A Review of the Aluminium Metal Matrix Composite and its Properties

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Abstract - *Aluminium metal matrix composites are gaining widespread acceptance for automobile, aerospace, agriculture farm machinery and many other industrial applications because of their essential properties such as high strength, low density, good wear resistance compared to any other metal. The present study deals with the addition of reinforcements such as graphite, fly ash, silicon carbide, red mud, organic material etc. to the Aluminium matrix in various proportions. Each reinforced material has an individual property which when added improves the properties of the base alloy. An effort has been made to review the different combinations of the composites and how they affect the properties of the different alloys of aluminium. A comprehensive knowledge of the properties is provided in order to have an overall study of the composites and the best results can be employed for the further development of the Aluminium reinforced composed. The investigation shows that Al metal matrix composites can be replaced with other conventional metals for better performance and longer life.*

***Key Words*: Aluminium; Reinforcement; Stir Casting; Silicon Carbide; Graphite; Fly Ash.**

1.INTRODUCTION

A metal matrix composite (MMC) is a composite in which two or more reinforced materials are added to the metal matrix in order to improve the properties of the composite. A hybrid metal matrix composite (HMMC) consists of three or more composites mixed with the matrix. Apart from metal matrix composite, there is polymer matrix composite (PMC) and ceramic matrix composite (CMC). In general, metal matrix is favored over polymer matrices because of its ability to meet the engineering demand. Composites are the most promising material of recent interest. In the modern applied sciences, the concept of mixing two dissimilar materials has gained much attention [1]. The combinations provide unique properties. The composite industry has begun to recognize the commercial application of composites which promise to offer much larger business opportunities in aerospace and automotive sectors [2]. The most commonly used metal matrix is aluminium, magnesium, titanium and their alloys.

Aluminium metal matrix composites (AMMC) are the composites in which aluminium is used as the matrix and several reinforced materials are embedded into the matrix. Some of the reinforced materials are silicon carbide, graphite, fly ash, particulate alumina, red mud, cow dung, rice husk etc. AMMC are in demand due to their properties like low density, high specific strength, high damping capacity, high thermal conductivity, high specific modulus, and high abrasion and wear resistance [3], low density, good mechanical properties, low thermal coefficient of expansion, better corrosion resistance [4], high strength to weight ratio and high temperature resistance [5] etc. Aluminium metal matrix composite provides lesser wear resistance when compared to steel and hence it is widely used as a matrix metal.

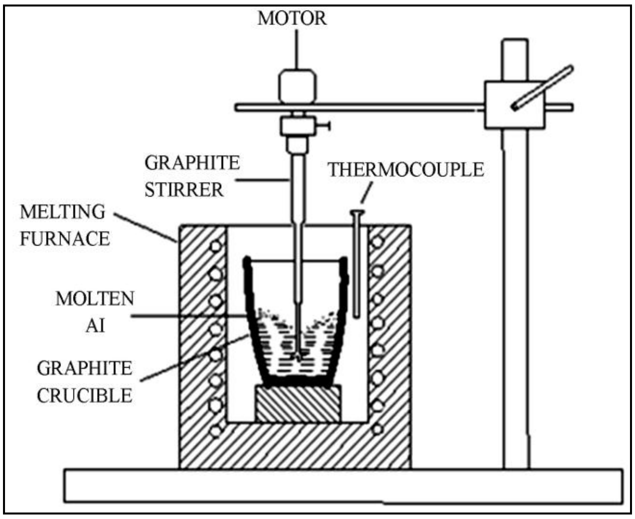
The AMMC can be manufactured by various manufacturing techniques such as stir casting, powder metallurgy, pressure infiltration, squeeze casting [6], chemical vapor deposition etc. Amongst all the processes, stir casting is the most common method used by the researchers [7]

1.1. Stir Casting

Stir casting technique is simple and the most commercial method of production of metal matrix composites. In preparing metal matrix composites by the stir casting method, there are several factors that need to be considered [8], including:

1. Difficulty in uniform distribution of the reinforcement material.
2. Wettability between the two main substances.
3. Porosity in the cast metal matrix composites, and
4. Chemical reactions between the reinforcement material and the matrix alloy.

In conventional stir casting method, reinforced particulate is mixed into the aluminium melt by mechanical stirring. Mechanical stirring is the most important element of this process. After the mechanical mixing, the molten metal is directly transferred to a shaped mould prior to complete solidification. The essential thing is to create the good wetting between particulate reinforcement and aluminium melt. The distribution of the reinforcement in the final solid depends on the wetting condition of the reinforcement with the melt, relative density, rate of solidification etc. Distribution of reinforcement depends on the geometry of the stirrer, melt temperature and the position of the stirrer in the melt. Figure 1 shows a schematic diagram of stir casting process.



Fi 1. Stir Casting Process

An improvement in conventional stir casting is a double stir casting method or two-step casting process. In the first stage, the matrix material is heated to above its liquidus temperature and then cooled down to a temperature to keep in a semi-solid state. At this stage, the preheated reinforcement materials are added and mixed with a mechanical stirrer. Again the slurry is heated to a liquidus state and mixed thoroughly. Nowadays, this two-step mixing process has used in the fabrication of aluminium because of more uniform microstructure as compared of conventional stirring [9].

A recent development in stir casting is three step stir casting for the fabrication of nanoparticle reinforced composite. In this method, first, the Al particles and reinforcement are mixed using ball milling process to break down the initial clustering of nanoparticles. Then the composite powder is mixed with melt by mechanical stirring [10].

