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Review Article

A Study On Effects of Reinforcement Materials In Aluminum-Based Metal Matrix Composites

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Abstract *- In this era, there has been a substantial growth market for latest-generation materials. Hybrid metal matrix composites (HMMCs) are still one of the emerging new materials having lightweight, incredibly good mechanical characteristics. To make hybrid MMCs, many different types of reinforcements (more than one) with various properties are added to the matrix material. These composites are commonly utilized in the manufacturing, aviation, and automobile industries. Aluminum Hybrid metal matrix composites (AlHMMCs) are a modern type of MMCS that contains Al as matrix material that can meet the current needs of specialized applications. These requirements can be met because of enhanced mechanical properties, convenient manufacturing, and the ability to reduce the fabrication cost. The efficiency of these materials primarily depends on the choice of the appropriate reinforcement material combination and reinforcement type. MMCs propensities are often calculated by the reinforcing content. Thus this study provides a brief overview of the hybrid metal matrix and aluminum-based hybrid composites. This article discusses the combinations of reinforcement materials Al203, SiC used in the manufacturing of hybrid AlMMCS. The result of the paper is that the use of reinforcement materials increased the overall efficiency of the composites produced and led to reducing overall expenses.*

Keywords *- Al2O3, Aluminum metal matrix composite, Aluminum hybrid metal matrix composite, Composites, Mechanical properties, SiC*

I. INTRODUCTION

Composite materials are a combination of two or even more materials of different physical characteristics to produce new material that satisfies certain characteristics. Standard materials in many industrial sectors no longer fulfill increasingly challenging demands, and so the required materials are constantly designed to meet unique requirements. The composite use in recent years has steadily risen and is unlikely to rise further in the future. Classification of composites is given in Fig.1.

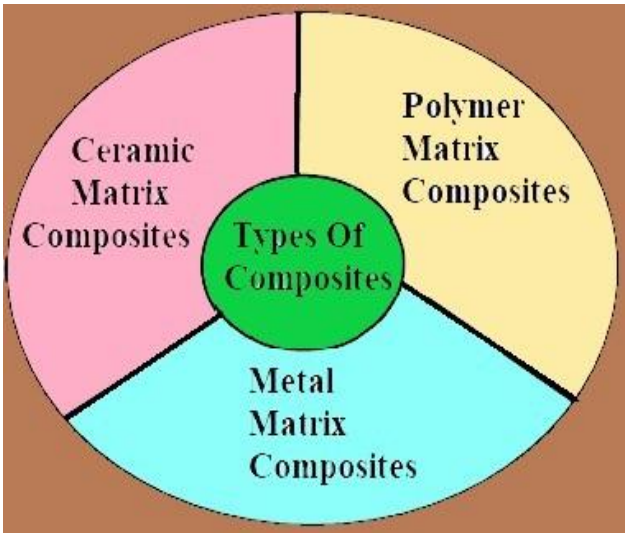

Fig.1:Types of composites based on Matrix Materials

MMCs give a broad variety of advantages compared to traditional materials in such circumstances. Metal Matrix Composites (MMCs) are steadily but gradually growing into use in many sectors. Commonly utilized metals as a matrix in the fabrication of MMCs are iron, magnesium, titanium, copper, and their alloys. In composites, reinforcements are mostly particles, fibers, and whiskers. Particulate-reinforced structures have certain benefits, including lightweight and reduced price than other materials. The heat and wear resistance properties are innate. Silicon carbide and alumina are different forms of particulate reinforcements mostly used [1].

Pure aluminum is lightweight, but it is not as solid as other metals. It may be drawn and wrapped into the wires and foil film. It is commonly utilized in the electronics sector in the development of electrical cables. Electricity transmission cables are primarily constructed of aluminum, saving a significant amount of costs on the site compared to copper. Outstanding resistance towards corrosion, low density, a strong strength-to-weight ratio, and reasonable toughness make aluminum a substance that is extremely economical and ideal for usage in the commercial fields due to these characteristics. Aluminum has outstanding

thermal conductivity. This feature made aluminum an effective metal for widespread usage in refrigeration and heating. MMCs are now being studied in the automobile industry to create automotive lightweight in order to replace conventional materials in main areas. MMCs are the best-suited material for the fabrication of the Space Shuttle, aircraft, motorcycles, many other materials for daily uses and cars. When researching composite materials, a large majority of them are constructed from AlMMC materials. Characteristics of magnesium, copper, iron, or titanium, like all other composites, the properties of aluminum matrix composites can be modified according to need. Aluminum alloys are normally used as matrix materials in AlMMCs shown in Fig. 2 and Fig.3 [2].

