Review on Mechanical Investigations of Aluminum Metal Matrix Composites

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Abstract- *Metal Matrix Composites are formed by combination of two or more materials (at least one of the materials is metal) having dissimilar characteristics. Although the hybrid aluminum MMC takes this part in some of the areas it is still advice able that these types of specialized reinforcement addition can yield much better results than its hybrid counterpart. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There are several techniques to produce composites, such as liquid state, solid state and semi-solid state production route. Among the entire liquid state production route stir casting route are simplest and cheapest.*

Keywords- Aluminum metal matrix composite, (MMC)

I. INTRODUCTION

Aluminum is a silvery-white metal, the 13 element in the periodic table. One surprising fact about aluminum is that it's the most widespread metal on Earth, making up more than 8% of the Earth's core mass. It's also the third most common chemical element on our planet after oxygen and silicon. At the same time, because it easily binds with other elements, pure aluminum does not occur in nature. This is the reason that people learned about it relatively recently. Formally aluminum was produced for the first time in 1824 and it took people another fifty years to learn to produce it on an industrial scale. The most common form of aluminum found in nature is aluminum sulphates. These are minerals that combine two sulphuric acids: one based on an alkaline metal (lithium, sodium, potassium rubidium or caesium) and one based on a metal from the third group of the periodic table, primarily aluminum. Aluminum sulphates are used to this day to clean water, for cooking, in medicine, in cosmetology, in the chemical industry and in other sectors. By the way, aluminum got its name from aluminum sulphates which in Latin were called alumen.

II. TYPES OF MATRIX

Broadly the composite materials in use in the industry today are classified into the three main categories as

(a) Metal Matrix Composites (MMCs)
(b) Ceramic Matrix Composites (CMCs)
(c) Polymer Matrix Composites (PMCs)

III. METAL MATRIX COMPOSITES

In general, the mechanical properties of metal matrix are inadequate for many structural applications, and their strength and stiffness are low when compared to metals and ceramics. These problems are rectified by Composites Metal matrix composites (MMCs) Ceramic matrix composites (CMCs) Polymer matrix composites (PMCs) reinforcing different materials with polymers. The processing of polymer matrix composites need not involve high pressure and high temperature. Due to this reason, the usage of polymer matrix composites has grown rapidly, and become popular for structural materials.

IV. ALUMINUM

Aluminum is the most abundant metal and the third most abundant element in the earth's crust, after oxygen and silicon. It makes up about 8% by weight of the earth’s solid surface. Aluminum is too reactive chemically to occur naturally as the free metal. Instead, it is found combined in over 270 different minerals. The chief ore of aluminum is bauxite, a mixture of hydrated aluminum oxide (Al O23 2 AxH O) and hydrated iron oxide 23 2 3 6 (Fe O AxH O). Another mineral important in the production of aluminum metal is cryolite (Na AlF). However, cryolite is not used as an ore; the aluminum is not extracted from it. Metallic aluminum was first prepared by Hans Oersted, a Danish chemist, in 1825. He obtained the metal by heating dry aluminum chloride with potassium metal.

$$AlCl_3 + 3K \rightarrow Al + 3KCl$$

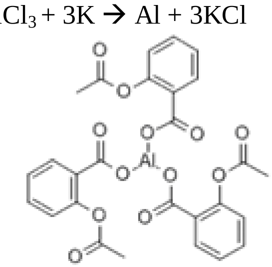

Figure 1 Chemical Structure of Aluminum

Table 1 Comparison of Mechanical Properties of Metal Matrix

Materials	Melting Point °C	Molar Mass g/mol	Density g/cm3	Boiling Point °C
Al_2O_3	2072	101.96	3.95	2977
Boran	2076	10.81	2.3	3927
Boran Carbide	2763	55.25	2.52	3500
Carbon	3550	12.01	2.25	4827
Silicon Carbide	2700	40.11	3.21	2730
Graphite	4300	12.01	2.26	4200

V. TYPES OF MATRIX

The various metal matrix used in the researches today along with the abundant metal matrix used to specific applications to bring about slight better mechanical properties are listed below.

a) Aluminum
b) Copper
c) Iron
d) Magnesium
e) Nickel
f) Titanium

VI. RULE OF MIXTURES

Composite stiffness can be predicted using a micro-mechanics approach termed the rule of mixtures which calculates to be

$$E_c = f\,E_f + (1 - f)E_m \quad \text{or} \quad E_c=V_mE_m+V_f\,E_f$$

Where,

f => $\frac{V_f}{V_f+V_m}$ is the volume fraction

Ef => Elastic modulus of fiber.