The present study deals with the stir cast aluminium matrix composite regarding their enhanced properties such as mechanical, tribological, and thermal.

2. MECHANICAL PROPERTIES

The aluminium metal matrix composites have various effects on the mechanical properties that impart many modern-day applications. Investigation on mechanical properties tends to make the study of composites in depth. The various mechanical properties that are considered in the present study are as follows:

2.1. Hardness

Singla et al. [5] produced aluminium-silicon carbide composite. The maximum hardness was obtained at a weight fraction of 25% with the values of 45.5 BHN. Siddique et al. [7] had experimented the indentation hardness on Aluminium-Silicon carbide with p-bond composite. The particle size of 74 microns of silicon carbide corresponding to 200 mesh had been taken. It was found from the results that with the increase in silicon carbide, the hardness value of the metal matrix composite increased drastically. The hardness increased by two times with weight fraction of 9% silicon carbide when compared to that of the pure form of aluminium. Vanarotti et al. [11] had found during the synthesis and characterization of Al 356 with silicon carbide that the BHN increased with increase in wt.% of silicon carbide.

Saheb [12] had developed aluminium matrix composites with particulates of silicon carbide and graphite in order to obtain a homogeneous dispersion. The experiments had been conducted with varying weight% of silicon carbide and graphite which resulted in the increase in hardness with the increase in weight%. The best results were obtained at 4% and 25% weight fraction of graphite and silicon carbide respectively. Bansal and Saini [13] had investigated the metal matrix composite of Al359 reinforced with silicon carbide and graphite. Graphite is a solid lubricant and it softens the composite. Hence, the hardness of Al359-silicon carbide was much better than that of Al359-graphite. Good bonding between SiC/Gr helps the material to be able to withstand higher loads. Basavaraju et al. [14] prepared a hybrid metal matrix composite of aluminium LM25 with the reinforcement of silicon carbide, graphite and fly ash and found that the Brinell hardness increased till 4% reinforcement and then decreased.

Singh et al. [15] performed trials of aluminium alloy LM 6 with the increase in weight fraction of silicon carbide and alumina and found that increase in weight fraction resulted in increase in the Rockwell hardness number. The reinforcement of fly ash with Al6061resulted in the increase in hardness throughout because of the hard fly ash particles [16]. Mali et al. [17] investigated certain properties on aluminium alloy 356 with fly ash and alumina as reinforcement in varying percent. It was observed that hardness of the composite increased to 94 BHN up to 12% and then decreased due to porosity. Rasidhar et al. [18] fabricated an Al-based nano-composite with Ilmenite as reinforced material. High energy ball milling was done prior to the stir casting. The results showed that the maximum hardness was obtained at 5% wt. of nano-composite.

Alaneme and Sanui [19] studied the microstructural characteristics of alumina, rice husk and graphite and observed that with the increase in weight fraction of rice husk, hardness decreases but becomes less effective with more than 50% of rice husk ash. Gladston et al. [20] estimated that addition of 8% rice husk to Al6061 increases the micro hardness up to 167.27%. Prasad and Krishna [3] found that the hardness of A356.2 increases with increase in the content of rice husk in it.

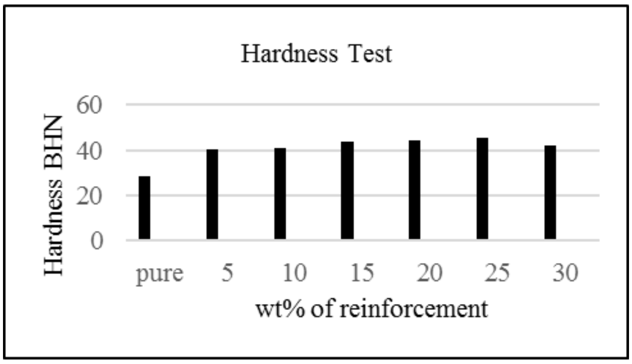


Chart 1. Variation of Hardness with wt.% of SiC [6]

Chart 1 shows the comparative bar chart of hardness against the various wt.% of SiC in Aluminium matrix. From figure, it is evident that up to 25 wt.% of SiC, the hardness increased and then decreased which might be due to that at higher wt.% the particles of SiC started settling down in the aluminium melt.

From the above discussion, it is evident that silicon carbide plays an important role in increasing the hardness of the composite. The most optimum range at which it shows the best results is at a weight fraction of 25%. The addition of other reinforcements also show an increase in the hardness but they are limited to a certain range after which they tend to decrease.

2.2. Tensile strength

In a study conducted by Rahman and Rashed [6] showed that the 20% weight fraction of silicon carbide in the aluminium matrix has the maximum tensile strength. The reason for the increase in the tensile strength is due to the tensile load transfer to the strongly bonded silicon carbide reinforcement which increases the dislocation density and thus resulting in the grain refining effect. The results of the tensile test on Al6061 reinforcement with silicon carbide and particulates of graphite showed that Al6061-graphite was having higher tensile strength than Al6061-silicon carbide. This is due to the high strength possess by the filler graphite. Interestingly, at 12% weight fraction, the tensile strength remained same due to poor wetting of graphite [19].

