Reinforcement with Aluminium (Al7075) Metal Matrix Composite: A Review

Sunil Kumar[1], Dr. Ashok Kumar Mishra[2]

PG Scholar[1], Assistant Professor[2]

Department of Mechanical Engineering,

SRM University, Delhi - NCR, Sonipat, Haryana – 131029, India.

Corresponding Email..suniljeeindia@gmail.com

Abstract:

A composite material is a combination of two or more chemically distinct and insoluble phases; its properties and structural performance are superior to those of the constituents acting independently. Metals and ceramics, as well, can be embedded with particles or fibers, to improve their properties; these combinations are known as Metal-Matrix composites. Aluminum 7075 alloy constitutes a very important engineering material widely employed in the aircraft and aerospace industry for the manufacturing of different parts and components. It is due to its high strength to density ratio that it a sought after metal matrix composite. In this paper we present a survey of Al 7075 Metal Matrix Composites.

Keywords: *Metal Matrix Composites (MMC's), Aluminium Metal Matrix, Beryl, Al7075, Aluminium alloy*

1. Introduction

The effects of research in Aluminium based Metal Matrix Composites (MMC's) are far reaching these days. These composites find various applications in the automobile industry, the aerospace industry and in defense and marine engineering because of their high strength-to-weight ratio, high stiffness, hardness, wear resistance, high temperature resistance etc., compared to others. In metal matrix composites, extensive research work has been carried out on Al alloys. The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together.

In structural applications, the matrix is usually a lighter metal such as aluminium, magnesium, or titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMC's can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD). Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMC's used boron filament as reinforcement. Discontinuous reinforcement uses whiskers, short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

Aluminium alloy 7075 is an aluminium alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable. 7075 aluminum 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 7075-0, 7075-T6, 7075-T651.

Aluminium Alloy 7075 offers the highest strength of the common screw machine alloys. The superior stress corrosion resistance of the T173 and T7351 tempers makes alloy 7075 a logical replacement for 2024, 2014 and 2017 in many of the most critical applications. The T6 and T651 tempers have fair machinability. Alloy 7075 is heavily utilized by the aircraft and ordnance industries because of its superior strength.

A few studies have been carried out on Al-beryl MMC's since the density of beryl is 2.71 g/cc which is almost equal to aluminum and hardness is ~1800 Hv. Most of work that has been carried out is on characterization of beryl particles. XRD, FTIR, EPR studies on beryl particles is also reported. The use of AlBeMet AM162, an aluminum–beryllium metal matrix composite, is an effective way to reduce the size and weight of many structural aerospace components that are currently made out of aluminum and titanium alloys.

For a MMC, large ceramic particles such as beryl, SiC, Al_2O_3, TiN and other ceramic particles are added and studied in detail. MMC's are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound Al_4C_3 on the surface of the fiber. To prevent this reaction, the carbon fibers are coated with nickel or titanium boride. The aim of this paper is to survey the work done in the area of Al7075 MMC's.

The reinforcements being used are whiskers, fibers, and particulates. Mainly particulate-reinforced composites are best quality for their flammability with a price advantage. Further, they are ingrained with wear and heat resistant properties. For MMCs SiC, Al_2O_3, Gr, B_4C, TiC, MoS_2 etc., is excessively applied particulate reinforcements.

Table -1: Mechanical Properties of Aluminum 7075

Density	2.81g/cm³
Hardness(Brinell)	150
Ultimate tensile stress	572Mpa
Tensile yield stress	503Mpa
Young's modulus	71.7Gpa
Machinability	70%
Shear strength	331Mpa
Melting point	635⁰C

