A REVIEW ON FLY ASH REINFORCED ALUMINIUM ALLOY COMPOSITE

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***Abstract*: Aluminum matrix composites (AMCs) are potential materials used in various applications due to their good physical and mechanical properties. The property can be improved or enhanced by addition of reinforcements into the metallic matrix which improves the stiffness, creep and fatigue, specific strength, wear properties compared to the conventional engineering materials. Fly ash is used as the reinforcement material which is abundantly available as industry byproduct with different weight fraction based on the property required. It is used as the reinforcement to produce composite by stir casting. Several works are been carried out using fly ash as reinforcing material. In manufacturing the particulate reinforced composites the stir casting is the suitable method used and which helps in achieving a uniform distribution of reinforcement within the matrix, which affects directly on the properties and quality of composite material.**

***Index Terms*: Reinforcement, Stir casting, Fly ash, Metal Matrix Composite.**

I. INTRODUCTION

The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Among various particulates used, fly ash is one of the least expensive and low density reinforcement available in huge quantities as solid waste by- product in thermal power plants [2]. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminum alloy will promote yet another use of this low-cost waste by-product[3].The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. These alloys are preferred matrix materials for the production of MMCs. The reinforcements being used are fibers, whiskers and particulates. The advantages of particulate-reinforced composites over others are their formability with cost advantage [5]. Among several series of aluminum alloys, heat treatable Al6061 and Al7075 are much explored, among them Al6061alloy are highly corrosion resistant, exhibits moderate strength and finds much applications in the fields of construction, automotive and marine applications. [6] It is therefore expected that the incorporation of fly ash particles in aluminum alloy will promote yet another use of this low-cost waste by-product. Now a days the particulate reinforced aluminum matrix composite are gaining importance because of their isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminum matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. Fly-ash may be helpful for making a light weight insulating composites. The particulate composite can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by casting. Casting route is preferred as it is less expensive and enable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one. The only problem associated with this process is the non-uniform distribution of the particulate due to poor wet ability and gravity regulated segregation. 6061Al is quite a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics. Among different kinds of the recently developed composites, particle reinforced metal matrix composites and in particular aluminum base materials have already emerged as candidates for industrial applications. [3]

Aluminium matrix composites (AMCs) are the competent material in the industrial world. Due to its excellent mechanical properties, AMCs are widely used in aerospace, automobiles, marine etc. [1].The Metal matrix composites (MMCs) are used in industrial applications for its lighter weight with high specific strength, stiffness and heat resistance. The processing of MMCs by casting process is an effective way of manufacturing. The effect of rpm on specific wear rate and comparison of mechanical properties of the metal matrix composites have been investigated.

The AL6061, chosen as a base metal and varying composition of Fly ash i.e. 10%, 15% and 20% was taken as reinforcement. It was found that tensile strength increase with addition of fly ash. Similarly 15% Fly ash found to be tensile whereas composite of 20%Fly ash was found to be of maximum hardness. Specific wear rate decreases with addition of fly ash up to a certain volume. Aluminum alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. 6061Al is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required. [2]

Stir casting is one of the simplest ways of producing aluminum matrix composites (AMCs). The fabrication of AMCs reinforced with various weight percentages of fly ash by modified stir casting route. The wettability of Fly ash particles in the matrix was by adding magnesium into the melt. The microstructure and mechanical properties of the fabricated AMCs were analyzed. The optical and scanning electron micrographs revealed a homogeneous dispersion of Fly ash particles in the aluminum matrix. The mechanical properties like hardness and tensile strength were improved with the increase in weight percentage of weight percentage of Fly Ash in the aluminum matrix. [1]

The aim which is involved in designing metal matrix composite materials is to combine the desirable properties of metals and particulates [4]. The aluminum based matrix composite has been done and related brief data are observed that the incorporation of fly ash particles in aluminums alloy has the potential for conserving energy intensive aluminums, and thereby reducing the cost of aluminums products, and at the same time causing a reduction in the weight of the products. The structure and the properties of the metal matrix composites are controlled by the size and type of the reinforcement and also the nature of bonding. From several researchers, some of the techniques for the development of these composites are stir casting, spray atomization, powder metallurgy, plasma spraying, co-deposition and squeeze-casting [5].