Viswanathan et al. [21] evaluated the increase in tensile strength of A356/SiC/Gr. The increase in tensile strength was due to SiC because it acts as hurdles to dislocation. The inter-particulate distance between the reinforcement increases the resistance to dislocation as the reinforcement increases. Improvement in tensile strength was also observed by Kumar et al. [16] during the evaluation of Al6061 with fly ash. Three sets of fly ash were reinforced with the weight fraction of 10%, 15%, and 20%. The increase in tensile strength was because of filler fly ash, as it possesses high strength but at the same time, there was a decrease in tensile strength beyond 15% due to poor wettability. It was found that the ultimate tensile strength increased to 192.74 MPa.

The research of Vinitha and Motgi [4] on the Al7075 alloy with the weight fraction of 3-6% silicon carbide/fly ash/red mud found the higher tensile strength of Al7075-silicon carbide-red in comparison to Al7075-silicon carbide-fly ash. Kumar and Kanagaraj [22] produced the aluminium hybrid composite of Al6061/silicon carbide/graphite/alumina and concluded that addition of 17% weight fraction of alumina increased the tensile strength but graphite showed no significant change. The reason might be the thermal mismatch which tends to be the major driving force for increasing the dislocation density of the base alloy.

Another author Muruganandan et al. [23] combined aluminium 7075 with fly ash and titanium carbide and evaluated that the reinforced aluminium alloy had 32% more tensile strength than the pure form of aluminium due to the hardening of the aluminium alloy by fly ash. Dhanalaxmi et al. [24] performed the processing parameters of LM 9 Aluminium alloy (Al-10%Si-0.6%Mg) with silicon carbide of p-bond. The processing parameters that was considered was the stirring speed. The reinforcement of silicon carbide at different speeds was studied. Ultimate Tensile strength and elongation were recorded at different speeds, and uniform distribution was observed at a speed of 500-550 rpm. Due to the less interfacial reaction, the highest tensile strength was achieved at 800^{o}C.

In the matter of tensile strength, both silicon carbide and graphite are prominent reinforcements which improve the tensile strength. Alumina also shows good results but not much has been spoken about it. The addition of other reinforcements such as fly ash and red mud increases the strength up to a point and then drastically decreases.

Aigbodian [25] developed a composite of Al-Si-Fe/Rice husk and the results showed that the ultimate tensile strength had its maximum value at 15% of rice husk addition. Fatile et al. [26] studied the microstructural properties of Al-Mg-Si alloy with corn cob ash and silicon carbide. The densities and porosities of various combinations of silicon carbide and corn cob ash were compared. The results showed that the tensile strength decreases in a step by step fashion. Corn cob ash is a new material introduced in the field of preparing composites. This is such a useful material which serves the purpose of both being economical and good composites.

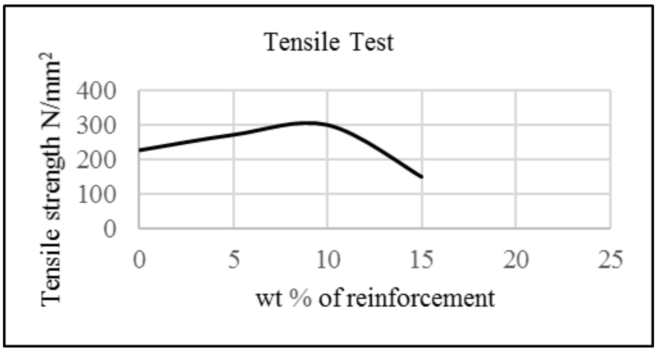


Chart 2. Tensile strength variation with wt.% of fly ash [17]

From Chart 2, it is evident that tensile strength increased with increase in the wt.% of fly ash and TiB_2 in the case of Al7075 reinforced hybrid composites. The highest value obtained was 298 N/mm² at 10 wt.% of reinforcement which was 25% greater than that of base alloy.

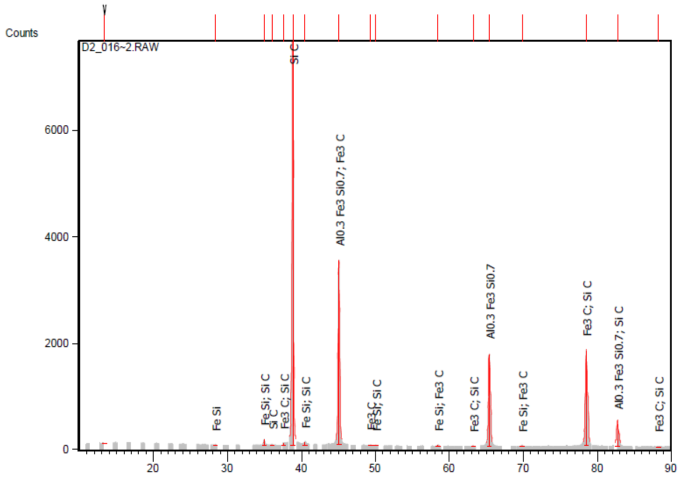


Chart 3. XRD Pattern of Al-Si-Fe with 10% rice husk ash [25]

Chart 3 represents the XRD analysis for Al-Si-Femetal matrix reinforced with 10 wt.% rice husk, and it is evident from the figure that inter planar space between particles was less and rice husk was present in the form of Fe_3C, FeSi,SiO_2, SiC and C phases. The crystalline phase of the aluminium alloy is clearly seen in the diffractograms.

