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IMPACT OF AL-COMPOSITES IN THE MANUFACTURING INDUSTRY: A NECCESSITY

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ABSTRACT

In the engineering sector today, the need to substitute for orthodox materials like wood, aluminium, steel and concrete, has led to the invention of raw materials that meet specific needs like hardiness-to-mass ratio, i.e. increased strength and light weight, increased strength of impact, dimensional constancy and resistance to corrosion. These materials are called composites. In this paper, we have assessed several articles by a number of researchers on the impact of composites in the manufacturing industry, making aluminium composites our focus. This review studied the properties, behaviours, applications, advantages and setbacks, of aluminium composites. From this study, it was observed that the automotive industry makes the most use of aluminium composites, for the manufacture of parts like pistons and connecting rods. However, processing of Al-dependent MMC's is costlier than other raw materials. And this is a major setback in the use of aluminium composites in the manufacturing industry.

Key words: Aluminium, Composite, AMMC.

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1. INTRODUCTION

The term "manufacturing industry" is used to describe those industries that are involved in the production and conversion of items and take part in either the conception of new commodities or in the addition of value [17]. The manufacturing industry constitutes a major part of the business sector in countries that are developed [21]. Manufacturing industries are divided into building construction industry, chemical industry, food and beverage industry, electronics industry, telecommunications industry, engineering industry, metalworking industry, energy industry, plastic industry, textile industry and transport industry [23] [31][46].

Silicon, Oxygen and Aluminium are the most abounding materials in the earth's crust [26]. The trademark features of aluminium that is, its high-quality strength to weight proportion, its good ability to form, its good opposition to corrosion, and its reusing potential, make it the perfect possibility to supplant heavier materials like copper and steel to react to the weight decrease demand in the manufacturing industry [29]. However, since aluminium and other conventional materials like steel, wood and concrete have been the custom materials for a while, the necessity to bring together a few properties that are not usually found in a single material, led to the invention of composites.

A blend of at least two materials or periods of a similar material, insoluble in each other, with better properties when compared with any of the segment constituents is called a composite material. Volume portion of part constituents ought to be over five percent (5%) of aggregate amount and their characteristics must be unique in relation to each other. For the most part, volume division of one constituent is essentially more than the volume divisions of the others and that constituent is called a matrix [41]. Matrixes can either be earthenware, polymer or metal.

Composites might be extensively classified into Metal Matrix Composites (MMC), Polymer Matrix Composites (PMC) and Ceramic Matrix Composites (CMC), each matrix is framed by consolidating at least two materials to accomplish improved and better properties when related to their segment parts. Properties that are significant to all the classes are; low thickness, improved quality and firmness, weight streamlined execution and high temperature opposition.

These properties are pretty much broad necessities for all kinds of composites, however, they may anyway be bestowed extra properties upgrade in special basic territories of uses, outstandingly in the aviation area. The downsides of composites, however, for example, decrease in toughness, when compared with the matrix alloy, variations in thermal properties, advanced heterogeneity and more cost, are the main reasons for the drawbacks in its application [13].

MMC's (Metal Matrix composites) are intricate resources comprising of a volume portion of unremitting and sporadic ceramic strengthening fibres put in the metallic alloy matrix [13]. AMMC's have taken a lead in the applications region, the push being an army. The choice of a specific framework require custom fitted relies upon the host of clashing necessities, which a framework needs to fulfil. The generation and properties of a few aluminium matrix composite either for constant fibre, irregular fibre or particulate strengthened is significantly influenced by the fortifications. These property improvements because of the fortification are contrasted with the matrix composites [13].

2. FINDINGS

Surappa [37], categorized AMMC's into four types which are dependent on the class of reinforcement.

- PAMC's (Particle-Reinforced Aluminium Metal Composites): contain equal ceramic fortification with an aspect ratio not as much as 5.
- SFAMC's (Short fibre-Reinforced Aluminium Metal Composites): contain fortifications with an aspect ratio more than 5 and are discontinuous.

- CFAMC's (Continuous Fibre-Reinforced Aluminium Metal Composites): look like incessant fibres of alumina, SiC or carbon with a smaller than 20µm diameter.
- MFAMC's (Mono filament-reinforced Aluminium Metal Composites): are higher distance (100-150µm) fibres, which are manufactured by CVD (chemical vapour deposition) of either B or SiC in a carbon fibre core.