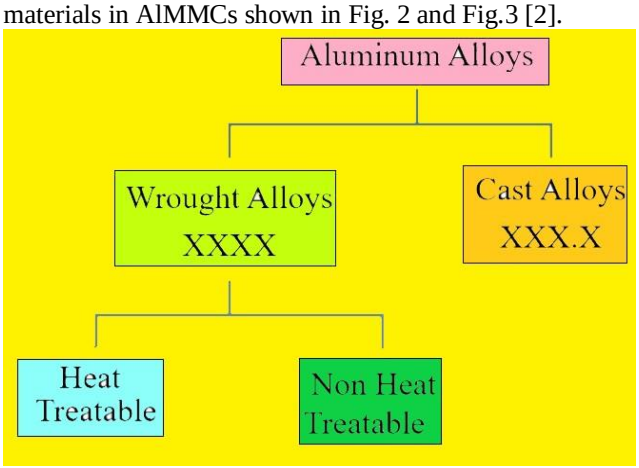

Fig. 2: Types of Aluminum Alloys

In order to attain the necessary characteristics, the matrix alloy, reinforcing content, reinforcement quantity, and form of reinforcement and manufacturing methods may be varied. However, aluminum composites provide low-cost advantages over many other MMCs, independent of their variants. They also deliver excellent thermal conductivity, strong shear strength, good wear tolerance, operation at high temperatures, non-flammability, limited fuel and solvent attacks, and the ability to shape and operate on traditional equipment. Most MMCs based on an aluminum base, and their alloys got significance in both research and development for several industrial applications; this is because aluminum is lightweight, which is the first requirement in most of the applications of the current MMCs. Additionally, It is cheap compared to other light metals, such as titanium and magnesium. Aluminum alloys are generally used in large quantities in the automotive and aeronautical industries. Its excellent resistance, ductility, and behavior against corrosion are already well-known and can be modified to meet the requirements of many different applications [3].

Based on the structural characteristics of the composites, their behavior and properties can be anticipated, and there is considerable significance of the constituent's engagement in the composite's physical properties. The strength of such composite depends on the amount and quality of reinforced particles, the constituents that were present react together to form a new group of properties. The form and size of the individual elements, the design structures in which they're placed, and their distribution are all significant contributing factors to the overall output of the composite. There are several aspects that decide the characteristics of composites. The ceramic particulate reinforcement composites also contributed to the development of custom-made technical products of the modern age with enhanced basic characteristics, for this the composition, characteristics, the volume of reinforcement, some of the methods for producing these composites include solid and liquid state fabrication methods are managed. The above techniques are most relevant. The liquid metallurgy method has been studied more in those days; in this study, we are contrasting and analyzing potential future research on differences in mechanical properties for AlHMMCs [4].

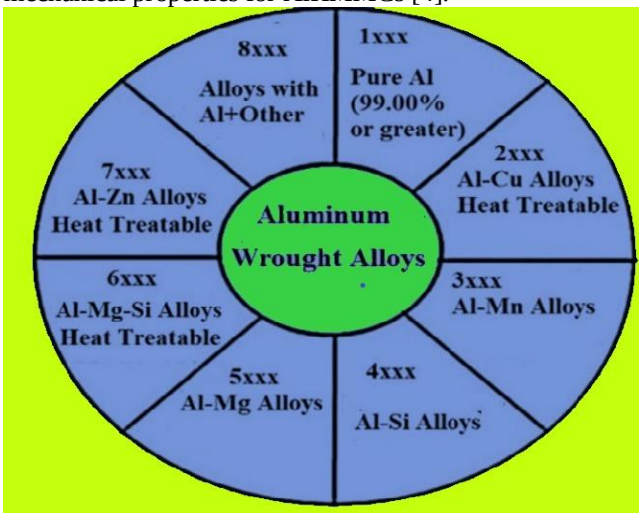

Fig. 3: Types of wrought Aluminum alloys

Although the manufacturing of aluminum matrix composites reinforced with continuous fibers is quite complex and expensive, it is used in some applications, mainly in the aerospace industry. Ceramic particulate reinforced composite tends to be more robust. Due to their advantages in regard to characteristics such as tensile and wear strength and corrosive resistance etc., the usage of MMCS is growing every day relative to alloys [5].