2.3. Compressive strength

The addition of graphite and fly ash with Aluminium alloy of LM 25 as the base metal with varying percentage of silicon carbide (2%, 4% and 6%) displayed the best combination that can withstand the compressive force [14]. The property of fly ash particles hardens the base alloy and as a result, the compressive strength increased with the increase in the size of the fly ash particles [16]. Hence, Fly ash is the most compatible reinforcement for compressive strength and it is economical too. Saravanan and Kumar [28] performed the experiment on aluminium (Alsi10Mg) with rice husk ash as the reinforcing material. Rice husk was added at 9 and 12 wt.% considering different weights of microns. After analyzing its properties, it was observed that the compressive strength increased in this aspect. However, all the properties tend to decrease with increase in the size of particles.

Figures 2 and 3 show the microstructure of Al6061 reinforced composites with 15 wt.% and 20 wt.% of fly ash respectively. It is clear from figures that uniform distribution has been obtained at both 15 wt.% and 20 wt.% reinforced composites.

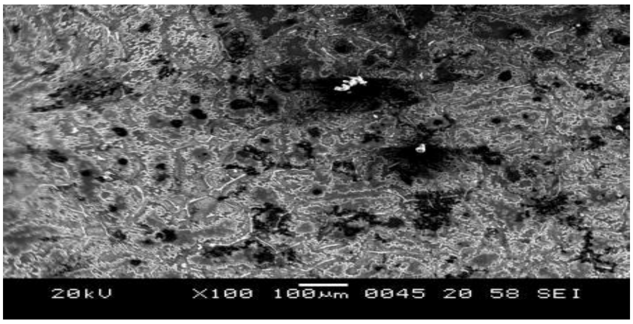


Fig 2. Microstructure of Al 6061 with 15%weight fraction of fly ash [8]

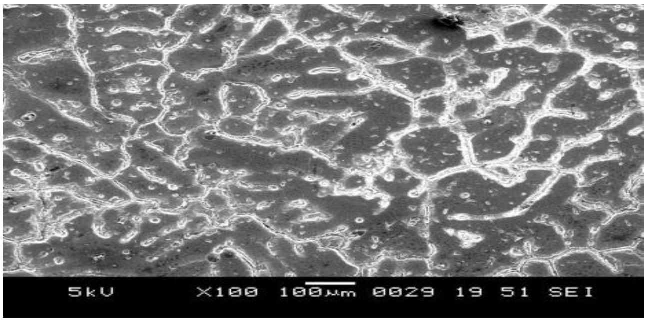


Fig. 3. Microstructure of Al6061 with 20% weight fraction of fly ash [11]

2.4. Ductility

Vanarotti et al. [11] developed the composite of the aluminium matrix with silicon carbide composite and found the throughout decrease in elongation as low as 2.4%. Bansal and Saini [13] fabricated two composites. One, Al6061 with silicon carbide and the other one Al6061with silicon carbide/graphite. In both types of composites, ductility reduced because of the fact of localized crack initiation. This was due to the local stress concentration factor which has resulted in the increase in embrittlement effect. The increase in the weight% of fly ash resulted in the reduction of the ductility due to the clustering and brittleness of the particles [16,23]. Subrahmanyam et al. [29] prepared a composite of AlSi10Mg with rice husk and fly ash as reinforcements. It was observed that with the increase in fly ash and a decrease in rice husk , the ductility is more.

It is evident that the Reinforcement such as silicon carbide, graphite, fly ash etc. resulting in a decrease in ductility.

2.5. Impact strength

Vinitha and Motgi [4] examined the parameters of Aluminium 7075 with reinforcements such as silicon carbide, fly ash and red mud. The results of Charpy impact test showed that the impact strength increased with increase in the percentage of silicon carbide but decreased with increase in the percentage of fly ash and red mud. When red mud and fly ash were compared, the former showed more impact strength. The composite of aluminium alloy with silicon carbide as the reinforced material showed that as the content of silicon carbide increased, the impact energy decreased and the reason behind this was the brittle nature of the material [30].

Mohan and Manoharan [31] used wrought aluminium alloy and alumina for the fabrication of composite. This combination was specially made for the applications of the turbocharger. Five specimens were prepared to have different combinations of both the matrix and the reinforced material summing up to 100%. The results of Charpy test evaluated that the weight percent of aluminium and alumina in the ratio of 98:2 showed the highest amount of energy absorbed. The increase in weight percent of alumina results in the increase of impact strength due to the efficient amount of bonding between the matrix and reinforcement Singh et al. [32].

Meena et al. [33] analyzed the behavior of the Al6063/SiC composite and performed the Izod test in order to find the effects of impact strength. It was inferred that the impact strength was directly proportional to the addition of silicon carbide in terms of proportions but indirectly in terms of particle size. Mathur and Barnawal [34] developed the composite of Aluminium with 4% of copper and 5% of silicon carbide and found in Izod test that the strength increased as the content of silicon carbide was increased.

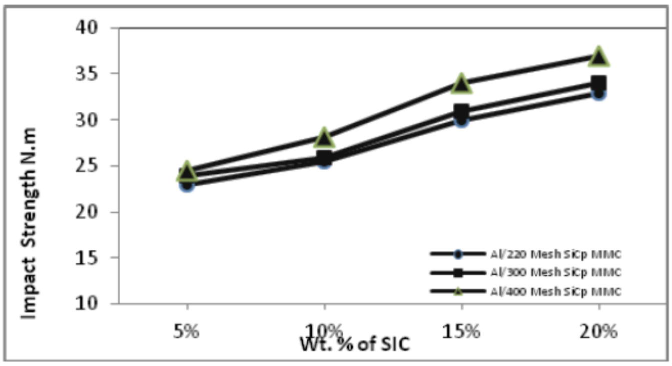


Chart 4. Impact strength variation of Al6061/SiC [27]

Chart 4 shows that the impact strength increased with the increase in the wt.% of SiC reinforced with Al6063 and the highest value was obtained at 20 wt.% of reinforcement.