Surappa. [37], further stated that the advantages of AMC's related to its parent materials are:

- Measured thermal expansion coefficient.
- Improved capacity of damping
- Higher strength
- Enhanced wear and abrasion resistance
- Improved and tailored electrical performance
- Greater stiffness factor
- Reduced weight
- Enhanced high temperature properties
- Thermal or heat control
- Management of mass (especially in reciprocating uses)

2.1. Casting Methods

Joel and Anthony Xavior [19], established that aluminium matrix composite can be processed by:

Stir Casting: In stir casting, the supply of the fortification phase in a molten metal is achieved by mixing it mechanically. This method is appropriate to produce composites with volume fractions less than thirty percent (30%) of reinforcement. The concentration of the particles is subject to the constraint of process and the behaviour of the material (i.e. strength of mixing, wetting, relative density and rate of solidification).

Compo casting: In this method, the fortification is added while the melt is solidifying and distressed well to share the particles. This process produced or provides better dispersal of the fortification particles, minor shrinkage, improved wettability and lesser porosity.

Squeeze casting: In this process or method, the metal hardens because of the pressure between the closed die halves. It is a mixture of gravity die casting and closed die forging processes. This brings about an increase metal yield, minor shrinkage, fine surface finish and reduced porosity. When it solidifies under pressure it results in an enhanced redefinition in structure and a decrease in the magnitude of the grain.

Powder Metallurgy: This is the method of mixing advanced materials in powder form, shaping them into a net shape and heating them in at a regulated temperature. The process has been improved to produce near net shaped components by mixing elemental powders. The process brings about the ability to combine a high-volume fraction with diverse fortifications with matrix systems.

2.2. Methodologies from Previous Works

Manivannan and Sasikumar. [27], examined that most research work done on stir casting method had two major problems or challenges which are poly-dispersed mixture of the reinforcement particles because of bad wettability in the blending or mixture of the reinforcement particles and the parent molten matrix or metal; and their agglomeration.

Panwar and Chauhan., [32], investigated the production of MMC’s. They mentioned that it can be reached by the addition of reinforcement or fortified phase to the parent matrix. Suitable methods of production or manufacture are spray atomization and co-deposition, powder metallurgy, squeeze casting, plasma spraying and stir casting. In the list of engineering of materials, the MMC’s can be produced by different processes or techniques such as casting because of its low cost and because it allows many choices for materials selection and processing conditions. The fortification particles are introduced into liquid or solid matrix either through liquid metallurgy by casting or a powder metallurgy method. The composite is prepared by infusing the fortification particles into the liquid, semi-solid or solid matrix by powder metallurgy process or through a liquid metallurgy by casting.

Surappa., [37], specified that the main processes to produce AMCS at an industrial rate can be grouped as follows;

Solid state processing

- PM processing (Powder blending and consolidation): The mixing of aluminium alloy powder and short ceramic fiber is a known technique for the manufacturing of AMCs. The mixing of AMCs is either carried out dry or in liquid state.
- Diffusion bonding: Aluminium metal composites fortified by mono filament are manufactured by the diffusion bonding (foil-fiber-foil) process or by evaporating comparatively thick deposits of aluminium on the face of the fiber.
- Physical vapour deposition: This process deals with the nonstop movement of fiber over a zone of high fractional pressure of the metal to be placed, condensation then occurs and a thick coat on the fibre is produced.

Liquid state processing

- Reactive processing (In-situ processing): Examples are liquid-liquid, liquid-solid, liquid-gas, and varied salt reactions.
- Spray deposition: This technique is divided into two separate classes, by incessant supply of a cold metal into an area of swift heat infusion (thermal spray process) or producing the droplet stream from a molten bath (Osprey process).
- Infiltration process: The liquid Al mixture is put into the cracks of the permeable pre-forms of the particle to bring about the production of AMC’s.
- Stir casting: The process comprises of the integration of ceramic particles in liquid Aluminium melt and letting the mixture to cool down and harden.

