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Review the Properties of Al7075 Matrix Composites

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Abstract—*In the past few years, materials R&D has shifted from monolithic to composite materials, adjusting to the global need for reduced weight, low cost, quality, and high performance in structural materials. The aluminum based composite Al7075 are increasingly being used in the transport, aerospace, marine, automobile and mineral processing industries, owing to their improved strength, stiffness and wear resistance properties. The ceramic particles reinforced aluminum composites are termed as new generation material and these can be tailored and engineered with specific required properties for specific application requirements. Various processing techniques for the fabrication of Aluminum matrix composites, testing of their mechanical properties are available. Several processing techniques like Stir casting, squeeze casting, ultrasonic assisted casting,, powder metallurgy, high energy ball milling, friction stir casting are recently being used for the production of Al7075 composites. The properties discussed include physical and mechanical behaviour of ceramic-reinforced Al7075 matrix composites and effects of reinforcement fraction, particle size, secondary process (heat treatment and extrusion processes) on these properties. The results obtained by many researchers indicated the uniform distribution of reinforced particles with localized agglomeration at some places, when the metal matrix composite was processed through stir casting method. The density decreased and hardness, compressive strength and wear resistance are increased with increasing reinforcement fraction.*

1. INTRODUCTION

During past few years materials research and development has shifted monolithic to composite materials to pursue low cost, light weight, environmental friendliness, performance and quality. Conventional monolithic materials have limitations with respect to achievable combinations of strength, stiffness, and density. In order to overcome these shortcomings and to meet the ever-increasing engineering demands of modern technology, metal matrix composites are gaining importance.

1.1 Composite materials

Composite materials are new generation materials developed to meet the demands of rapid growth of technological changes of industry. Composite materials are engineering materials, it consist two or more physically and /or chemically distinct constituent material, suitably arranged or distributed phase with an interface separating them. One constituent is called matrix phase and other is called reinforcing phase. Reinforcing phase is embedded in the matrix to give desire characteristic.

The composites are broadly classified into a) Metal Matrix composites (MMC), b) Ceramic Matrix composites (CMC), c) Polymer Matrix composites (PMC)

Metal matrix composites (MMCs**)**, It consist of at least two components, one is the metal matrix and the second component is reinforcement. The matrix is defined as a metal alloy In the productivity of the composite, the matrix and the reinforcement are mixed together. When the matrix is a metal, the composite is termed a Metal-Matrix Composites.

Ceramic matrix composites (CMCs) consist of ceramic fibers embedded in a ceramic matrix. The matrix and fibers can consist of any ceramic material, whereby carbon and carbon fibers can also be considered a ceramic material.

Polymer-matrix composites (*PMC*s) consist of a polymer resin as the matrix, with fibers as the reinforcement medium. These materials are used in the greatest diversity of composite applications, as well as in the largest quantities.

1.1.1 Aluminum Matrix Components (AMC)

The need for engineering materials in the areas of aerospace and automotive industries had led to a rapid development of metal matrix composites (MMC). Researchers are turning to particulate-reinforced aluminum metal matrix components (AMC) because of their relatively low cost and isotropic properties. In AMC one constituent is aluminum/aluminum alloy termed as matrix phase. The other constituent is embedded in this aluminum/aluminum alloy matrix and serves as reinforcement. Mostly ceramic materials such as SiC, Al_2O_3, B_4C, etc are used reinforcement. The major advantages of AMCs compared to unreinforced materials are, it gives greater strength, improved stiffness, reduced density(weight), improved high temperature properties, improved abrasion and wear resistance and enhanced and tailored electrical performance, etc

1.2 .Al7075 Alloy

Aluminium 7075 is an aluminium alloy, in which zinc as the primary alloying element. Al7075 alloy's composition roughly includes 5.6–6.1% zinc, 2.1– 2.5% magnesium, 1.2–1.6% copper, and less than half a percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-O, 7075-T6, 7075-T651. It has maximum tensile strength no more than 40,000 psi (276 MPa), and maximum yield strength no more than 21,000 psi (145 MPa). The material has an elongation (stretch before ultimate failure) of 9–10%. 7000 series alloys such as 7075 are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio.Their strength and light weight is also desirable in other fields. Rock climbing equipment, bicycle components, and hang glider airframes are commonly made from 7075 aluminium alloy.

