FABRICATION AND MECHANICAL CHARACTERISTICS OF ALUMINIUM BASED METAL MATRIX COMPOSITE

[1]Amit Kumar Yadav, [2]Manoj Kumar

[1]M.Tech. Scholar, [2]Assistant Professor
Department of Mechanical Engineering,
CBS Group of Institutions, Jhajjar, Haryana

***Abstract*: Geotextiles have recently found wide-spread use in pavement construction. Under paved and unpaved roads, geotextiles are mostly utilized for separation and stability. Another great benefit of geotextiles in roadways is their ability to separate, stabilize, strengthen, and filter. When considering the environmental and economic advantages of natural gate construction materials, geotextiles often do not serve a function, and may instead be replaced or cut altogether. The following pain concerns will be presented in the current research: Pain problems that develop in road building due to different variables are reviewed in the research. Infrastructure development has a significant role in a country's overall economic growth. Available. There is a limit to the amount of time we can devote to road maintenance owing to budgetary constraints which effect the function of the road. Use of Geotextiles enables more power to be applied to the pavement in this study, which revealed that the road's bearing capacity was higher when the ground was covered with the fiber products. Geotextiles are manufactured materials used to aid with soil improvement. Most plastic bags are constructed of biodegradable polymers which degrade only after bacterial or fungal growth. While most substances are generally non-reactive, some petrochemicals may hurt certain individuals, and most substances are affected by UV radiation.**

***Keywords*: Aluminium Metal Matrix Composites, Process, Reinforcement, Casting.**

I. INTRODUCTION

Composites are materials made up of micro, meso, or macro-scale structures that combine two or more separate elements or phases, each of which has its own unique physical and chemical characteristics. Because of advancements and uses of single components, such metals, porcelain, and polymers, their mixing to make synthetic mixtures has become a viable option. Improvements in human well-being have resulted from the advancement of composite materials, which have enhanced contemporary material systems.

One biopolymer that can outperform the sum of its parts is known as advanced composites. Often integrating the most recent breakthroughs in a number of distinct specific materials, advanced composites may be thought of as the end outcome of structural design and optimization over several dimensions and levels. It is via the compositing of interface or geometric effects at various levels that composites are able to realise either improved performance or a novel function that cannot be provided by a single constituent material. Composite science is based on these elements. The defense and aerospace sectors' stringent standards sparked the development of cutting-edge composites in the 1950s and 1960s. As industrial technology continues to progress, advanced composites will continue to be a material of focus for structural applications. Various novel materials and methods, such as nanocomposites, functional & multifunctional composites, intelligent composites, or composites with integrated function and structure, are being created as our understanding of composite science and technology expands. [1]

It is well known that progress in technology is dependent on new discoveries and innovations in the field of materials science. Anyone can see that even the most cutting-edge turbine or aircraft design is useless without sufficient materials to withstand the service loads and circumstances. Whatever the area, materials are always the limiting factor in terms of how far it can go. In this respect, composite materials are a major advance in the never-ending quest for material optimization.

The concept of composite materials has been around for quite some time. Composite materials may be found all around nature. For instance, the coconut palm leaf is a prime example of a cantilever that employs the principle of fibre reinforcement. Fibrous composite that consists of cellulose fibres embedded in a matrix of lignin. The lignin matrix links the fibres and provides the stiffness, while the cellulose fibres themselves have a high tensile strength while being relatively flexible. Bone is another type of natural composite that helps to bear the body's weight.

In addition to these composites found in nature, numerous additional technical materials have been in use for centuries and can be broadly classified as composites. Some examples of frequent fillers include the carbon black in rubber, the Portland cement or asphalt combined with sand, and the glass fibres in resin. This demonstrates that the concept of composite materials has been around for quite some time. Yet, the beginning of the 1960s is generally seen as the start of the separate study of composite materials. Since the early 1960s, industries as varied as aerospace, energy, and civil construction have shown a rising need for materials that are stiffer and stronger while remaining lightweight. All materials fall short of the mark because of the wide range of requirements placed on them to improve overall performance. As a result, the age-old idea of blending diverse materials into a single composite material to meet customer needs has seen a renaissance. [3]

Such composite material systems give the enormous benefit of a customizable design and produce results that are impossible with the separate components. This means that we may create a composite material that serves the purpose, whether it be for an aeronautical construction, an automotive, a boat, or an electric motor. One further notable change is the incorporation of material science and engineering into every stage of production and design, from initial ideation through final handover and beyond, including inspections during the product's lifecycle and post-failure analysis. Lightweight, yet robust and rigid, composite materials are rapidly meeting the growing need for such designs across all areas of human endeavour. The advantages of composites over more traditional monolithic materials like aluminium and steel are illustrated in Fig. 1 (Deutsch 1978, [4]).