Article [3], stated that the effects of machining parameter on AMC’s are:

- The amount of flank wear is large at a small cutting velocity due to the formation of accumulated edges and the high force of cutting needed when fabricating Aluminium/SiC metal matrix composites. While at a large cutting velocity, the temperature at the cutting edge is very high which then cause’s fast deformation of the tool used. The ideal cutting velocity zone for fabricating aluminium/SiC metal matrix composite is within the interval of 60m/min and 150m/min
- The collective outcome of feed and velocity on the flank wear leads to the conclusion that the feed is not as susceptible to the wear of flank as it is to the speed of cutting. Therefore, it is better to add to the amount of wear than to increase the cutting velocity.
- The depth, feed and velocity of cut have the same output on the texture of the surface.

- The initiation of built-up edge gotten when fabricating Al/SiC at a low velocity when cutting brings about a rise in the angle of rake, which is related to increment in the force of cutting.

2.3. General Findings from Past Works

Ahmed et al., [1] examined the fusion of Al-Ti-Cr Composite as wear component to be used in brake disc application. The Al-Ti-Cr metal matrix compound with inconstant quantity of B4C and SiC elements was prepared with a stir die technique as well as a chill casting technique. The resulting composite was analysed with an X-ray diffraction analysis, XRD, a Fourier transform infrared (FTIR) spectroscopy and a Scanning electron microscopy (SEM). The composite was also caused to undergo friction and wear tests at various operating parameters. The outcome established that increment in the percentage of B4C and SiC increased the ductility and ultimate strength of the composite, making it suitable for use as wear materials for brake discs.

Banhart [6], discussed the use of aluminium foams to produce lighter vehicles. The diverse methods of formulating these foams were listed. Some of which include foaming specifically prepared molten metals with attuned viscosities by inserting gases or by including gas-releasing blowing agents which decompose in-situ, instigating the development of bubbles. Another way is to begin with solid precursors comprising of a blowing agent, compressing the mix and then foaming the compact by melting. The applications of aluminium foam in vehicle design ranges from light-weight manufacture, effect energy absorption to various types of thermal insulation and acoustic damping.

Duflou et al., [10], evaluated how composite CFRP (carbon fibre reinforced polymers) use in car manufacturing impacts the environment. It was revealed that the use of light composites as alternatives for the steel structures led to a very slight difference in properties. This means that composites in car design needs more intensive use and development. The composites indicated improvement and power and energy consumption reduction as opposed to the steel structures. The life cycle of CFRP will determine if its use will be intensified. The analysis revealed a breakeven point of life cycle of CFRP at 132,000 km. Composite use in car manufacturing and engineering is innovative and of high importance, it can become a superior form of car manufacturing and technology.

Fatchurrohman et al., [12], performed a sustainable analysis to determine if Al-MMC’s brake disc can be used to swap the traditional cast iron brake disc. The manufacturing procedure of both brake discs were examined the results showed that the entire charge of cast iron brake disc is higher than that of Al-MMC’s brake disc. Though, the physical cost for cast iron is lower than that of Al-MMC’s for a single unit component, the equivalent of weight reduction could save a lot more. In addition to this, the life cycle of Al-MMC’s brake disc could save up to 50% when compared to that of cast iron brake disc. Even though, the processing of Al-MMC’s brake disc cost more than cast iron brake disc because it involves preheating the SiC particulates, and it requires more energy to process than cast iron brake disc. Regardless, recycling Al-MMC’s consumes less energy because Al-alloys have low melting point. They concluded that Al-MMC’s could replace cast iron brake discs.

Gon et al., [14], investigated that some aluminium alloys show enough tensile and thermal characteristics but have low wear opposition. To improve the wear resistance is achieved by using a MMC’s. Powder metallurgy gives advanced mechanical properties but has a high price of production. The liquid production or fabrication processes have low production costs.