2. PROCESSING OF AL7075 MATRIX COMPOSITES

Primary processing for manufacturing of AMCs can be classified into two main groups. a) Liquid state process include stir casting, squeeze castings, and ultrasonic assisted castings, b) Solid state process include powder blending followed by consolidation (Powder metallurgy), high energy ball milling, friction stir process.

2.1 Liquid state process

Stir casting process is a liquid state process, in this process the aluminium alloy is matrix phase and ceramics are reinforcement phase. The aluminum alloy is heated in liquid state and reinforcing phases (usually in powder form) are distributed into molten Aluminum alloy by mechanical stirring. The key element in this process is Mechanical stirring in furnace.

Squeeze casting process is the combination of gravity die casting and closed die forging. In this process, pressure is applied on the solidifying liquid metal. The steps involved in this process are: (i) pouring of metered quantity of liquid metal with adequate super heat in to the die cavity, (ii) application of pressure on the liquid metal and maintaining the same till the solidification is complete and (iii) removal of the casting and preparation of the die for the next cycle.

Ultrasonic Assisted Casting is combines solidification processes with ultrasonic cavitation based dispersion of nanoparticles in metal melts has been developed. Ultrasonic cavitation can produce transient (in the order of nanoseconds) micro ‚hot spots‛ that can have temperatures of about 5000ºC,pressures above 1000 atms, and heating and cooling rates above 1010 K/s.

2.2 Solid state process

The powder metallurgy process generally consists of four basic steps: (1) powder manufacture, (2) powder mixing and blending,(3) compacting, (4) sintering. Compacting is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducting at atmospheric pressure. Optional secondary processing often follows to obtain special properties or enhanced precision.

High energy ball milling is a simple and useful technique to produce aluminium matrix composites and consists of repeated flattering and welding, fracturing and rewelding of a mixture of powder particles in a high energy ball milling. Powder particles in the ball mill are subjected to high-energy collision, which causes the powder particles to be cold-welded together and fractured

Friction stir processing is a method of changing the properties of a metal through intense, localized plastic deformation. This deformation is produced by forcibly inserting a non-consumable tool into the workpiece, and revolving the tool in a stirring motion as it is pushed laterally through the workpiece. This process mixes the material without changing the phase (by melting or otherwise) and creates a microstructure with fine, equiaxed grains.

3. PROPERTIES OF AL COMPOSITES MATERIALS

The factors that determine properties of composites are, microstructure, volume fraction isotropy and homogeneity of the system and these are strongly influenced by proportions and properties of the matrix and the reinforcement.

3.1 Physical Properties

Density is a physical property of matter, as each element and compound has a unique density associated with it. Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. Density play very important roles in the composite material study. These materials using in space crafts and automotive industry, they must be light weight. So the density should be reduced by adding some reinforced material like Al_2O_3,Sic, B_4C,etc, in Aluminum alloy. In a composite, the volume fraction(v) ,which is commonly used in property calculation.Density can be calculated by dividing the mass of specimen by the volume displaced by that specimen in the water beaker

3.2 Mechanical Properties

Mechanical properties such as Tensile strength, Hardness, Wear resistance, Young's modulus are essentially function of the manufacturing process. Improving such mechanical properties is usually major attraction of composite materials.

Hardness is the resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching. It measured by hardness tests such as Brinell, Knoop, Rockwell, or Vickers. Since there is no standard hardness scale, each test expresses its results in its unique (and arbitrarily defined) measure. For some metals (such as steel) the hardness and tensile strength are empirically related. Theoretically the rule of mixture type $H_c=V_rH_r+V_mH_m$ (suffix 'c', 'r' and 'm' stand for composite, reinforcement and matrix respectively and V and H for volume fraction and hardness respectively.