Vf – Volume of Fiber

Em => Elastic modulus of matrix.

Vm – Volume of matrix

VII. METHOD OF MANUFACTURING

1) Liquid stage process
   - Stir casting method
   - Infiltration method
     - Gas pressure infiltration
2) Solid state process
   - Diffusion bonding
   - Powder processing (or) Powder metallurgy
3) Deposition Process
   - Spray forming
   - Electro plating
   - Spray deposition
   - Chemical vapour deposition
4) In-Situ process
5) Two phase (Solid & Liquid) process

VIII. LITERATURE SURVEY

Velugula Mani Kumar et al. has Evaluation of mechanical characteristics for Aluminum-copper Metal matrix Composite. use of high performance materials in both the airframe and propulsion systems enables the modern aircraft to rotate larger degree while retaining its strength. The attractiveness of aluminum is that it is relatively low cost, light weight metal that can be heat treated to fairly high strength levels and it is one of the most easily fabricated high performance materials, which usually correlates with lower costs. The aluminum-copper and aluminum-zinc alloys are the primary alloys used in airframe structural applications. The aluminum-copper metal matrix composites are used in damage tolerance applications such as the lower wing skins and fuselage structure of commercial aircraft. In the present study, aluminum alloy specimens (6061) will be developed with variations of % of copper in the composition viz., 4%, 6%, 8%, 10% using die casting process. The mechanical properties like tensile strength, hardness, % elongation, impact strength and micro structures analysis will be carried out. It is a metal casting process that is characterized by forcing molten metal under high pressure into a mould cavity. Results al 92% ,with copper 8% is the maximum value of tensile strength 131.37 N/mm^2 , hardness number is 157 and elongation 6%.

V. Ramakoteswara Rao et al. Has Tribological properties of Aluminum Metal Matrix Composites (AA7075 Reinforced with Titanium Carbide (TiC) Particles). AA7075 Alloy as the matrix metal and Titanium carbide (TiC) particles (2-10%) with an average particulate size of 2μm as reinforced material were processed by stir casting route. Computerized pin on disc wear tester was used for wear test with counter surface as EN32 steel disc (58-60 HRC) and cylindrical pin as the composite specimens. SEM-XRD analysis revealed the presence of TiC and other phases. The better wear properties (wear rate, coefficient of friction and wear factor) was observed with 8 wt% TiC composite compared to other composites as well as matrix metal. The weight percentage of reinforcement was most significant parameter affecting the hardness of composites produced by stir-casting process. ThusAA7075 matrix containing 8% of TiC particulates exhibited the highest micro-hardness**.** The wear rate of the composites decreased with increasing the weight percentage of Titanium carbide (TiC) particulates than the base alloy. The wear resistance of TiC reinforced composite increases with increase in the TIC content. However, the addition of 10% TiC does not improve the wear resistance considerably.

B.Venkatesh et al. Has Mechanical properties of metal matrix composites (Al/Sicp) particles produced by powder metallurgy. Metal matrix composites (MMCs) have become attractive for engineering structural applications due to their excellent specific strength property and are increasingly seen as alternative to the conventional materials particularly in the automotive, aerospace and defense industries. Al/SiC MMC has aluminum matrix and the silicon carbide particles as reinforcements and exhibits many desirable mechanical properties. SiC particles containing different weight fractions (10 and 15 wt. %) and mesh size (300 and 400) is used as reinforcement. The paper presents the processing of Al/SiC by powder metallurgy method to achieve desired properties and also the results of an experimental investigation on the mechanical properties of Al/SiC are determined. Heat treatment after sintering is increasing hardness as well as density. After heat treatment the percentage of density is increasing as the SiCp reinforcement, weight % and mesh size increasing.