Goni et al., [43], investigated a new low budget matrix composite. This investigation was aimed at producing train brake discs, clutch discs, and pistons with the newly developed composite. The in-situ production route was used in the evaluation of this experiment, as opposed to the powder metallurgy route (which has an excessively high cost of production), or the casting process (in which the mechanical properties are affected by the reactivity between the matrix and the reinforcement). Even as material engineering is key in component development, new materials with extremely high performance have the tendencies to be used in new applications. From surveys carried out, it was estimated that today, if weight was reduced by an approximate of 10%, fuel consumption will improve by approximately 8%. In relation to this problem, aluminium matrix composites (AMCs) are meeting the high fuel saving aspirations. AMCs are also extremely essential in terms of material selection to produce train brake discs, clutch discs, and pistons to reduce weight. On the contrary, some customary aluminium alloys show adequate tensile and thermal properties, however, they have limited wear resistance. Fortunately, wear resistance can be improved by the introduction and usage of metal matrix composite (MMC).

Han et al., [15], compared the mechanical behaviour of two key assembly knowledges for aluminium sheets for the automotive industry. As stated earlier, weight is a major issue in the automotive industry today. Thus, there has been an urgency for the reduction of weight, not only in response to environmental issues (in the case of greenhouse gases), but to reach the level of expectation from customers. Lightweight materials have been deployed (such as aluminium composites) as a result. It was discovered that when compared with RSW aluminium sheet, the self-piercing riveted aluminium sheet had a higher static strength. They observed that SPR joints can portray a reduced amount of scatter than the resistance spot welding joints. The performance of self-piercing riveted joints is proportional to the thickness: as thickness increases, the self-piercing riveted joint performance gets better.

Hooker and Doorbar., [16], discussed the potential application of aluminium composites can be used to produce blades and vanes for or in compressor and used in front of compressors for aero engines and annulus filters.

Hunt et al., [18], reviewed that as the demands for lighter weight and higher performance in automobile components increases, the use of higher performance materials are considered. These materials have been applied for high performance space structures and defence applications, high costs have limited there use in the industry. A class of materials that has gotten a lot of attention is discontinuously reinforced Metal Matrix composites (DMMCs). A lot of research is focused on lower cost DMMCs (especially ones based on casting processes) to reach the expectations of the automobile industry.

Karthik et al., [20], reviewed friction accumulation to produce more AMC’s fortified with nanocrystalline HEA particles. The candidate HEA system was chosen to be CoCrFeNi because of its acceptance of aluminium. So that when some aluminium circulates into CoCrFeNi elements during the process, they do not give up their entropy.

Kumar et al., [25], studied the effects of SiC particle magnitude and particulate mass portion on the weariness performance of 2080 Al and discovered that a diminution in particle magnitude and rise in volume gave an increase in opposition to fatigue. Powder metallurgy method for valve guides and iron-based valve seats was experimented on and was discovered that opposition to wear was improved by the accumulation of phosphorus and copper which formed hard inter-metallic phases.

Kumar et al., [44], conducted an experiment on the outcome of Surface Micro Patterning through High Energy Pulse Laser Peening on Aluminium Reinforced Composite for usage in the aerospace industry. Their work focused on enhancing the surface properties of Al7075 strengthened with SiC and Zirconia through the laser peening technique. Laser peening technique is a developed surface engineering technique used to advance the microstructure and surface morphology of materials. The characteristics of the resulting products such as impact strength, tensile strength, percentage elongation and hardness were analysed. Properties related to surface such as harness and microstructure, which play a vital part in prohibiting commencement of cracks on the surface, were then improved with laser peening technique. Their research results proved that laser peening technique enhances the surface layer of aluminium composite.

Manivannan and Sasikumar [27], studied the effects of using Aluminium Matrix Composites with strengthened micro-sized cubic boron nitride (CBN) particles as a material in the production of fins. Fins are materials that are used to diffuse heat from an object for cooling purposes. Aluminium Matrix Composite is made by bottom stir casting process in which two percent of magnesium is supplemented as a wetting agent for the even distribution of CBN. The results showed that the process of producing quality composites in bottom stir casting process would take two steps, and that Aluminium Boron Nitride composites can be used as heat dissipation materials at high-level temperature uses.

Mavhungu et al., [28], reviewed the tendencies and advances in the production and refining of Aluminium Metal Matrix Composites for usage in industries. AMC's have reinforced mechanical and physical properties, for example, suitable ductility, high modulus and high strength, superior wear resistance, exceptional corrosion resistance, excellent strength to weight ratio, poor thermal expansion coefficient, improved fatigue strength, advanced temperature creep resistance. Simple alloy composite materials have a high probable use in the automobile engineering industry (covers, crankshaft main bearings, part-strengthened cylinder blocks, piston rods, valve trains, piston pins and pistons, engine blocks, cylinder heads.) Partially short fibre enhanced aluminium alloy piston is an example of the effective use of aluminium composite materials within this spectrum.