II. ALUMINUM METAL MATRIX COMPOSITES (ALMMCs)

Early in the 20th century, man started working with new materials such as aluminum alloys, tungsten, and even plastics. Nevertheless, these materials struggled to reach expectations. In the last 2 decades, the most critical requirement of the industrial sector is to tackle environmental issues. Through one aspect, this may be achieved by enhancing performance. Parallel to other materials, an AlMMC is actually incredibly excellent since it possesses good characteristics as good wear resistance, corrosion resistance that renders it an extremely sophisticated material along with many valuable uses. These materials aren't that recent in terms of research, but now they are being researched widely. The Previous study has demonstrated AlMMC has high toughness, low

density, low thermal expansion coefficients, and outstanding wear resistance. It is claimed that somehow a significant fraction of ceramic reinforcements in AlMMC added to give a remarkable increase inefficiency. Furthermore, through a varying percentage of strengthening stage and choosing of the required processing methods, the properties of these materials may be changed[6].

The creation of discontinuously strengthened AlMMCs is currently an appealing choice for research scientists. This may have been attributed to the economic feasibility, almost homogeneous structure, and flexibility in the manufacturing of reinforced AlMMCs. The cumulative characteristics of Al-composites have also been documented and focus on the nature and proportion of reinforcement materials. Studies used different kinds of reinforcements to boost Al matrix efficiency. Particulate reinforcements used in composite production are typically classifiable in two large classes: hard, which have a high modulus of elasticity, such as SiC , Al2O3, B4C, and TiC, particles and soft, such as Gr, MoS2, and TiO2, with a low . The integration of hard ceramic particles into soft Al matrix improves their toughness, wearability, and thermal properties, whereas the existence of soft particles automatically improves lubrication properties in materials. The basic resistance towards wear of Al alloy is enhanced dramatically by the inclusion of ceramic particles. Many shortcomings in the usage of Al alloys/ceramic composites have even been identified. The inclusion of ceramic particles has also been shown to improve the density of the resulting composites. The modulus of elasticity of ceramic particles is higher than the Al alloy. In determining the characteristics of the composites generated, reinforcement generally plays a vital role; commonly used reinforcing materials are illustrated in Fig.4, and Few applications of AlMMCs are shown in Fig.5[7].

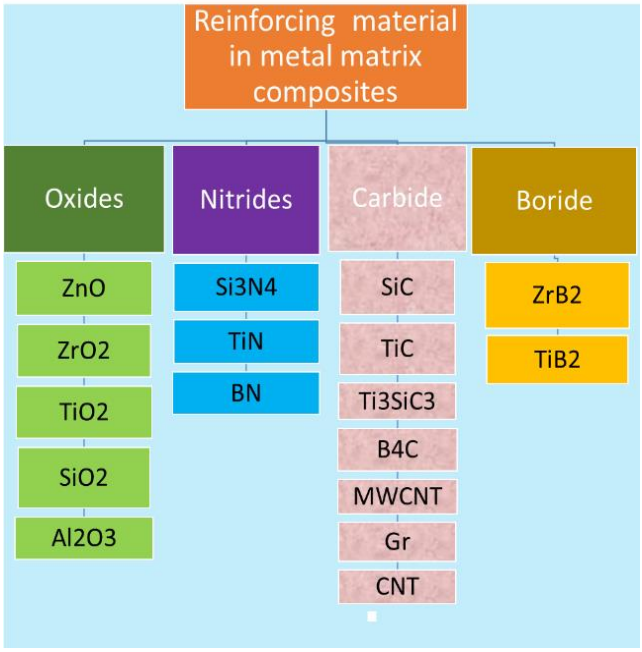

Fig. 4: Types of Reinforcing Materials

Using agro and industrial waste materials can often minimize the hybrid composites' price and weight without affecting their mechanical characteristics. However, a lack of awareness of service efficiency and usage of these composites may restrict their wider use. The usage of advanced AlMMC fabrication strategies has been seen to be very helpful in fulfilling varied service requirements, including life expectancy, design complexity, and cost criteria. In the latest years, the better solution for commercially manufacturing AlMMC is stir casting, as it is an easy, inexpensive, versatile, and highly efficient process. In this method, reinforcements are inserted by stirring the rotor and casting the composites into their molten state. This production method enables controls to achieve sufficient microstructure characteristics of those varieties by regulating the parameters, for instance, feed intensity, stirring time, and temperature of preheating for reinforcements. In reality, the clustering of the particles in the composites is a typical phenomenon that can reduce the AlMMC's strength and wear resistance [8].