MMCs containing up to 15% fly ash particles could be easily fabricated. Uniform distribution of fly ash was observed in the matrix. The fluidity and density of MMCs decreases, whereas hardness increases with increase in percentage of particulates. The tensile strength, compression strength, and the impact strength increases with increase in percentage of particulates. Increasing the amount of fly ash the density of the composites was decreased and the hardness was increased. The increase in compression strength was observed with increase in amount of fly ash. Fly ash particles lead to an enhanced pitting corrosion of the aluminum–fly ash (ALFA) composites in comparison with unreinforced matrix (AA 2024 alloy). The experimental investigation of metal matrix composites with fly ash reinforced aluminum alloy (Al 6061) composites samples, processed by stir casting route are reported. The aluminum alloy was reinforced with 3 wt. %, 6 wt. %, and 9wt. % fly ash. Hardness of the composite were tested it was found that when the hardness of the composites can be increased when compared to Al 6061[2].

Many technical challenges exist with the technology of casting, so to overcome this problem many different manufacturing techniques are used. One such challenge is in achieving a uniform distribution of reinforcement within the matrix, which directly affects on the properties and quality of composite material. To develop Aluminium based particulate reinforced MMCs with an low cost method of producing and to obtain homogenous dispersion of ceramic material the two step-mixing method of stir casting technique has been proposed and subsequent property analysis has been made. [8].

II. VARIOUS FABRICATION PROCESS OFALUMINUM MMC

The manufacturing of metal matrix composites is done using liquid state or solid state process based on the property required and the type of the reinforcement used[7].

A. Liquid state fabrication route

S.No	MMC fabrication route	Inference	Applications	Cost Aspects
1	Stir casting	Depends on material properties and process parameters. Suitable for particulate reinforcement in AMC.	Applicable to large quantity production. Commercial method of producing aluminium based composites.	Least expensive
2	Squeeze casting	Pertinent applicable to any type of reinforcement and suitable for mass production.	Used in automotive industry and aeronautical industry for producing different components like pistons, connecting rods, rocker arms, cylinder heads, front steering knuckle, cylindrical components etc	Moderate
3	Compo casting (or) Rheocasting	Apt for discontinuous fibres, particularly suitable for particulate reinforcement. Lower porosity is observed.	Used in automotive, aerospace industry , manufacturing industry.	Least expensive
4	Liquid metal infiltration	Filament type reinforcement normally used.	Production of tubes, rods, structural shapes and structural beams.	Moderate/ Expensive
5	Spray casting	Particulate reinforcement used and used to produce full density materials	Cutting and grinding tools, electrical brushes and contacts.	Moderate
6	In-situ (reactive) processing	Good reinforcement/ matrix compatibility, homogeneous distribution of the reinforcing particles.	Automotive applications.	Expensive
7	Ultrasonic assisted casting	Nearly uniform distribution and good dispersion.	Mass production and net shape fabrication of complex structural components.	Expensive

B. Solid state fabrication route

S.No	MMC fabrication route	Inference	Applications	Cost Aspects
1	Powder Metallurgy (PM route)	Both matrix and reinforcements used in powder form. Best for particulate reinforcement.	Production of small objects (especially round), bolts, pistons, valves, high-strength and heat-resistant materials. Vast applications in automotive, aircraft, defense, sports and appliance industries.	Moderate
2	Diffusion bonding	Handles foils or sheets of matrix and filaments of reinforcing element.	Manufacture sheets, blades, vane, shafts, structural components.	Expensive
3	Vapour deposition techniques	PVD coatings are sometimes harder and more corrosion resistant than coatings applied by the electroplating process.	Aerospace,Automotive, Surgical/Medical Dies and moulds for all manner of material processing. Cutting tools, Firearms Optics Watches, Thin films (window tint, food packaging, etc.)	Moderate
4	Friction Stir Process	Used as surface modification process. Increase in micro hardness of the surface, significant improvement in wear resistance.	In Automotive and Aerospace applications.	Moderate/ Expensive

III. STIR CASTING PROCESS USED FOR MMCs

In Stir casting method of composite materials fabrication, a dispersed phase is mixed with a molten metal matrix by using mechanical stirring. The composite material which is in liquid state is then cast by conventional casting methods and can be processed by conventional metal forming technologies. The stir casting method is relatively low cost and very simple. This can be prepared by conventional processing equipment and also can be carried out on a continuous and semi continuous basis by using stirring mechanism as shown in Fig 1 [6].