Table-2: Composition of Aluminum-7075

Al	Zn	Cr	Ti	Mn	Si	Fe	Cu	Mg
88.85%	5.5%	0.15%	0.2%	0.3%	0.4%	0.5%	1.6%	2.5%

II. MECHANICAL BEHAVIOR OF COMPOSITES

2.1. Hardness

Hardness of the composite depends on the particulate reinforcements with low aspect ratio. The hardness of the MMCs is measured on the polished sample using Zick/Roll Micro hardness tester. The tests were carried out by applying an indentation load with the Vickers indenter. Many researchers contributed a lot regarding the effect of particulate reinforcement on the hardness of the AMCs and HAMCs which have been summarized. Rajmohan et al., [3] investigated the hardness value of the Al-composites reinforced with fixed amount (10%) of SiC particles and different mass fraction of mica particles. The results showed that the maximum hardness value is achieved with 3% mica particles after that the hardness value of the composites goes on decreasing. He also suggested that the low hardness and strength of a composite is favorable for good machining characteristics. Suresha and Sridhara [4] in their research observed that the hardness value of the hybrid aluminium based composite reinforced with SiC and Graphite particles increased up to 2.5 wt% reinforcement content for both reinforcing materials and then decreased. The increase in hardness may be due to the presence of hard ceramic particles and decrease in the hardness may be due to the soft graphite reinforcement particles.

2.2. Fracture toughness Fracture toughness of a composite material is a property which describes the ability of a material containing a crack to resist fracture, and is one of the most important properties of any material for many design applications. Particle cracking, particle deboning or interfacial cracking are some of the primary reasons which may lead to the fracture in the material. Ceramics particles are generally hard and brittle because of this they have fewer tendencies to resist rapid crack propagation. Generally the metallic composites reinforced with hard conventional ceramics possess poor fracture toughness. By investigating and analyzing the results by the different researches it is found that the fracture toughness of most of the engineering materials varies inversely with the yield strength. It has been reported from various researches that the presence of the Bamboo leaf ash (BLA) and Rice husk ash (RHA) in the AMCs and HAMCs increase the fracture toughness properties of the composites; it might be due to the presence of silica (SiO_2) particles in these compounds. Silica is a soft material as compared to the other ceramic reinforcements such as SiC etc. Alaneme et al., [8] in their research on hybrid aluminum based composites observed that the fracture toughness can be enhanced by increasing the content of BLA in the Al/SiC/BLA hybrid Composite. Alaneme et al., [9-10] made another research in order to determine the fracture toughness value of HAMCs. They used load extension plot to determine the fracture toughness of the composite. Ravesh and Garg [11] in their research reported that there is an increase in the fracture toughness of the Al/SiC/Fly ash composite with the increase in the weight percentage of reinforcements. They observed that the maximum value for toughness was obtained for the composite containing 10 wt% SiC and 5 wt% Fly ash content.

2.3. Tensile strength AMCs have two types of strengthening mechanism i.e. direct strengthening and indirect strengthening. Chawla and Shen [12] reported that the direct strengthening can be achieved by the addition of hard and stiff reinforcement in the soft matrix. Due to this hard reinforcement in the matrix the applied load is transferred from the matrix to the reinforcement, this increased the resistance of composite to plastically deform during external loading. The reason for the indirect strengthening was high thermal mis-match between the matrix having higher coefficient of thermal expansion (CTE) and the reinforcing particles having lower CTE during the cooling and solidification. As the temperature changes, it generates the thermal stresses in the composite that lead to the formation of dislocations at the matrix/reinforcement interface. This increase in the dislocation density leads to the improvement in the strength of the composite. It is also observed that the increase in the reinforcement or the decrease in the particle size of the reinforcing material leads to increase in the dislocation density hence strength increases.

2.4 Density and Porosity

The theoretical density was calculated by the rule of mixture, actual density was measured by Archimedes principle and porosity of the composites was obtained by theoretical and actual densities. S. Suresh et al. [31] it is clear that the density values reduced with increasing weight % of Nano Al_2O_3 particles when compared to the base metal (Al 7075). G. B. Veeresh Kumar et al. [2] the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of reinforcement content in the composites. It can be concluded that Al7075-Al_2O_3 composites exhibits higher density than that of the Al6061-SiC and can reasoned for the higher density values of Al_2O_3.

III. LITERATURE REVIEW

R.Kartigeyan [1] et al. (2012) has effectively developed Al 7075 alloy and Short Basalt Fiber composite through liquid metallurgy technique. The increase in short basalt fiber maximizes the ultimate tensile strength, yield strength and Hardness. The composite containing 6% wt of short basalt fiber signifies higher hardness value of 97.1 Mpa when compare to base matrix hardness 92Mpa. The Al-7075/short basalt fiber reinforced 6 vol % maximizes the ultimate tensile strength by 65.51%. The distribution of reinforcements in metal matrix is genuinely uniform.