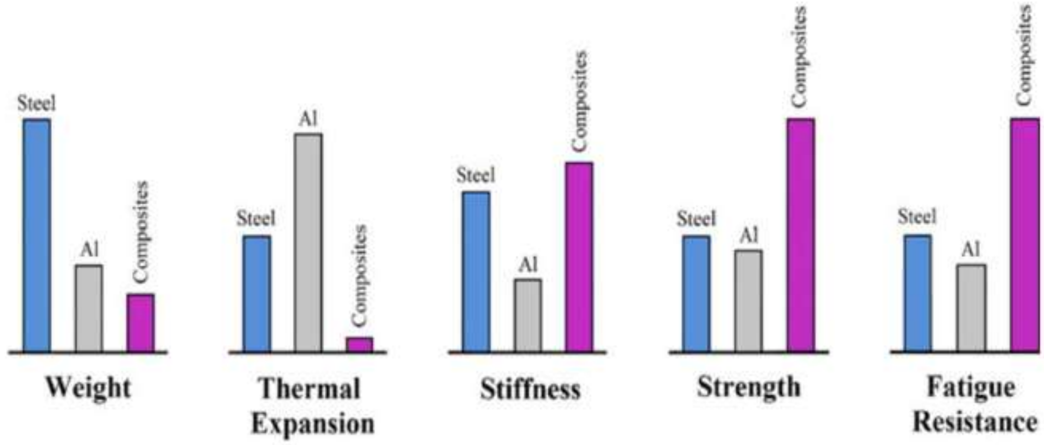

Fig 1 Comparison between conventional monolithic materials and composite materials(from Deutsch, 1978, used with permission).

In this world, almost everything is made of composite materials. A typical chunk of metal is therefore a composite (polycrystals) of many grains (or single crystal). A definition like that would make things quite complicated. For our purposes in this article, we must therefore come to an operational definition of a composite material. We will refer to a material as a composite material if it meets the criteria listed below [5]:
1. It is produced (that is naturally occurring composites, such as wood are excluded).
2. It comprises of at least two matrix phase and reinforced phase phases, which are physically and/or chemically distinct, appropriately organized or distributed phases, separated by an interface.
3. It possesses qualities that none of the parts taken alone can capture.

II. Literature Review

During the literature studies of various work on the AMMC; I found that there are many scholars worked on hybrid AMMC or mostly worked with the silicon carbide(SiCp) reinforcement or aluminium oxides(Al_2O_3) or boron carbide(B_4C) in our country as well as abroad. But very few researchers had worked with the monolithic composite with the boron carbide(B_4C) . The contributions of the AMMCs in the fields aerospace engineering, military applications, automobile industries, sheet metal manufacturing and many more [13].

So, I started reading and collecting some more information on this interesting topic and some paper that gone through had helped me so much from various universities sites, different books, international journals as well as google and other media plateforms to write this thesis, and here i would like to mentioned some among many as:

Zhang et al.[12] used a bottom-up approach and flake powder metallurgy to fabricate bio-inspired laminated composites with brick-and-mortar structure. The powders of both aluminum and alumina were in a flake form. It was observed that the addition of 5vol% of alumina led to 22% increase in strength with only 7% compromise in ductility. Using flakes of alumina led to a 17% increase in the toughness of the composite. It was reported that the strain hardening led to dislocation accumulation at the Al/Al2O3 interface. This dislocation accumulation at the interfacial region delayed the necking, leading to increased strength. In the same way, Gabric et al.[13] studied the fabrication of Al/Al2O3 composite by a special sintering process called as spark plasma sintering. Here different samples containing a different volume of reinforcement phase were used to compare the improvement in their properties. In their studies, they used 5, 10, 15, and 20 vol% of the reinforcement phase. After sintering the powder compacts, the samples had a porosity content ranging from 1.27% to 5.07%. It was proved that as the content of the reinforcement phase increased, the density, hardness, tensile strength, and compressive strength of the specimens increased. The samples with maximum Al2O3 content (20%) had the highest hardness and strength (compressive).

Nourouzi et al. **[14]** prepared Al/Al2O3 composites in order to study the wettability and how the Al2O3 reinforcement particles were distributed in the matrix. Alumina particles were injected into the molten metal in four different forms. They were untreated alumina particles, heat-treated particles, milled Cu-Al2O3 particles, and Al/Al2O3 composite powder. The microstructural features of the composite were evaluated using a scanning electron microscope. The yield strength, impact energy, resistance to wear, and hardness were measured for the different samples, and the maximum values for Al/Al2O3 composite were 142MPa, 8J, and 79BHN. Further, the authors Zadeh et al.**[15]** has used mechanically activated nano crystalline alumina particles as reinforcement. In their research, alumina powder was milled for 20 hours in a ball mill. 1vol% of this milled powder was added to the molten metal. Studies were then conducted on the composite's morphological properties, wear properties, and tensile properties. XRD studies showed that the size of milled powders was in the nano-meter regime. Peak broadening and Scherrer formula proved the above results. Due to the smaller crystalline size an improvement in the UTS and the hardness were observed.