Table 1 shows the mechanical properties of single reinforced aluminium matrix composites (AMCs) and hybrid aluminium matrix composites (HAMCs). It is observed from the table that when aluminium like pure Al, Al6061, Al 7075 and A356 is reinforced with various wt.% of SiC reinforcement both the hardness and tensile strength improved as compared to that of the base matrix with increase in the wt.% of reinforcement. The Hardness value of Al356 also increased when reinforced with graphite at lower wt.% of graphite, like 0.5, 1, 1.5 wt.%. Both the hardness and tensile strength of AA7075 increased when it is reinforced with B_4C, Al_2O_3, and SiC respectively.

It is also evident from the table that when Al6061 is reinforced with SiC+FA and SiC+Gr, the hardness, tensile strength, and yield strength of reinforced hybrid composites were higher than that of base matrix Al606. When LM 25 aluminium matrix reinforced with SiC+Gr, the hardness and tensile strength of hybrid composites were more than that of base metal LM25 at all wt.% of reinforcements. In a nutshell, we can conclude from table 1 that the mechanical properties like hardness, tensile strength, and yield strength of the base metal improved both in the case of single reinforced and hybrid composites.

3. TRIBOLOGICAL PROPERTIES

Tribological properties include wear rate, the coefficient of friction and porosity. After the fabrication, these parameters are also investigated along with mechanical properties in order to have an overall study of the reinforced composites. Apart from the regular usage, it finds its application in wind turbines, biomedical field, the information storing chips etc.

3.1. Wear rate

Shanmughasundaram [35] fabricated Al7075-silicon carbide composite and studied the sliding velocity and varying load on wear rate using a pin-disc test. The precipitated heat treated composite (T6 Aged for 6 hours) showed higher wear resistance at a load of 20 N and sliding velocity of 1m/sec. It was seen that wear increased by 26% when the load was doubled and by 21% when the sliding velocity was doubled. The author also said that wear resistance of the heat-treated composites increased with ageing irrespective of load and velocity.

Rahman and Rashed [6] studied the characteristics of silicon carbide reinforced aluminium matrix composite in various proportions. The loss of mass for aluminium-silicon carbide was less in comparison to the pure form of aluminium. This happens because the softer Al gets worn away and leaving behind the hard silicon carbide particles during wear test. These exposed particles of silicon carbide protect the matrix from any further wear. The maximum resistance to wear was observed at 20% weight fraction of silicon carbide.

Muthu and Rajesh [36] worked on the dry sliding characteristics of aluminium 7075 with 3% of silicon carbide along with 5% of fly ash. The author ascertained that addition of silicon carbide to Al7075 increased the density and decreased the wear rate whereas, in the case of fly ash, both the parameters decreased. Interestingly, the wear rate and specific wear rate increased when the sliding velocity increased from 2 to 3 m/s and then decreased after that up to 4m/s. Bansal and Saini [13] have revealed the wear behavior of Al359 with silicon carbide/graphite reinforced and has done a detailed analysis under (SEM). The analysis showed that wear resistance of the reinforced matrix increased with higher sliding velocities, sliding distance conditions and loading. The variation of wear rate with different composites was plotted on the graph. Graphite, which acts as a lubricant reduces the wear rate at higher loading in comparison to silicon carbide. Cracks of large size, groves, ploughing marks and voids are found on the surface of Al359-silicon carbide. It was ascertained that the cracks, grooves, and micro-cracks appear to be very fine in Al/SiC/Graphite in comparison to that of Al/SiC.

Basavaraju et al. [14] analyzed the characteristics of LM alloy along with silicon carbide/graphite and silicon carbide/fly ash separately. The most prominent wear resistance was obeyed in 2%SiC/2%graphite and in the other case, it was 4%SiC/2%fly ash. Hence, it is evident form these results that the addition of silicon carbide in this alloy makes the material lose the wear characteristics at the higher percentage. Few researchers like Raghavendra and Ramamurthy [37] have taken alumina as the reinforced material and have shown that the wear rate reduced with the increase in wt. % of alumina up to 20%. Further, there was no change at all.

Other researchers such as Thirumalai et al. [38] and Mahajan et al. [39] have used unusual reinforced material such as boron carbide and titanium boride and they all showed the tendency of increase in wear resistance up to a certain wt.%. Kumar et al. [40] studied the dry sliding behavior of Al2219 with aluminium oxide and molybdenum disulphide. The results showed the decrease in wear rate for the increase in reinforcement. But the wear rate increased with increase in load and sliding distance. In contrast, the addition of molybdenum disulphide increased the wear resistance by making a layer at the interface during testing. Rana et al. [41] studied the behavior of Al5083 with micro and Nano SiC using stir casting. Mainly wear rate was focussed upon. The wear rate of composite increased with increase in sliding distance. It was higher in the base alloy. At higher loads and sliding distance, the micron particle showed better wear resistance when compared to nano particles of SiC. But the case was opposite at low speed and low loads.