Silicon carbide(SiC) is among the structural ceramics which widely used as wear-resistant rather than tungsten carbide. In a semi-solid casting of composites, the condition greatly decreases the clustering of particles. The relative motions of the strengthening particles inside the liquid alloy because of the density are greatly decreased, which further eliminates particle clusters in the composites. Therefore, the interface characteristics of the elements have been strengthened, and the mechanical performance of the AlMMCs has been enhanced. SiC has a very hard, rigid material and an excellent resistance to thermal shock, which retains its strength even at extreme temperatures without loss of strength. SiC has outstanding mechanical characteristics and is an outstanding abrasive material. SiC is also used in a large range of applications due to
its low density and good hardness. [9].

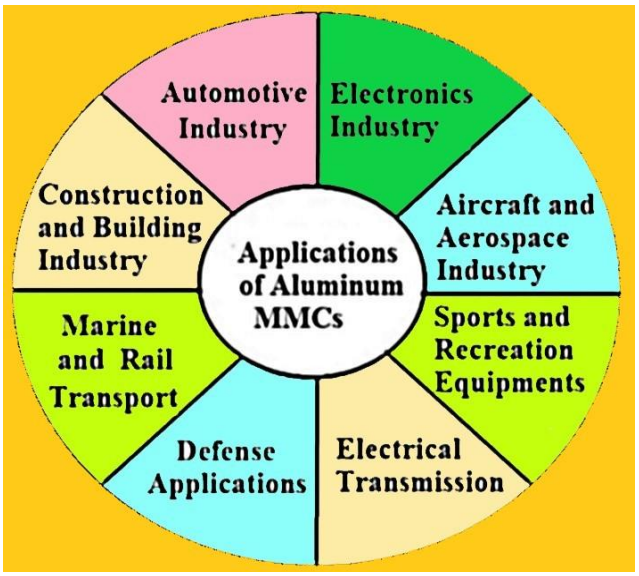

Fig.5 Applications of AlMMCs

N.K. Maurya et al. performed experimental research on the effect of SiC on Al 6061 aluminum alloy. Composites with a different weight fraction of Sic (0, 1, 2, 3, and 5) with Al6061 are produced through the stir casting technique. As the SiC material was improved, the density of AlMMC, The inclusion of Sic content enhances the efficiency of the Al6061/SiC composite manufactured. The density of AlMMC was raised by 1.4 percent, the manufactured composite's hardness value has greatly increased with the 5% reinforcement [10].

A pkumbhar et al. performed a study on the effect of SiC as reinforcement on the properties of Al-based MMC Al 6061 was used as a matrix, and as a reinforcement, SiC with various weight percent (0, 3, 6, and 9) was used, the stir casting technique was employed for making composite material. The result is that increases with mechanical characteristics improved with SiC weight proportion [11].

V.Bharath et al. investigated the mechanical characteristics of a new composite, which was manufactured by stir casting process where matrix as AA6061 used and reinforced with Al2O3. In the processing of composites, Al2O3 particles have been used as reinforcement materials with sizes 125μm and with different weight percentages (6, 9, and 12). Hardness is improved as the matrix content is gradually reinforced, but densities decreased respectively. The performance, as well as tensile strength of the AlMMC, were enhanced by the inclusion of the reinforcing material [12].

III. ALUMINUM HYBRID METAL MATRIX COMPOSITES (AlHMMCs)

Studies illustrated that the limited mineral resource availability increased manufacturing costs and a seeming restriction on the capacity to produce high-strength metal components, which necessitated the introduction of new materials that fulfilled the requirements of industrial need in line with technology. In various aspects of everyday life, metal composites are commonly used. Researchers are searching for lightweight and tougher materials to achieve sustainable efficiency. These materials are known as advanced composites and are used to substitute several of the metals commonly used. The striking characteristics of aluminum consist of the comparatively low cost, lightweight, the most readily processed high-performance. The physical mixture of aluminum with multiple reinforcement materials allows for the creation of Aluminum hybrid metal matrix composites. AlHMMCs are common composites in the industry where low cost and easy manufacturing capability is needed. Hybrid composites incorporate features such as good compressive resistance and impact strength that are not available in normal composite materials. In recent years, highly effective, high-performing composite materials have been developed, such as hybrid composites, and their usage is increasingly growing. Hybrid composites are typically utilized by integrating the properties of multiple types of materials. For several years, to develop good characteristics composite materials, AlHMMC is the most popular area for scientists [13].