Tong et al.**[16]** studied the fabrication of Al2O3/Al/alumina sandwich composite with the help of micro-arc oxidation on an aluminum foil with with 50 micron thickness. The exterior layers of the composite were extremely flexible (could tilt by more than

90o) without fracture or delamination. The morphology of the coating made from micro-arc oxidation was studied using an SEM. The XRD studies and the spectroscopic methods such as EDS proved that the coatings mostly consisted of γ-Al2O3. The well-adhered layers helped in improving the fracture strength of the coating. Simsek et al.**[17]** studied the microstructural and the wear behavior og the Al/Al2O3 based composites. The alumina and graphite powders were mixed with aluminum powder and milled for 60 minutes in their study. The powders were then sintered at 600oC under a pressure of 700MPa for 2 hours. The samples were then characterized using an SEM and XRD. The hardness and the density were also measured to calculate the porosity in the samples. The wear test of the samples was done for four different sliding distances at three different loads. It was observed that for 12vol% of reinforcement there was minimum weight loss in the sample (highest wear resistance).

Rezayat et al.[18] used accumulative roll bonding as a novel method to manufacture particle reinforced Al/Al2O3 based composite. In this study, the aluminium matrix was reinforced by submicron-sized reinforcement. The effect of ARB cycles on microstructural features and mechanical properties of the MMC was studied. The studies proved that the yield and the ultimate strengths of the samples increased with the number of ARB cycles. SEM studies showed a random distribution of the particles in the matrix and there was strong mechanical bonding at the interfacial regions. The composite showed maximum strength at 2vol% alumina which was 5.1 times the strength of annealed aluminum. Prasad, et al.[19] compared the properties of the same composite which were made by two different processing routes. The different methods were powder metallurgy and pressure infiltration of porous performs of liquid alloy. The results showed that it was possible to obtain a new type of composite material with the required structural properties. The new type of composites had great applications in the automotive sector.

Akbari et al.[20] used a novel process to fabricate Al2O3 nanoparticles, which were reinforced in to the aluminum matrix to avoid agglomeration. In this study, alumina particles were milled separately from aluminum and copper powders at different milling durations. The powder was incorporated into the melt by the stir-casting method to make A356 alloy. The effect of different milling times on the mechanical properties was evaluated by hardness, tensile, and compression tests. The tests proved that the composite has better mechanical properties when compared to pure aluminium. Characterization of the samples showed that the alumina particles were uniformly dispersed in the matrix with grain refinement of A356 alloy.

Ma et al.[21] observed the tensile behavior of alumina in the Al-Si matrix. The composite by processed by hot extrusion where the samples were initially pressed at elevated temperature. The mechanical properties of the composite with varying additions of reinforcement were studied and the influence of different types of strengthening mechanisms was studied carefully. Significant agglomeration of particles was observed when 10% alumina was added to the alloy. The best combination of mechanical properties was observed when 5vol% of alumina was added to alloy. The contribution of different strengthenings such as Orowan looping, CTE mismatch and load transfer effect was studied. It was observed that CTE mismatch effect had the maximum contribution.

Daniel et al.[22] processed Al-Al2O3 composites with varying reinforcement content by mechanical alloying. They studied the effect of the reinforcement content on the mechanical and physical properties of the composite. In their study, they used aluminium chips and alumina powder to make the composite. The compacts were sintered using a conventional sintering process, and it was observed that the properties improved as the reinforcement content increased.

Krishna et al. [23] observed the mechanical properties of Al-Al2O3-SiC nanocomposite. The alumina content was the same in all the samples at 3vol%. The SiC content varies from 3% to 7% in different samples. The composite was prepared using stir-casting method, where the melt was kept at 750oC. The reinforcement materials were heated to 300oC and then mixed in to the melt by stirring at 350Rpm. It was observed that the reinforcement consolidated at some regions due to density differences. Mechanical and creep behaviour of these specimens was studied and it was observed that intermediate SiC (5%) concentration had the best combination of properties.

III. METHODOLOGY

First of all we started the furnace (Muffle Furnace) and wait for the 500^0C temperature and then put the aluminium sheet into the crucible and further wait till the temperature to reach 800^0C and then after we added all the reinforcement powder and stirred for 10 minutes so that it could mixed well with the base material and we will be able to cast the homogeneous composite, it will take around 4 to 5 hrs for one piece of composite to be ready to poured in a rectangular mould and wait around 3 hrs for the cooling of the casting. This process we repeated for all four specimen of 3%, 6%, 9% and 12% of weight. See following figures from the thermal lab:-Figure 2 Base material A7175 in a 30mm×60 mm×95 mm size.