Tensile strength is the ability of a material to withstand a pulling (tensile) force. It is customarily measured in units of force per cross-sectional area. This is an important concept in engineering, especially in the fields of material science, mechanical engineering and structural engineering. The AMCs are found to have more tensile and fatigue strength over monolithic materials. Ceramic materials like Al_2O_3, SiC, B_4C, etc. are reinforcement with AMCs, these reinforcement materials significant increase in its elastic modulus, hardness and wear resistance.

3.3 Tribological Properties

Wear is the progressive loss of material due to relative motion between a surface and the contacting substance or substances The wear damage may be in the form of micro-cracks or localized plastic deformation. W*ear* may be classified as adhesive wear, abrasion wear, surface fatigue wear and corrosive wear. Commonly available test apparatus for measuring sliding friction and wear characteristics in which, sample geometry, applied load, sliding velocity, temperature and humidity can be controlled are Pin-on-Disc, Pin-on-Flat, Pin-on-Cylinder, Thrust washers, Pin-into-Bushing, Rectangular Flats on a Rotating Cylinder and such others.

4. LITERATURE REVIEW

G.B.Veereshkumar [2] et al (2010), analyzed the physical and mechanical properties of Al7075-Al_2O_3 and Al6061-SiC composites. He manufactured Al7075-Al_2O_3 and Al6061-SiC (Al_2O_3, SiC particle size 20 µm) composites by liquid methodology technique. The test for density, hardness and tensile were carried out as per ASTM standards. He observed densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites. The hardness of the composite is greater than that of its base matrix alloy and the hardness of the Al7075- Al_2O_3 composite are higher than that of the composite of Al6061-SiC. He also found the tensile strength of the composites are higher than that of their base matrix Also he observed that the tensile strength of the Al7075-Al_2O_3 composites is higher than that of the composites of Al6061- SiC.

Muhammad Hayat Jokhio [3] et al (2010**),** investigated the mechanical properties of 7xxx aluminum matrix reinforced with alpha "Al_2O_3" particles using simple foundry melting alloying and casting route. He manufactured 5 different combination of matrix alloys(Cu-Zn-Mg) reinforced with Al_2O_3 particles in 4 weight percentage (2.5,5,10 and 15). 40 samples were prepared and tensile strength, elongation was determined using universal testing machine. He observed that "Al_2O_3" particles up to 10% increase the tensile strength 297 MPa and elongation 17% in aluminum alloy matrix The higher tensile strength was obtained reinforced with 2.5% "Al_2O_3" particles. Aluminum cast composites up to 2.77% Mg contents which increases wetability, reduces porosity and develops very good bonding with "Al_2O_3" particles.

A. Ahmed [4] et al (2010), examined the reasons for the poor performance of the nanometric scale SiC (n-SiCp) particulate-reinforced Al 7075 composites. The composites having different volume fractions of the n-SiCp were synthesized via powder metallurgy (P/M) route and were uniaxially tested at room temperature. Uniaxial tensile tests were performed at room temperature. He observed significant drop in the hardness and tensile properties of the composites in comparison with those of the monolithic Al. 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 the reactivity of Mg with O and its segregation at the grain boundaries and the SiC-Al interface.

Hossein Bisadi [5] et al (2011), evaluated the mechanical properties of the Al7075/TiB_2 Surface Composite fabricated by Friction Stir Process. The Vickers hardness of the stirred zone was measured on a cross section and perpendicular to the processing direction using a Vickers hardness tester. He observed highest microhardness value is 179 HV when the tool rotation speed is 1115 rpm with the traverse speed of 60mm/min. The average hardness of as-received AL7075 alloy was 64HV. The tensile tests were carried out using a GALDABINI universal testing machine. He observed tensile tests also revealed that the addition of reinforcement significantly increased the yield strength of the composite from 91Mpa to 184Mpa. Increasing of the rotational speed enhanced the ultimate strength but has not affected on the yield strength of composite.