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 "Al2O3" 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 "Al2O3" 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 fly ash (2%, 4%, 6% and 8%) 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 Eglass fiber and Fly ash as compared to base metal and composite was able to take more compressive load due to presence of E-glass fiber 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 B_4C 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 cavitations 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. **Rama Rao et al. [23]** studied the fabrication and mechanical properties of aluminium-boron carbide composites. The aluminum alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fractions (2.5, 5 and 7.5%).The authors observed that Uniform distribution of the boron carbide particles in the matrix phase, hardness of the composites increased and density was decreased with increasing the amount of the boron carbide in the matrix phase.

S.Balasivanandha Prabu et al. [24] investigated on Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite. The AMMC (A384 as matrix alloy and SiC as reinforced material) was stirred continuously for the different combination of processing conditions by varying the stirring speed (500/600/700 rpm) and stirring time (5/10/15 min).The author observed that in some places without SiC inclusion in matrix at lower speed and lower stir time, while increasing the stirring speed and time better homogeneous distribution of SiC in the Al matrix. The author also revealed that stirring speed and stirring time effect on the hardness of the composite and obtained better hardness of the composite at higher stirring speed and stirring time.

Mahendraboopathi.M et al. [25] studied evaluation of mechanical properties of aluminum alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites. Al-SiC, Al-fly ash, Al-SiC-fly ash composites were successfully prepared by two-step stir casting process. The author observed that optical micrographs both the SiC and fly ash particles were distributed uniformly in aluminium matrix. They reported that tensile strength, yield strength and hardness of the hybrid composite increased with Increase in area fraction of reinforcement in matrix. They also concluded that the addition of SiC and fly ash with higher percentage the rate of elongation of the hybrid MMCs is decreased significantly.

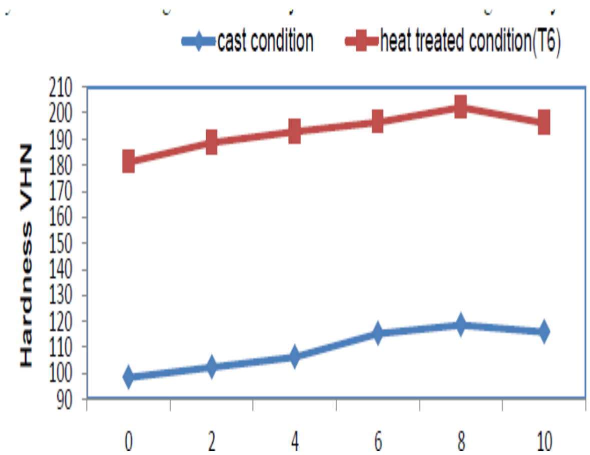

Fig.2. Hardness behavior of Al 7075 alloy and Al7075/TiC Composites

Anilkumar et al. [26] produced three sets of Al (Al6061) metal matrix composites reinforced with fly ash of particle sizes 75-100, 45-50 and 4-25 μm with the weight fractions of 10, 15 and 20%.The author observed that tensile Strength, compression Strength and hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash and ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash.

Dora Siva prasad et al. [27] investigated on mechanical properties of aluminum hybrid composites. They produced aluminum hybrid composites reinforced with different volume percentages of (2, 4, 6, and 8wt %) Rice hush ash (RHA) and SiC particulates in equal proportions by double stir casting process. They found that up to 8% rice hush ash and SiC particles could be easily fabricated. The authors observed that density of hybrid composites decreases, whereas the porosity and hardness increases with the increase in percentage of the reinforcement and yield strength and ultimate tensile strength increase with the increase in RHA and SiC content. **N. Fatchurrohman et al. [28]** studied the solidification characteristic of titanium carbide particulate reinforced aluminium alloy matrix composites. They used aluminium-11.8% silicon alloy (LM6) specimen as matrix material and reinforced with weight fractions of 5 and 15% of titanium carbide particulate (TiCp) by gravity casting. They have shown that by adding TiCp as reinforcement to LM6, the solidification time faster and it gives finer grain size and better mechanical property. The author also observed that hardness number is increased as more TiCp particulate is added to the matrix material.