Fig 2 A7175 Material

Figure 3 and figure 4 Reinforcements in a very fine powder form that could be added in the molten metal and further stirring will done on it.

B_4C(Boron carbide), SiC(Silicon carbide), Graphite fine powder

Fig 3 B_4C(Boron carbide), SiC(Silicon carbide) and Graphite fine powder

Graphite powder Boron carbide

Fig 4 Graphite & Boron Carbide Powder

Figure 4 shows Muffle furnace reading 647^{0}C further it will reach at 800^{0}C where we will add the reinforcement and stir for 10 to 15 minutes with the help of electric stirrer at 400 rpm or manual, here we go through the manual stirring of the reinforcement.

IV. RESULT ANALYSIS

As we know that the hardness test of the specimens had been recorded from the testing lab. For all four specimens i.e. 3%wt, 6%wt, 9%wt and 12%wt of reinforcement addition the hardness value obtained are different, one thing that we see is the hardness value increases with the increase percentage of reinforcements. The tests were taken at "GLOBAL TEST HOUSE PVT.LTD, New Delhi'' at 250 kgf and see table 4.2 for the results:-

Table 1 shows value of Hardness test

Sample No	Test Parameter	Grade	% of reinforcement composition	Results	Test method
GTHPL20220808/01	Brinell Hardness HB	A7175	3	98.8	IS1500:2005
GTHPL20220808/02	Brinell Hardness HB	A7175	6	105.3	IS1500:2005
GTHPL20220808/03	Brinell Hardness HB	A7175	9	113.5	IS1500:2005
GTHPL20220808/04	Brinell Hardness HB	A7175	12	123.0	IS1500:2005

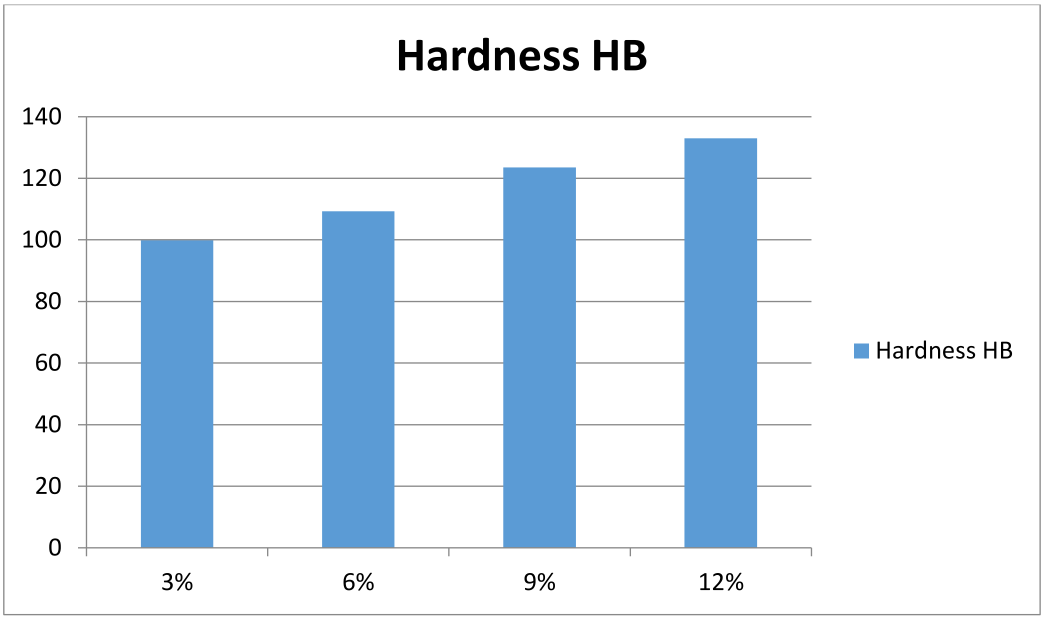

Fig 5 shows Hardness HB on bar chart

V. RESULT ANALYSIS

From the present study on the fabrication and mechanical properties of the aluminium metal matrix composite, following conclusion have been drawn. The fabrication process of the AMMCs is very diverse and need more study that help during casting as well as precautions and safety procedures of the thermal labs needed to be follow. The weight measurement of the reinforcement and base materials should be proper otherwise there is a possibility of variations in the end results. The elongation percentage has been found in a decreasing way which means one can say that, when percentage of reinforcement increases the composite tends to be more harder and more stronger and that is why least percentage of elongation and minimum (1.19%) has been found at the 12% wt of reinforcement.

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