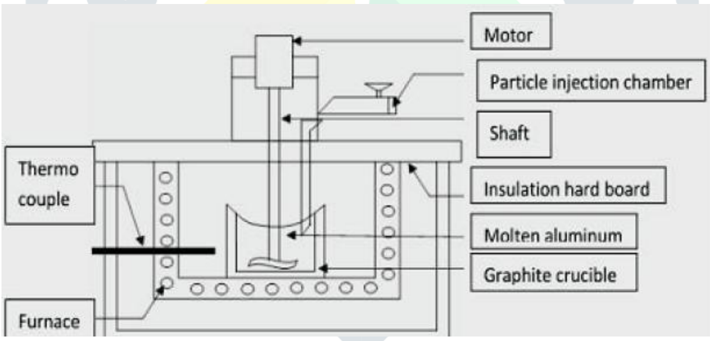

Figure 1 Stir casting Experimental set up

In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained.

The simplest and the most cost effective method of liquid state fabrication is Stir Casting [3].
Stir Casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30 vol. %).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous.
- There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.
- The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition. The method using stirring metal composite materials in semi-solid state is called Recasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase.

Fly ash reinforced Aluminum alloy (Al6061) composites, processed by stir casting route were used. Liquid metallurgy route was used to synthesize the hybrid composite specimens. The matrix alloy was first superheated above its melting temperature and then the temperature was lowered gradually until the alloy reached a semisolid state. The required quantities of fly ash (10, 15 and 20 Wt. %) and powder were taken in containers. Then the fly ash was heated to 450°C and maintained at that temperature for about 20 minutes. A vortex was created in the melt due to continuous stirring by a mechanical stirrer. At this stage, the blended mixture of preheated fly ash and graphite particles were introduced into the slurry and the temperature of the composite slurry was increased until it was in a fully liquid state. Small quantities of magnesium (4 Wt % fixed) were added to the molten metal to enhance wettability of reinforcements with molten aluminum. Stirring was continued for about 5 minutes until the interface between the particle and the matrix promoted wetting and the particles were uniformly dispersed. The melt was then superheated above the liquid us temperature and solidified in mould to obtain desired samples.

IV. Aluminum as MMC

Metal Matrix Composites are composed of a metallic matrix like Iron, cobalt, aluminum, magnesium, copper and a dispersed ceramic (oxides, carbides) or metallic (lead,Tungsten, molybdenum) phase.

Aluminum alloys possess a number of very attractive characteristics which, and light weight, which make them extremely attractive for many applications. Further, their versatility with respect to options of how to shape them and strengthen them provides an amazing variety of choices when we look for an ideal material for special application.

The 6xxx alloys are heat treatable, and have moderately high strength coupled with excellent corrosion resistance. Extrudability is the unique feature, which make them the first choice for architectural and structural members where unusual or particularly strength- or stiffness-criticality is important.

Higher strength 6061 alloy finds broad use in welded structural members such as truck and marine frames, railroad cars, and pipelines. Among specialty alloys in the series: 6066-T6, with high strength for forgings, 6111 for automotive body panels with high dent resistance and 6101and 6201 for high strength electrical bus and electrical conductor wire, respectively.
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V. FLY ASH

The residues generated in the combustion of coal is Fly ash, which is an industrial by-product recovered by the flue gas of coal burning power plants. Depending upon the source and type of the coal being burned, the components of the fly ash vary, but all fly ash includes substantial amounts of silica components.