Radhika et al. [42] fabricated the composite of LM 25 with SiC and alumina. Wear rate of the metal matrix composite decreased with increase in wt.%. Another important thing noted was that as the wt.% was increased, the measure of grooving on the worn-out surfaces decreased. Pavithran et al. [43] studied AL6061 with SiC and graphite and found that the wear rate decreased with the addition of both SiC and graphite. Wear behavior of the composite Al356/alumina/graphite prepared by squeeze casting was studied in detail by Sukesha et al. [44]. The most important parameter in controlling the wear behavior was the formation of lubricating layer. The mass loss increased with increase in applied load and this is because of the pull out of graphite and the presence of alumina ceramic phase in the metal matrix composite.

Manikandan and karthikeyan [45] studied the wear behavior of Al7075 with silicon carbide, alumina and boron carbide as the reinforcements. The wear test was performed on pin disc for varying applied load and sliding distance. The composite with boron carbide showed superior wear resistance than others. This is because of the heat resistance and hardness of the particle. Kumar et al. [46] developed the performance of nano-SiC particles of AA2024 with the addition of nano-graphite. The inclusion of silicon carbide increased the wear resistance and the addition of graphite increased it further more. Interfacial bonding was good in the composite as analyzed by XRD.

It is evident from the literature review that the wear resistance can be improved by the addition of both silicon carbide and graphite. The composite is defended by the particles of silicon carbide that are prominent on the outer layer of material while the graphite helps in reducing the wear rate when the composite has to be dealt at higher load. Other reinforcements are not as effective as these two and neither there is any consistency in their results.

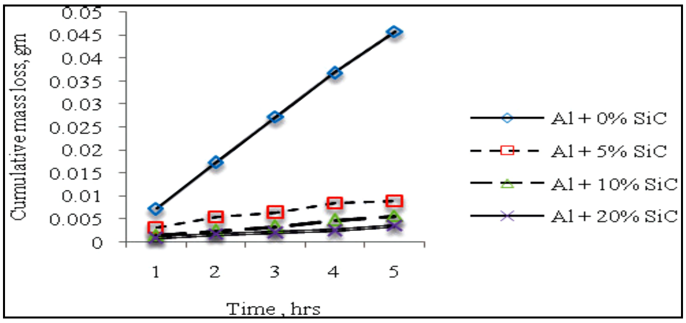


Chart 5. Wear rate vs function of Time [14]

From Chart 5, it is clear that the wear rate of the base alloy was greater than the SiC reinforced composites. This might be due to high hardness of composites as compared to base alloy, also the wear resistance increased with increase in wt.% of reinforcement.

Chart 6 shows the Variation of the wear rate for Al359 for various reinforcements at a sliding velocity of 2.5 m/s and sliding distance of 2000 m. The wear resistance of Al-SiC-Gr hybrid composite had less wear at lower loads. At a slightly higher load, the wear resistance of Al-SiC was less.

Chart 7 shows the XRD pattern for Al2024/SiC reinforced hybrid composites, it is clear from figure aluminium alloy is represented in the form of larger peaks, and whereas silicon carbide by lower peaks and the peaks of SiC increased as the wt.% of SiC increased.

Chart 8 show**s** the relation between wear loss and applied load. It is evident from the figure that wear loss decreased with the increase in the reinforcement wt.% at constant load.

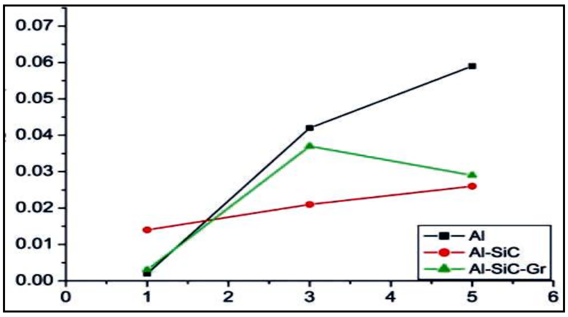


Chart 6. Variation of Load (x-axis) vs Wear rate (y-axis) for Al359 [3]

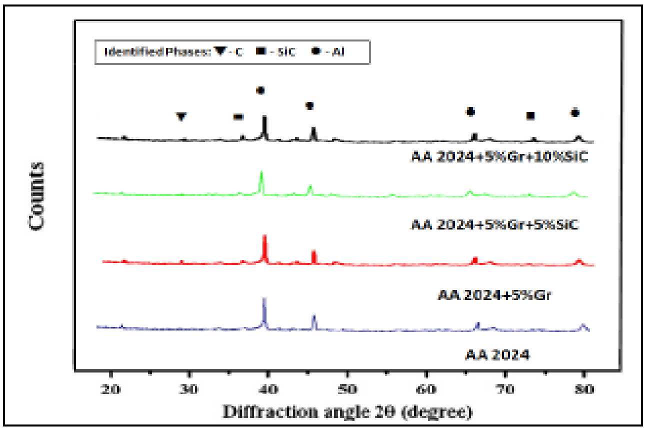


Chart 7. XRD Pattern of the prepared Nano Composites [46]

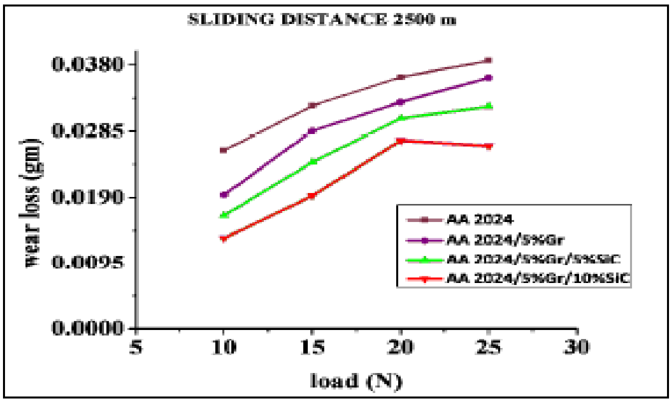


Chart 8. Wear Loss of the Nano Composite [46]