IV. THE WEAR AND MECHANICAL CHARACTERISTICS OF AlHMMC

AlHMMCs are addressed in the current study, which is based on the literature review. The AlHMMCs may be expanded applications inside the transport, aerospace, maritime, industrial, and mining industries due to their enhanced properties as they are the best substitute for the normal composites, which are singly reinforced. The most often used reinforcements are SiC in the form of particulate, aluminum oxide, and graphite. By adding these, improved aluminum composites may be manufactured for particular applications and developed with specific properties needed [14].

HenifiÇinici investigated the properties of a hybrid composite; in this analysis, the powder metallurgy process was used to create composites utilizing Al 2024 alloy as the matrix. B4C, SiC, and Al2O3 were used as reinforcement. The ceramic forms employed in composite manufacturing have been found to influence mechanical features; this analysis indicates that the type of particle to be used in the development of hybrid composites is significant for good mechanical properties. Studies have been shown that the reinforcement Al2O3, B4C, and SiC in the matrix are reasonably equally distributed,10% wt, B4C–Al2024 showed good hardness and strength compared to Al2024 [15].

Radhika N et al. studied attributes of hybrid composite made by stir casting process, LM25 alloy reinforced with SiC and Al2O3, samples made are LM25+5%SiC+5%Al2o3,LM+10%SiC+10%Al2o3,LM+15%SiC+15%Al2o3. The wear rate decreases with the rising weight percentage of the reinforcement. From tests, it was concluded that the mechanical attributes, as the tensile strength as well as hardness, enhanced as the weight fraction of the reinforcement was increased [16].

M Senthil Kumar et al. studied composites made through the powder metallurgy method, and pure Al reinforced by alumina(fixed 5 wt%) and silicon carbide variedwt.%. (0,3,5,6,8).The results revealed that an enhancement in mechanical properties by the addition of hybrid reinforcement was observed. Hardness and compressive strength of AlHMMCs improve with increment in wt% of SiC. SEM study showed that al2O3 and SiC were uniformly dispersed in the AlHMMC [17].

Shakil Hossain et al. studied Aluminum-based composite is produced by the stir casting technique in this research. Al-6103 was used as a matrix substance, al2O3 and SiC were used as reinforcing material. The content of Al2O3 is set at 1% wt, and the content of SiC is varied by (0, 2, 4, 6, and 8) wt. An investigation was performed. The following results are taken upon the basis of the present experimental research. The microstructure reveals that Al2O3-SiC reinforcements are spread reasonably evenly that tend to enhance composite microstructure. The Al2O3-SiC strengthened composite densities have been shown to be less than pure Al alloy. The findings show that the

inclusion of reinforcements in the matrix Al-6103 of increases the hardness and resistance towards wear of this material. The peak hardness is obtained at 8 wt% SiC, and 1 wt% Al2O3 reinforced AlMMCs, with an increment, in reinforcing materials, the hardness value of the composites improves [18].

M. Ravikumar et al. studied hybrid composites properties made by stir casting method then age-hardening done, Al7075 reinforced by al2O3 and SiC. The behavior of SiC-Al2O3-containing MMCs has been found very resistant to wear. Hardness improves in the hybrid AlMMCs as wt% increases [19].

V. CONCLUSIONS

This paper discusses mostly on mechanical and wears features of Al-based composites. The study indicates that inserting two ceramic particles in Al alloy will boost the mechanical and wear-resistant properties of AlHMMCs. Overall, the analysis indicates that hybrid composites with Al-based have big promise to replace the ceramic-based composites and the alloys which are used for many industrial applications, where low cost, good strength/weight ratio, and exceptional wear resistance are needed. In this respect, a variety of literature was reviewed, and the processing criteria were observed to be customized such that the Al-composites could achieve a uniform structure. With the increase of a weight fraction of SiC+Al2O3, the hardness and tensile strength value of the composite improved. Ceramic particle inclusion has been seen to be important to give required strength and toughness to composites. The ceramic varieties employed in composite manufacturing have been considered to enhance the mechanical characteristics. This study shows that the reinforcing material types being used in hybrid composite manufacturing are critical as concerning mechanical properties. Determining the varieties of ceramics, which used in the manufacturing of composites would affect the characteristics of composite materials. Tests, indicating that the mechanical performance of Al matrix composites may be greatly improved by the B4C, SiC, and Al2O3 particles as reinforcement materials.

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