S Sulaiman et al. [29] have reported that the split tensile strength and Young's modulus values decreased gradually as the silicon dioxide content in the composite increased from 5% to 30% by volume fraction due to the dominating nature of the compressive strength of the quartz particulate reinforced in the LM6 alloy matrix.

Anand Kumar et al. [30] studied the fabrication and characterizations of mechanical Properties of Al-4.5%Cu/10TiC Composite by In-Situ Method. In this composite, TiC was used as reinforcement which was formed by adding Ti in elemental form and activated charcoal powder in the melt. It was found that yield, ultimate tensile strength and hardness was increased by 12.64%, 19.72%, and 35.79% respectively in the composite material. The yield strength and ultimate strength varies from 76 to 87 Mpa, 118 to 147 Mpa respectively after 10% TiC reinforcement in Al-4.5%Cu.

IV. 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.

REFERENCES

[1] R. Karthigeyan, G. Ranganath, S. Sankaranarayanan "Mechanical Properties and Microstructure Studies of Aluminium (7075) Alloy Matrix Composite Reinforced with Short Basalt Fibre" European Journal of Scientific Research, ISSN 1450-216X Vol.68 No.4 (2012), pp. 606- 615.

[2] G. B. Veeresh Kumar, C. S. P. Rao (2010) "Studies on Al6061-SiC and Al7075- Al_2O_3 Metal Matrix Composites" Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55, 2010

[3] Muhammad Hayat Jokhio, Muhammad Ibrahim Panhwar (2011) "Manufacturing of Aluminum Composite Material Using Stir Casting Process" mehran university research journal of engineering & technology, volume 30, no. 1, january, 2011

[4] A. Ahmed, A.J. Neely, K. Shankar, P. Nolan, (2010), "Synthesis, Tensile Testing, and Microstructural Characterization of Nanometric SiC Particulate-Reinforced Al 7075 Matrix Composites", Metallurgical And Materials Transactions A, 1582—Volume 41a, June 2010.

[5] Hossein Bisadi, Asghar Abasi, (2011), " Fabrication of Al7075/TiB2 Surface Composite Via Friction Stir Processing", American Journal of Materials Science. 2011; 1(2): 67-70

[6] R. S. Rana, Rajesh Purohit, and S.Das, (2012) "Review of recent Studies in Al matrix composites" "International Journal of Scientific & Engineering Research Volume 3, Issue 6, June- 2012