Mrazova, M., [30], analysed the future of developed composites in the aerospace field. Metal Matrix Composites (MMC's) are made up of titanium or aluminium matrix and oxide, carbide or nitride reinforcement. They have more benefits over monolithic materials. But they are not as rigid, are costlier and are not easy to machine. They can be used in the manufacture of greatly loaded surfaces such as turbine fan blades, helicopter blades and floor support.

Petrousek et al., [45], evaluated the malleability of rolled aluminium alloy-based Al-Mg-Si for the automotive industry. Its mechanical properties like yield strength, strain hardening exponent, tensile strength, coefficient of surface anisotropy and elongation were obtained through static tension test. Videoextensometry was used to measure the variations in depth, and width in real-time and elongations. All this was used to consider the applicability of the material for stamping technology. The results showed that sheets of aluminium alloys can indeed compete with steels based on their mechanical properties, effective formability, and lightweight.

Prasad and Asthana., [34], evaluated the tribological considerations of AMMC's (Aluminium Metal Matric Composites) for automobile applications. Prominence has been made on developing inexpensive Al MMC's, strengthened with Al2O3 and SiC, which will result in the decrease in weight of the engine and an increase in its efficiency. Substituting cast iron engine mechanisms with light-mass aluminium compounds entails incapacitating the seizure resistance and poor adhesion of aluminium by dissolving graphite particles, SiC or Al2O3 in aluminium.

Thirumoorthy et al., [38], stated that aluminium MMC's castings are competitive economically with iron and steel mouldings. The existence of particles resilient to wear lessens the ability to machine the alloys, which makes their machining cost high because of the wearing of the machining tool.

Tisza et al., [39], studied the implementation of aluminium and steels in lightweight manufacture of automotive components. Aluminium's density is one-third of steel. The specifically immense strength of aluminium composites complies with the stiffness and torsion specifications of automobile components. Because of this, aluminium composites are regarded as the prominent engineering solution. However, because aluminium raw materials are costlier than steel, aluminium has only been used to manufacture premium cars. Development progress in the use of aluminium has raw materials in the production of car components has been limited even though its use has intensively been increasing over the past decade. They stated that the requirement to replace steel components in automobiles with aluminium composites is primarily triggered by legal demands to adhere to environmental protection standards by improving fuel efficiency and decreasing vehicle weight.

Vencl et al [41], investigated the tribological performance of Aluminium-dependent metal matrix composites and the employment of these composites in automotive industries. They analysed the technologies of production of the Al-based composites, their physical and mechanical behaviours, their tribological properties, and their application. They listed powder metallurgy, squeeze casting method, compo casting method, and vortex method as the methods for producing the aluminium MMC's. They stated Aluminium-dependent alloys, with silicon as the primary alloying component, strengthened with $Al2O3$ and SiC, as the most commonly used composite in the automotive industry. They concluded that the employment of composite resources in the automobile industry still is and would keep growing because of the increasing demand to minimize automobile weight and the amount of vehicle emission and to improve fuel economy. They also stated that the performance advantages of using Al-based MMC's are numerous. Some include increased thermal conductivity compared to regular materials (grey cast iron and steel) and increased wear resistance.

3. CONCLUSIONS

Aluminium Composites have several unique properties which make them frequently preferred amongst several raw materials for the same application in the manufacturing industry, especially the automobile industry. However, a major disadvantage of its use is the cost of machining these composites. This paper covers a portion of the important regions of MMC innovation. The huge change in composite quality shown by the most recent preparing procedures guarantee upgrades in execution and unwavering quality. Cost is still a germane factor and it is most apparent that critical effort is needed in order to lessen the expense of the materials and procedures in order to attain the cost targets for future components. Moreover, utilizing the technologies and methods studied, there is a high possibility of a scope of components being created. In a nut shell, this review work has really justified the impact of aluminium composite in manufacturing industry.

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