In general, fly ash consists of SiO_2, Fe_2O_3, Al_2O_3 as major constituents and oxides of Na, K, Mg, Ca etc. as minor constituent. The shape of Fly ash particles is mostly spherical in nature and the size range from less than 1μm to 100μm, with a specific surface area typically between 250 and $600m^2/kg$. The specific gravity of fly ash vary in the range of 0.6-2.8gm/cc. Depending upon the type of coal burned and the burning conditions the physical properties of fly ash varies. Class 'F' fly ash is generally produced from burning high rank (containing high carbon content) coals such as anthracite and bituminous coals, whereas, Class 'C' fly ash is produced from low rank coals.

Fly ash particles are classified into two types.
1. Precipitator
2. Cenosphere.

The solid spherical particles of fly ash are called precipitator fly ash and the hollow particles of fly ash are called cenosphere fly ash. The precipitator fly ash density ranges between 2.0–2.5 g cm-3 can, which helps in improving various properties of selected matrix materials, including stiffness, strength, and wear resistance and reduce the density. Cenosphere fly ash, which consists of hollow fly ash particles, can be used for the synthesis of ultra-light composite materials due to its significantly low density, which is in the range 0.4–0.7 g cm-3, compared with the densities of metal matrices, which is in the range of 1.6–11.0 g cm-3. Coal fly ash has many uses including as a masonry blocks, as a concrete mixture, cement additive, as a material in lightweight alloys, as a concrete aggregate, in roadway/runway construction, in structural fill materials, as roofing granules, and in grouting. The largest application of fly ash is in the cement and concrete industry, though, creative new uses for fly ash are being actively sought like use of fly ash for the fabrication of MMCs. [3]

Component Lignite	Bituminous	Sub bituminous	Lignite
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15

CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

VI. WHY FLY ASH IS USED?

1. The fly ash is used as a filler or reinforcement in metal and polymer matrices which is a byproduct of coal combustion, available in very large quantities at very low costs since much of this is currently land filled. Use of manufactured glass microspheres has limited applications due to high cost of production. The costs of composite materials can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. The attempts have been made to incorporate fly ash in both polymer and metal matrices. Density of cenosphere fly ash has a lower density than talc and calcium carbonate, but higher than hollow glass. The cost of cenosphere is much lower than hollow glass .Cenosphere is one of the lowest cost fillers in terms of the cost per volume.

2. Fly ash has high electrical resistivity and low thermal conductivity. Light weight insulating composites can be obtained due to its low density.

3. Fly ash as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance, improves the machinability, damping capacity, coefficient of friction etc. which are needed in various industries like automotive etc. [3]

VII. CONCLUSION

- SEM micrographs revealed the presence of SiC and Fly ash particles in the composite with homogeneous dispersion.
- The micro and macro hardness of the composites were increased with respect to addition of weight percentage of SiC and constant weight percentage of Fly ash particles.
- The reinforcement of Fly ash up to 15% particles has enhanced the tensile strength of aluminum matrix and composites. With further addition tensile strength decreases.
- Fly ash increases hardness whereas graphite decreases hardness in a little amount but improves machining.
- Increasing the percentage of fly ash more than 15% fly ash increased hardness and this may be concluded that material becomes less ductile that is why on increasing addition of fly ash specific wear rate increases.
- From the study it is concluded that we can use fly ash for the production of composites which can turn industrial waste into industrial wealth. This can in turn solve the problem of storage and disposal of fly ash.
- Fly ash up to 10% by weight can be successfully added to Al by stir casting route to produce composites.
- The hardness of pure Al increased from 16 BHN to 18 BHN with addition of 10% fly ash.The addition of fly ash in Al melt, there was appreciable reduction of density from 3.398 gm/cm^3 to 2.807 gm/cm^3.
- Both the friction coefficients and the wear rates decreased significantly with the incorporation of fly ash in Al melt.
- Strengthening of composite is due to dispersion strengthening and particle reinforcement.

VIII. FUTURE SCOPE

- From the conclusions above we can suggest a better material by varying the weight fraction, the manufacturing process and the heat treatment process.
- The heat treatment process can vary the properties as required.
- Varying the particulate size leads to change in property of the composite to be produced.

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