[7] Prabhakar Kammer, H.K.Shivanand (2012) “Experimental Studies On Mechanical Properties Of E-Glass Short Fibres & Fly Ash Reinforced Al 7075 Hybrid Metal Matrix Composites” International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No.2231-6477, Vol-1 Issue-4, 2012
[8] Deepak Singla, S.R. Mediratta, (2013) “Evaluation Of Mechanical Properties Of Al 7075-Fly Ash Composite Material” International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 4, April 2013
[9] Deepak Singla1, S.R. Mediratta, (2013) “Effect of Load and Speed on Wear properties of Al 7075-fly ash composite material” International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 5, April 2013
[10] R.Ramesh, N.Murugan, (2012) “Production and Characterization of Aluminium 7075 – T651 Alloy / B4C Surface Composite by Friction Stir Processing” International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012
[11] Ravinder Kumar, Suresh Dhiman, (2013) “A study of sliding wear behaviors of Al-7075 alloy and Al-7075 hybrid composite by response surface methodology analysis”, ELSEVEIR Materials and Design 50 (2013) 351–359.
[12] Arjun Haridas, Ravikumar M, Uvaraja V C, (2013), “Production And Wear Analysis Of Aluminium Metal Matrix Composite”, International Journal Of Innovative Research & Development, March, 2013 Vol 2 Issue 3
[13] T Senthilvelan, S Gopalakannan, S Vishnuvarthan (2013), “Fabrication and Characterization of SiC, Al2O3 and B4C Reinforced Al-Zn-Mg-Cu Alloy (AA 7075) Metal Matrix Composites: A Study”, Advanced Materials Research Vols. 622- 623 (2013) pp 1295-1299, Trans Tech Publications, Switzerland
[14] S.Gopalakannan, T.Senthilvelan, (2013)“ Application of response surface method on machining of Al–SiC nanocomposites”, ELSEVEIR Measurement 46 (2013) 2705–2715
[15] Baradeswaran , A. Elaya Perumal (2013), “Study on mechanical and wear properties of Al 7075/ Al_2O_3 / graphite hybrid composites”, ELSEVEIR Composites: Part B 56 (2014) 464– 471
[16] Baradeswaran, A. Elaya Perumal,(2013) “Wear and mechanical characteristics of Al 7075/graphite composites”, ELSEVEIR Composites: Part B 56 (2014) 472–476
[17] Gowri Shankar M.C, Jayashree P.K, Raviraj Shettya, (2013) “Individual and Combined Effect of Reinforcements on Stir Cast Aluminium Metal Matrix Composites-A Review” International Journal of Current Engineering and Technology, Vol.3, No.3 (August 2013)
[18] Jayashree P .K, Gowri Shankar M.C, Achutha Kinia, (2014), “Review on Effect of Silicon Carbide (SiC) on Stir Cast Aluminium Metal Matrix Composites”, International Journal of Current Engineering and Technology ISSN 2277 – 4106, 2013 INPRESSCO
[19] K.Gajalakshmi, S.Kathiresan, K.S.Sreenivasan (2014), “ Investigation of Microstructure and Mechanical Properties af Silicon Nitride reinforced AMMC using stir casting method”, IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) e-ISSN: 2278-1684, p-ISSN : 2320–334X PP 61-65.
[20] Dipti Kanta Das, Purna Chandra Mishra, Saranjit Singh, (2014), “Properties of ceramic-reinforced aluminium matrix composites - a review”, International Journal of Mechanical and Materials Engineering 2014,
[21] Raghavendra N, V S Ramamurthy, (2014), “Effect of Particle Size and Weight Fraction of Alumina Reinforcement on Wear Behavior of Aluminum Metal Matrix Composites” International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 4, April 2014
[22] A.Sert, O.N.Cellik (2014), “Wear Behaviour of Sic Reinforced Surface Composite Al7075-T651 aluminium alloy produced using Friction Stir Processing”, Indian Journal of Engineering & Material Science, Vol 21 February 2014, pp 35-43
[23] S.Rama rao, G. Padmanabhan, “Fabrication and mechanical properties of aluminium-boron carbide composites”, international journal of materials and biomaterials applications, 2, 2012, 15-18.
[24] S.Balasivanandhaprabu, I. Karunamoorthy, S. Kathiresan, B. Mohan, “Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite”, Journal of materials processing technology, 171,2006, 268-273.
[25] M.Mahendra boopathi, K.P. Arulshri N. Iyandurai, “ Evaluation of mechanical properties of aluminum alloy 2024 reinforced with silicon carbide

and fly ash metal matrix composites", American journal of applied sciences, 10, 2013, 219-229 .

[26] H.C. Anilkumar, H.S. Hebbar and K.S. Ravishankar, "Mechanical properties of fly ash reinforced aluminum alloy (Al6061) composites", international journal of mechanical and materials engineering 6,2011,41-45 .

[27] Dora siva Prasad, Chintada Shoba, Nallu Ramanainah, "Investigations on mechanical properties of aluminum hybrid composite", mater res technol., 3, 2014, 79-85.

[28] N.Fatchurrohman, S.Sulaiman, M.K.A. Ariffin, B.T.H.T Baharuddin, A.A. Faieza , "solidification characteristic of titanium carbide particulate reinforced aluminium alloy matrix composites", Journal of Engineering Science and Technology ,7,2012,248 – 256.

[29] Sulaiman, S.Sayuti and M.Samin, "Mechanical properties of the as-cast quartz particulate reinforced LM6 alloy matrix composites", Journal of Materials Processing Technology, 201, 2008, 731-735.

[30] Anand Kumar, Manas Mohan Mahapatra, Pradeep Kumar Jha, "Fabrication and Characterizations of Mechanical Properties of Al-4.5%Cu/10TiC Composite by In-Situ Method", Journal of Minerals and Materials Characterization and Engineering, 11, 2012, 1075-1080.

[31] S. Suresh, G. Harinath Gowd and M.L.S. Deva Kumar, "Experimental investigation on mechanical properties of Al7075/Al_2O_3/Mg NMMC's by stir casting method" Sadhana 44:51, (2019)