3.2. Coefficient of friction

Marwaha et al. [47] statistically investigated the wear parameters of aluminium/silicon carbide/graphite using Taguchi's technique L9 orthogonal array. The software ANOVA was used to find out the effect of sliding speed, applied load and track diameter on the coefficient of friction. A detailed analysis was done which consisted of finding weight loss, the mean value and S/N ratio for the coefficient of friction etc. After developing a mathematical model, the author concluded that the track diameter had the highest influence on the coefficient of friction which was then followed by sliding speed and applied load. Muthu and Rajesh [36] fabricated a hybrid metal matrix composite with aluminium 7075/silicon carbide/fly ash. The combination which established the lowest coefficient of friction was Al7075/3%SiC/5%fly ash.

From the literature review, nothing much has been revealed about the coefficient of friction and its performance depends solely on the composition.

3.3. Uniform distribution

Saheb [12] conducted experiments by adding silicon carbide and graphite to aluminium and when observed under a microscope, it was revealed that the aluminium-silicon carbide was less uniformly distributed in comparison to that of the aluminium-graphite composite. The barriers that occur at the surface were eliminated with the help of the stirrer and this is due to the property of poor wettability of the graphite. Flow transition such as axial and radial flow takes place and results in proper distribution and settling. The interfacial analysis showed a strong bond between the composite and the alloy. In the matrix, the particles were well embedded in the alloy and there was no sign of any voids or separation. Prashant et al. [27] noticed the uniform distribution of Al-6061 silicon carbide and Al-6061-graphite during the microstructural studies.

Kumar et al. [16] investigated certain parameters by mixing Al6061 with fly ash and observed a uniform distribution of the fly ash particles due to good bonding between the Al6061 and fly ash. No voids and discontinuities were seen when examined under scanning electron microscope. Prasad and Krishna [3] showed that addition of composites like rice husk also resulted in a uniform distribution. They mixed fairly well and has good retention properties. Thus, apart from silicon carbide and graphite, organic composites also show this behavior. Mahajan et al. [39] studied the microstructure of the silicon carbide and titanium boride and found that the silicon carbide is uniformly distributed in the matrix. The structure of silicon carbide was revealed to be interdendritic whereas, the titanium boride was in the form of hexagonal crystals.

Thus, in order to get a uniform distribution, graphite and fly ash are better than silicon carbide. Moreover, it also depends on upon the stirring conditions and directions which have to determine properly before fabrication.

4. THERMAL PROPERTIES

Krishna et al. [48] evaluated the heat flow distribution characteristics of the metal matrix composite of Al6061 with silicon carbide and graphite using ANSYS software. The results showed the reduction of thermal conductivity due to the inclusion of graphite. Okumus et al. [49] studied thermal expansion and thermal conductivity of matrix Al-11.8 wt.% SiC with silicon carbide and graphite. It was found by generating thermal stress response curve for varying proportions of SiC and graphite that increasing amount of graphite in SiC reinforced base alloy points to higher strain rate but the low coefficient of thermal expansion values. Increasing the graphite content leads to grain refinement for both primary and aluminium dendrites and eutectic silicon. Thus, it results in low thermal expansion. On the other hand, the inclusion of more amount of graphite gives a dimensional stability to the composite because the graphite particles absorb thermal expansion due to their layered structure.

Behera et al. [50] experimented the solidification behavior and forgebility of Aluminium LM6 with the reinforcement of silicon carbide using stir casting. Cooling curves were obtained at different modulus of casting and it was observed that silicon carbide plays a crucial role in decreasing the cooling rates. Also, analysis of forgebility stated that deformation decreases with the increase in the weight percent of silicon carbide.

It has been observed that the Graphite seems to be the excellent material for the thermal property because of its multiple advantages. It reduces the properties like thermal expansion, thermal conductivity etc. which are not desirable. Not only this, it also reduces the chances of cracks and fracture that occur on the composite.

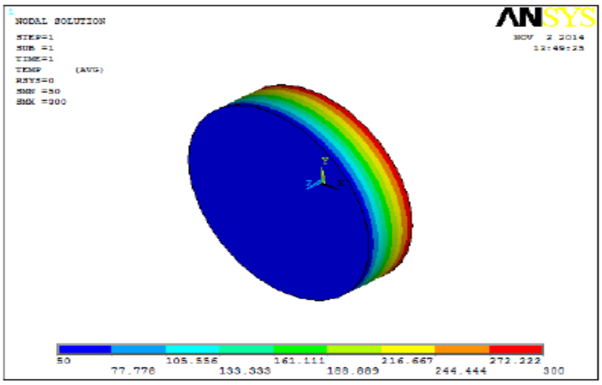


Fig. 4. Temperature distribution of Al6061 with 5% SiC and 5% Graphite [48]