Prabhakar Kammer [7] et al (2012), investigated the mechanical properties Al7075 with reinforced E- Glass (1%,3% and5%) and flyash (2%,4%,6% and8%) hybrid metal matrix composite fabricated by liquid methodology method. The specimen were conducted the tensile test and compressive strength. He observed increase in UTS due to presence of E-glass fibre and Fly ash as compared to base metal and composite was able to take more compressive load due to presence of E-glass fibre and Fly ash the compressive strength increased. He found Tensile strength and Compression

Strength of the composite had improved when compared to Al 7075 alloy alone

Deepak Singla [8] et al (2013), reinforcement the fly ash in AL7075 alloy different volume fraction, Al7075 500g reinforcement fly ash 10gm,20gm,30gm and 40 gm. This composite produced by stir casting method and analyzed the physical and mechanical properties of composite. He observed the composite material density had reduced compared the base alloy. He carried Rockwell hardness, Charpy and Izod impact and tensile test. He observed the hardness, toughness and tensile of the composites increased up to 30g volume fraction and decreased exceed 30 g volume fraction.

R.Ramesh [10] et al (2013), fabricated Al 7075-B_4C surface composites by friction stir processing (FSP). . After preparing specimens the specimens are subjected to Brinell hardness test. He found that the average hardness of friction stir processed surface composite was 1.5 higher than that of the base metal Aluminum 7075 – T651. The increase in hardness was attributed to fine dispersion of B_4C particles and fine grain size of the Aluminum matrix. Microstructural observations had been carried out. Processed surface at nugget zone has higher hardness due to the fine dispersion of B4C particles.

Ravinder Kumar [11] et al (2013), investigated the specific wear rate of Al 7075 with SiC (7 wt.%) and graphite (3 wt.%) hybrid aluminum metal matrix composite fabricated by using stir casting method. The unlubricated pin-on-disc wear tests were conducted to examine the wear behavior of the composites. He observed specific wear rate of the hybrid composite is lower than that of the unreinforced Al 7075 in all combination of loads, sliding speeds, and sliding distances. He found specific wear rate decreases up to the speed of 4 m/s and then starts increasing. worn surfaces and wear debris tested samples were examined using scanning electron microscope (SEM and EDX) and X-ray diffraction (XRD). Response Surface Methodology (RSM) had been used to find out the most significant factor, which influence the specific wear rate. He concluded that load is most significant factor which leaves an effect on specific wear rate.

Arjun Haridas [12] et al (2013), Analyzed the mechanical behaviors of Al7075-reinforcement with SiC and Ni composites fabricated by stir casting method. The specimen carried the XRD test, Optical Microscopic Test and Rockwell Hardness test. He observed hardness of the matrix material Al7075 has improved by added reinforcement material Sic and Ni. The matrix and reinforcement material are well mixed by the stir casting and gives the better material profile. Profile had changed while adding different amount of reinforcement material.

T Senthilvelan1 [13] et al (2013), investigated mechanical properties of Al 7075-SiC, Al 7075-Al_2O_3, Al 7075-B_4C composites fabricated by stir casting method. The specimens carried hardness, Tensile and Scanning electron microscopy tests. The hardness of the samples was measured using a UHL Vickers micro hardness measuring machine by applying a load of 0.5kg. He found Al/B_4C has maximum hardness (138 Hv) due to the complete distribution of B_4C particles and their hardness. Tensile strength Al/B_4C offers 143% improvement, Al/Al_2O_3 offers 88% improvement and Al/SiC offers 46% improvement. He concludes among the three MMCs, Al/B_4C showed the strongest bonding as revealed by the good mechanical properties.

S. Gopalakannan [14] et al (2013), fabricated metal matrix nano-composite (MMNC) of Al 7075 reinforced with 1.5 wt% SiC nano-particles was prepared by a novel ultrasonic cavitation method. The hardness of the samples was measured using a UHL Vickers micro hardness measuring machine by applying a load of 0.5 kg and this load was applied for 20 s yielded 134.1 HV. The nano-composite of 1.5 wt% SiC offers ultimate strength and yield strength of 290.278 MPa and 245.833 MPa respectively. He developed mathematical models and multi response optimization for fabrication and machining aspects.