G.Shaikshavali et al. has Mechanical Properties of Al6061 Based Metal Matrix Composites Reinforced with Ceramic Particulates and Effect of Age Hardening on its Tensile Characteristics. Aluminum materials has a huge requirement in the fields of automotive, aerospace and different engineering applications in order to meet requirements of various fields a material with good mechanical and thermal properties is developed which is metal matrix composites in which aluminum alloys is used as common matrix phases and reinforced used are different material particulates and fibers. Experimental MMC components are being developed for use in aircraft, satellites, jet engines, missiles, and space shuttle. In present study ceramic materials is used as reinforcements for MMCs such as Sic, Al_2O_3, B4C and TiB2. Metal matrix composites are fabricated using different ceramic reinforcements and Al6061 material using liquid metallurgy technique in this study stir casting method is used. Liquid metallurgy techniques were successfully adopted in the preparation of Al6061-10% Sic, Al6061-10%, Al_2O_3, Al6061- 10% B4C and Al6061-10% TiB2. Metal matrix composites.

K. Yoganandam et al. Has Mechanical and Micro Structural Characterization of Al6082-TiO2 Metal Matrix Composites produced via Compo Casting Method. Aluminum Matrix Composites (AMCs) are considered as a distinct category of the advanced materials, which have superior strength, light weight and good wear resistance. Methods/Statistical Analysis: In the present study, Al6082 is chosen as matrix material and Titanium Oxide (TiO2) particles as reinforcement. Aluminum-TiO2 composites reinforced with various weight percentages (0, 3, 6 and 9 wt. %) were produced by semi-solid state compo casting route. The higher mechanical properties were observed for the composites compared with un reinforcement alloy. Optical images displayed the nearly uniform distribution of reinforcement in the AA6082 matrix. Ultimate Tensile Strength of the produced composites found to increase with enhanced TiO2 up to 9%. Highest hardness was obtained for AA6082-9 wt. % TiO2 composites.

Dewan Muhammad Nuruzzaman et al. Has Fabricated and Mechanical Properties of Aluminum-Aluminum Oxide Metal Matrix Composites. Three different types Al- Al_2O_3 composite specimens having 10%, 20% and 30% volume fractions of Aluminum oxide were fabricated using conventional powder metallurgy (PM) route. It can be also observed that the sharpness of the microstructure is very strong. Figure 7(d) shows the micrograph of 70%Al-30% Al_2O_3 composite prepared under 20 ton compaction load. The increase in the volume fraction of Al_2O_3 particulates results in an increase in the hardness of Al/ Al_2O_3 composites.

Prashant Karandikar et al. Has Al/ Al_2O_3 Metal Matrix Composites (MMCs) and Macro composites for Armor Applications. Metal matrix composites (MMCs) combine the desirable characteristics of metals (ductility and thermal conductivity) and ceramics (high hardness, high stiffness, low thermal expansion). Al/ Al_2O_3 MMCs with varying alumina content were produced successfully. Characterization of Al/ Al_2O_3 MMCs with varying alumina contents showed that density, elastic modulus, and strength increased with increased particle content. Failure strains (ductility), on the other hand, decreased with increasing particle content. Al/ Al_2O_3 MMCs with Al-1Mg-0.6Si0.4Cu matrix showed the highest failure strain, followed by Al/ Al_2O_3 MMCs with Al-4Mg matrix, and the Al/SiC MMCs with Al-10Si alloy matrix showed the lowest failure strain.

Madhu Kumar YC et al. Has Evaluation of Mechanical Properties of Aluminum Alloy 6061-Glass Particulates reinforced Metal Matrix Composites. This work focuses on the fabrication of aluminum alloy (6061) matrix composites (AMCs) reinforced with 3 to 12 wt% glass particulates of 75μm, 88μm, 105μm and 250μm using stir casting route. The microstructure and mechanical properties of the fabricated AMCs were analyzed. Aluminum-Glass particulate composite was successfully synthesized by the stir casting method. The tensile strength of the composite increased with increase in wt% of glass particulates up to 9%.The micro hardness of the composites increased with increase in wt% of the dispersion upto 9 wt% and further addition of dispersion showed that the hardness decreases.

Rajesh Purohit et al. has fabrication of al-sicp composites through powder Metallurgy Process and Testing Of Properties. Al-SiCp composites with 5 to 30 weight % of SiCp were fabricated using powder metallurgy process. The density, porosity, hardness, compressive strength and indirect tensile strength of Al-SiCp composites were found to increase with increase in the wt. % of SiCp from 5 to 30 weight percent. Mechanical alloying of aluminum and silicon carbide powders for 12 hours of milling results in fine homogeneous equiaxed composite powder structure. SEM studies of ball milled powders at intermediate stages reveal that due to impact of steel balls, the repeated cold welding, fracturing and re-welding of powder particles takes place and SiC particulates get embedded in the aluminum matrix. Finally the Al-SiCp composite powders are obtained. Mechanical alloying of aluminum and silicon carbide powders for 12 hours of milling results in fine homogeneous equiaxed composite powder structure. SEM studies of ball milled powders at intermediate stages reveal that due to impact of steel balls, the repeated cold welding, fracturing and re-welding of powder particles takes place and SiC particulates get embedded in the aluminum matrix. Finally the Al-SiCp composite powders are obtained.