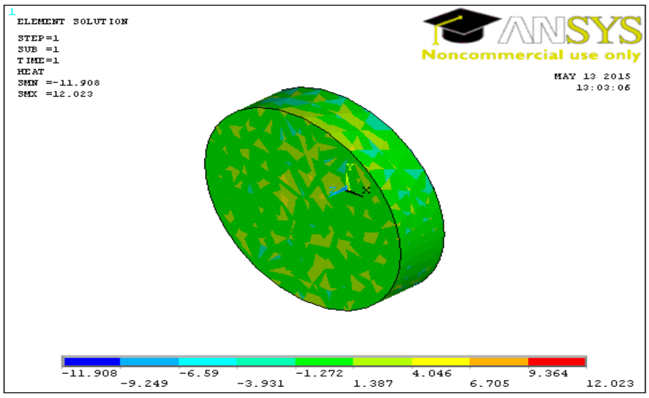


Fig. 5. Heat flow Al6061 with 5% SiC and 5% Graphite [48]

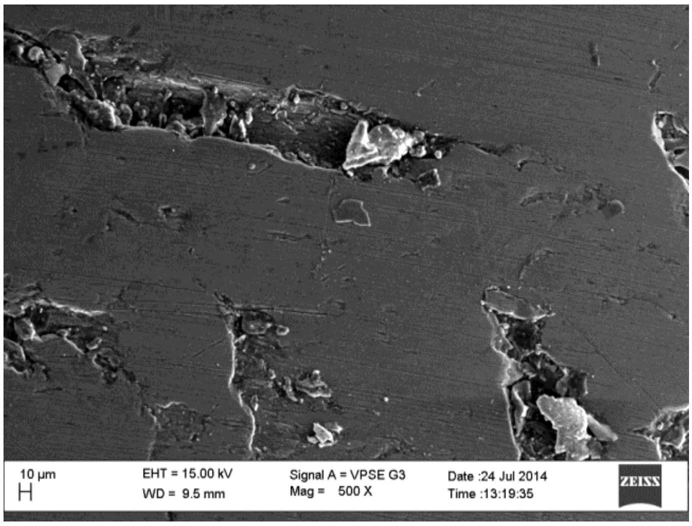


Fig. 6. SEM Microstructure of Al6061 with 5%SiC and 5% Graphite [48]

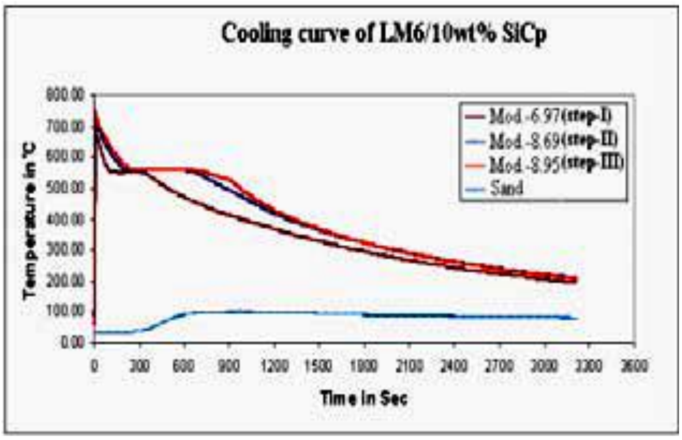


Chart 9. Cooling Curve graph of LM6 with 10wt% SiC at different modulus of casting [50]

Fig. 4 and 5 show the temperature distribution and heat flow analysis respectively. It is observed that Al6061/ 5wt.%SiC/ 5wt.%Gr reinforced hybrid composite shows minimum heat flow and minimum thermal conductivity at a temperature of 300°C as compared to the Al6061 alloy. The thermal flux also decreases for all the different compositions prepared which tends to reduce the heat flow.

Fig 6 shows the microstructure under SEM for Al6061 with 5%SiC and 5%Gr.

Chart 9 shows the cooling curves at different steps of casting. As the wt.% of SiC increased, the cooling rate decreased. Also, the eutectic solidification time increased with increase in the wt.% of reinforcement. The addition of SiC particles decreased the liquidus temperature as compared to the base alloy which in turn strengthen the composite.

5. CONCLUSION

The purpose of this literature review is to have a broader perspective about the different grades of aluminium and choosing the best combination of the individual parameters considered.

1. Hardness shows the best results when the silicon carbide is employed at 25% weight percent.
2. Hardness increases with the increase in silicon carbide but decreases with increase in graphite. Hence to obtain an optimum hardness of the desired number, both the reinforced material can be used in proper proportions.
3. Several reinforced materials such as graphite, fly ash, red mud and alumina has shown better results pertaining to tensile strength when compared to Silicon carbide.
4. For the improvement of compressive strength, fly ash particles are the most appropriate ones as it indurates the base alloy.
5. Ductility is one such property which tends to decrease with the addition of reinforced material. It decreases constantly when silicon carbide is reinforced whereas in the case of fly ash, it decreases drastically up to the addition of 10% and then gradually.
6. Reinforcing the matrix with silicon carbide and graphite results in no pores if the mixing is done well.
7. Various organic reinforced material such as rice husk ash and cow dung also plays a significant role in the improvement of properties and are in recent trends due to its economic value.
8. The addition of silicon carbide consistently shows prominent results in increasing the wear resistance.
9. Various mathematical models and analysis prove a useful technique in determining the optimum machining parameters.
10. Uniform distribution is apparently more evident in Aluminium-Graphite composite rather than aluminium-silicon carbide.
11. The addition of graphite results in the decrease in the thermal expansion of the composite.
12. Apart from mechanical and tribological properties, thermal is one such area where the further research can be concentrated upon.

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