A. Baradeswaran [15] et al (2014), investigated the mechanical and tribological properties of Al 7075/Al_2O_3 hybrid composite. He prepared Al 7075 with 5 wt.% graphite particles addition and 2, 4, 6 and 8 wt.% of Al_2O_3 . The hardness measurements were carried out on a Brinell hardness testing machine. He observed hardness of the Al 7075/ Al_2O_3/graphite hybrid composite increases with the addition of Al_2O_3. It was higher than that of base alloy. He found higher hardness values for the hybrid composites containing 8 wt.% of Al_2O_3 is due to the presence of hard Al_2O_3 particles. He also investigated the hardness of Al7075 with 5, 10, 15 and 20 wt.% of graphite composites. He observed decrease in hardness with increasing graphite content in Al 7075. Tensile test was carried as per the ASTM E08-8 standard, in universal testing machine. The tensile strength was increased with increasing Al_2O_3 content. Wear test was conducted in pin on disc test apparatus with various loads of 20 N, 40 N and 60 N at a sliding speed of 0.6, 0.8 and 1.0 m/s for the constant sliding distance of 2000 m. He observed wear rate decreases with the addition of Al_2O_3 and reaches a minimum at 2 wt.% Al_2O_3/ 5 wt.% graphite and it is about 36% less than that of the matrix material .

K.Gajalakshmi [19] et al (2014), investigated the micro structural and mechanical properties of Al7075 with 20% Al_2O_3 and Silicon Nitride (2.5g and 7.5g). The composites fabricated by Stir casting method and hardness test was conducted using Rockwell hardness machine, tensile test carried in universal testing machine and Microstructural analysis was done using metallurgical microscope. She observed hardness value goes on increasing with increase in Si_3N_4 weight,Tensile strength of the component had been decreased when the percentage of Si_3N_4 is increased and microstructure shows the grain boundaries, interdendritic network of aluminium oxide and silicon nitride particles distributed in a matrix of aluminium solid solution throughout the structure

Raghavendra N [21] et al (2014), Studied the effect of particle size and weight fraction of Al 7075- Al_2O_3 composites in varying particle size of 100,140 and 200 mesh & varying reinforcement weight fractions of 3%,6%,9% and 12% by stir casting process route. Brinell hardness test and Pin on disc wear test were carried on the composite material. He observed hardness of the composite was found to increase with reduction in the particle size and the wear rate for varying particle size reduces with reduction in particle size. Also he observed highest wear rate is obtained for the lower particle size. The 12% reinforced MMC indicates improved wear rate and lower speed the wear rate was significantly higher due to more contact area and high friction.

A Sert [22] et al (2014), Analyzed the wear behavior of Al7075 – SiC surface composite produced by Friction Stir Processing method. The sliding wear characteristics of the specimen were determined using a reciprocating wear tester in the ball on disc configuration. The test conducted at room temperature using loads of 2 ,4 and 5N, at a speed of 2.5cm/s, at a distance of 20m. He observed wear characteristic of surface composite obtained by FSP method improved compared with main material. The rate of wear increased with an increase the load. The wear characteristic of composite surface obtained addition of SiC particles were found improved.

5. CONCLUSIONS

This review presents the views, theoretical and experimental results obtained and conclusions made the recent years by varies investigators in the field of aluminum 7075 alloy - MMCs.

- It has been concluded that the density of the Al7075 composites were found to be decreased with reinforcement into the matrix material..
- It was observed that the hardness of Al7075 matrix composites increased with the reinforcement contents increased in the matrix material. The hardness of ceramic-reinforced composites can also be improved by heat treatment, ageing temperature
- The Al7075-matrix composites found to have high elastic modulus and tensile strength over the base alloys.
- It was found the Wear rate of composites increases with increasing applied load and speed and also observed highest wear rate is obtained for the lower particle size.

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