Madeva Nagaral et al. Has Effect of Al_2O_3 Particles on Mechanical and Wear Properties of 6061al Alloy Metal Matrix Composites. fabrication of 6061Al composites with different weight percentage of Al_2O_3 particles up to 0-9% was processed by liquid metallurgy route. For each composite, reinforcement particles were preheated to a temperature of 200°C and then dispersed in steps of three into the vortex of molten 6061Al alloy rather than introducing all at once, there by trying to improve wet ability and distribution. Aluminum based metal matrix composites have been successfully fabricated by melt stir method by three step addition of reinforcement combined with preheating of particulates. Strength of prepared composites both tensile and yield was higher in case of composites, while ductility of composites was less when compared to as cast 6061Al. Further, with increasing wt% of Al_2O_3 improvements in tensile strength were observed. 6061Al– Al_2O_3 composites have shown higher hardness when compared to the hardness of 6061Al-alloy. Also hardness of composites increases with increasing wt% of reinforcement. Higher wear rate was observed in as cast 6061Al alloy when compared to 6061Al- Al_2O_3 composites.

Surya Kumar et al. have done Analysis and Testing of Aluminum Silicon Carbide Metal Matrix Composites. Materials are frequently chosen for structural applications because they have desirable combinations of mechanical characteristics. Density of the AlSiC with different composition of SiC metal matrix composites is investigated. Marginal increase in density to very high increase in strength was noted. Tensile strength of the aluminum silicon carbide metal matrix composites increases gradually with the increased composition of the silicon carbide, but at 15% of SiC in Al give the best tensile strength as per the weight percentage ratio.

K.Hemalatha et al. has Processing and Synthesis of Metal Matrix Al 6063/ Al_2O_3 Metal Matrix Composite by Stir Casting Process. Aluminum-Alumina composites have increasingly widened their use due to merits of processing, high specific strength and modulus of elasticity while carrying good deformability and conductivity comparable to metals. Hence stir casting method of casting is adopted and Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%, 9%). Also the distribution of Alumina and Aluminum is examined by microstructure analysis, hardness distribution and the material is tested for its mechanical Properties such as tensile strength and Hardness. In the research work, a newly formulated composites (Al- Al_2O_3) is prepared by the stir casting process. In this stir casting method of casting Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%,9%). Also the distribution of Alumina and Aluminum is examined by microstructure analysis, hardness distribution and the material is tested for its mechanical Properties such as tensile strength and hardness. stir casted Al alloy 6063 with Al_2O_3 reinforced composite is clearly superior to base alloy Al6063 in the comparison of tensile strength as well as hardness.

Akhilesh Jayakumar et al. has Property Analysis of Aluminum (LM-25) Metal Matrix Composite made by centrifugal casting, Composite is primarily synthesized by liquid metal stir casting method. Cylinders of pure alloy and composite were fabricated using vertical centrifugal casting technique. The maximum hardness of 140 HV is observed towards the outer periphery and minimum hardness of 90 HV is observed towards the inner periphery of the heat treated cylinder. The base alloy also shows higher hardness (107 HV) towards the outer periphery than the inner periphery (85 HV) due to the refinement of primary Aluminum grains and eutectic silicon phases. Similar to the hardness observations, higher tensile strength is observed towards the outer periphery.

IX. CONCLUSION

This paper presents the different combination of reinforcements used in the synthesis of hybrid AMCs and how it influences its performance. Furthermore, comparison has been made between the hybrid composites with the single reinforced grades in order to determine how much improvement is obtained when hybrid reinforcement is used. For the new generation of hybrid composites, which involve the use of agro and industrial waste derivatives, improved performance in comparison with the unreinforced alloy, have been established. The major conclusions derived from the prior works carried out can be summarized as SiC reinforced Al MMCs have higher wear resistance than Al_2O_3 reinforced MMCs. It has been found that the increase in volume fraction of Al_2O_3 decreases the fracture toughness of the Al MMC.

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