed that boron carbide can introduced successfully using friction stir processing and impart higher wear resistance compared to that of other carbides like silicon carbide and tungsten carbide. The test result shows that the attributes like nano-scale dispersoids of Al2O3, crystalline and amorphous AlN and Al4C3, high dislocation densities in both NC-Al and CG-Al domains, interfaces between different constituents, and nitrogen concentration and distribution leads to increase in strength. Investigated the characteristics of surface quality on machining hybrid aluminium-B4C-SiC metal matrix composites using taguchi method. Aluminium alloy reinforced with SiC and B4C were compared and the experiments showed the the wear resistance of SiC reinforced MMC is higher than that of B4C reinforced MMC.

C. Flyash

Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, composite material and reaction at the interface. Fly ash particles are potential discontinuous dis-persoids used in metal matrix composites due to their low

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cost and low density reinforcement which are available in large quantities as a waste by product in thermal power plants. Compared the effect of the three different stir casting methods on the properties of fly ash particles reinforced Al-7Si-0.35Mg alloy. The three stir casting methods are liquid metal stir casting, compo-casting, modified compo-casting followed by squeeze casting. But in addition of fly ash particulate decreases the tensile strength of the composites. Experimentally[3] found that the wear resistance of Al MMC increases with the in- crease in flyash content, but decreases with increase in normal load and sliding velocity, and also observed that the corrosion resistance decreases with the increase in fly ash content.

D. Carbon Nano Tubes

As a result, these materials offer great potential as a reinforcing fibre in composite materials. Some success has already been achieved in incorporating CNTs into polymer and ceramic matrices, and a few studies have focused on the preparation of metal matrix composites (MMC) reinforced with CNTs. In these composites there is evidence of poor interfacial bonding between the CNTs and the metal matrix, and this may be detrimental to the mechanical properties of these composites. Furthermore, agglomeration of the CNTs may produce an uneven dispersion within the matrix which reduces their effectiveness. Potential damage of the nano-tube structure and chemical reactions with the matrix may also reduce the mechanical properties of these composites, as well as their orientation within the matrix. These are all challenges that need to be addressed in optimizing the synthesis of CNT metal matrix composites.

The effects of processing parameters on particle dispersion, and hardness were investigated in Al-alloy reinforced with multi- walled carbon nanotubes by friction stir processing. SEM and TEM confirmed that nanotubes were embedded in the lamellae regions of the Al-alloy stir zone and their multi-walled was retained, how- ever evidence was observed that the nanotubes may have fractured during friction stir processing. It was found[4] that increasing the tool rotation speed from 1500 and 2500rpm and increasing the tool shoulder penetration depth improved the distribution of nanotubes in the Al-alloy matrix. A completely uniform distribution could not be achieved when regularly tangled nanotubes were used as the base material and it is suggested that multiple passes may be required to further improve the dispersion of nanotubes in the matrix.

E. Titanium Carbide

In the present investigation, [5] an attempt has been made to fabricate Al 7075/TIC composites with different weight fractions ranging between 2 and 10%.TiC is particularly attractive as it offers high hardness and elastic modulus, low density, good wettability yet low chemical reactivity with aluminium melts. Al7075 contains 5% Si. Therefore, there is a possibility for undesirable interface reaction between Tic and Al alloy if the processing involes much higher temperature and processing time. Appropriately estimated amount of Alminium alloy was fed into the electric furnace and was melted at 800 C. The magnesium ribbons are added at high temperatures to increase the wettability of aluminum so that the reinforcement added to the metal is evenly dispersed. An appropriate amount (2% of the wt. of base metal) of Titanium Carbide (TiC) powder was then added slowly to the molten metal. The TiC powder added to the molten metal was pre-heated upto 300 C to remove the moisture (if any) in it. Simultaneously, the molten metal was stirred thoroughly at a constant speed of 300 rpm with a stirrer. The high temperature molten metal was poured into the pre-heated (300 C) cast iron moulds to get the required specimens.

F. Aluminium Oxide

The investigations reveled the microstructural observation shows that the aluminium oxide and glass particles are uniformly distributed in the Aluminium alloy 7075 matrix up to 9 wt%. In 12 wt% the dispersoids are agglomerated. The Tensile strength of aluminium matrix composite increased with increase in wt% of Al_2O_3 and glass particles up to 9 wt% found to be 149N/mm2 to 190 N/mm2 and decreases in 12 wt% was found to be 129.17 N/mm2. Micro-hardness of the Al7075-Al_2O_3-glass particles of hybrid metal matrix composites increased with increase in filler content of Al_2O_3 and Glass particles up to 9 wt% found to be 127 to 150 VHN and decreases in 12 wt% was found to be 136VHN.

G. Silver Nano Particles

In this study, Morphology-controllable silver nanoparticles were deposited on a carbon fiber surface via a facile and green electro chemical deposition method in the presence of poly (Vinylpyrrolidone). It was found that the presence of poly and its molar ratio relative to silver nitrate both played important role in determining the geometric shape of Ag NPs. Interestingly, [7] Electro-Chemical deposition of Ag Nps improved both the tensile strength of the carbon single fiber and the interfacial property of the carbon fiber/epoxy composite by as much as 57.2% and 27.2% respectively. The Ag NPs-loaded carbon fibers exhibited superior electrical conductivity, which was a 2-fold enhancement as compared with that of the virgin carbon fiber. It means that the Ag NPs-loaded carbon fibers could be used as ideal reinforcement materials for advanced aerospace systems.

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H. Hybrid Reinforcements

The effect of Al2O3 and graphite addition on the hardness of the hybrid composites results in the increased with increasing Al2O3 ceramic particulates. The hardness of hybrid composites increases with increasing Al2O3 and it was higher than that of base alloy in all compositions. Addition of Al2O3 particle increases the tensile strength, compression strength and flexural strength of the hybrid composite and it was higher than that of base alloy. Addition [8]of graphite to aluminium alloy is known to decrease the hardness, tensile strength, compression strength and flexural strength and it was overcome by the addition of Al2O3 particulates in the hybrid composites. The presence of graphite in the hybrid composites exhibited a trend for keeping the wear, less due to the formation of thin layer of graphite on the tribo surface. The governing wear mechanism is abrasion and delamination. The presence of graphite in the hybrid composite as also been able to decrease the coefficient of friction of the composite and this is attributed to the release of graphite which acted as the solid lubricant during the wear process.

V. Conclusion

Particulate reinforcements are predominantly added to the Al7075 Alloy for improving its properties and as a result the properties are altered when it is subjected to reinforcement. From the above study it is evident that the each reinforcement is added to improve a particular property of the composite and the amount of reinforcement also contributes to the change in the properties. It the choice now in front of us to choose the amount and type of reinforcement to be add with Al7075 aluminum alloy according to our tailored requirement of various properties.

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