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EFFECT OF SILICON CARBIDE (SiC) REINFORCEMENT ON MECHANICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITE: A REVIEW

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Aluminium based metal matrix composite (AMMCs) finds wide industrial applications such as automobile, aerospace, structural, marine due to their low cost and excellent mechanical properties like high heat resistant, high corrosion resistance, high wear resistant makes them an attractive industrial option and these composites can perform over a wide range of operating conditions hence in today scenario they are replacing conventional materials. The reinforcement plays a major role in AMMCs that enhance the mechanical properties and also reduce some properties by selecting different volume fraction of it for the particular application and most commonly used reinforcement for AMMC's is silicon carbide (SiC) and aluminium oxide(Al_2O_3) . In this paper a review has been done regarding effect of silicon carbide reinforcement on mechanical properties of AMMC's.

***Keywords*: AMMC, Reinforcement, Aluminium, Silicon Carbide (SiC)**

1. Introduction

Composite is a system of materials which is a combination of two or more phases of dispersed materials and each material phases has its own specific volumetric region and properties and this class of material is called as Metal Matrix Composites (MMCs) [1] based on chemical nature of the matrix phase, composites are classified as polymer matrix composite (PMC), ceramic matrix composite (CMC) and metal matrix composite (MMC). In aluminium metal matrix composite pure aluminium or an alloy of it is the matrix phase and non- metallic serve as reinforcement which is commonly ceramic like silicon carbide(SiC), aluminium oxide(Al_2O_3), silicon oxide(SiO_2), boron carbide(B_4C). Aluminium alloys are mostly used matrix material due to its better corrosion resistance, high damping capacity, low density and better electrical and thermal conductivity, in different engineering applications including functional and structural the aluminium metal matrix composites proved its usefulness[1].In different categories of Metal Matrix Composites (MMCs) aluminium based metal matrix composites is the first attraction for researchers and industries. [2]Alloys of Aluminium like 2000, 5000, 6000 and 7000 series are most commonly utilized as matrix materials in the fabrication of MMCs for aerospace applications. The reinforcement which is most commonly used in AMMC's is silicon carbide (SiC) and aluminium oxide (Al_2O_3), by the addition of silicon carbide reinforcement density, wear resistance, hardness, tensile strength of aluminium and its alloys increases. [3.4, 5]Alloys of Aluminium find wide applications in automobile industry due to their high strength to weight ratio, formability and better cast ability, high electrical and thermal conductivity and better corrosive resistance. The need for high specific strength to be maintained even at high temperature results in the development of MMC's. Aluminium metal matrix composites reinforced by carbides, borates, nitrides and oxides have been successfully fabricated either by powder metallurgy techniques or casting methods.[6] Silicon carbide(SiC) is the hardest of the conventional abrasives, but has lower impact resistance than aluminium oxide (Al_2O_3), and shows a higher wear rate when used for grinding steels. Silicon carbide wears more rapidly when used to grind metals that have an affinity for carbon such as iron and nickel. It is therefore used primarily for non-ferrous materials. [7] The size of reinforcements in commercial Metal Matrix Composites (MMC) generally ranges from a few micrometers to several hundred micrometers because of fabrication difficulties only recently reinforcements with nanometric size have been used. [8]The major advantages of Aluminium Metal Matrix composites (AMMC's) are greater strength, improved stiffness, reduced density (weight), improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance, control of mass (especially in reciprocating applications), improve damping capabilities.

Depending on the type of reinforcement Aluminium metal Matrix Composites can be classified as:
a) Particle – reinforced AMC's (PAMC's)
b) Whisker- or short fibre-reinforced AMC's(SFAMC's)
c) Continuous fibre-reinforced AMC's(CFAMC's)
d) Mono filament- reinforced AMC's (MFAMC's)

Primary processes for manufacturing of AMC's at industrial scale can be classified as:
- Solid state processes
- Liquid state processes

2. Literature Review

A mechanical property is very important and is a special requirement for a composite. Elastic modulus of pure aluminium can be enhanced from 70GPa to 240GPa by reinforcing with 60 vol% continuous aluminium fibre also there is possibility to processAl-9% Si-20 vol% SiC_p composites having wear resistance equivalent or better than that of grey cast iron [8]. Aluminium metal matrixes composites (AMMC's) can be more easily produced by the method of stir casting reinforcement materials like silicon carbide (Sic) and aluminium oxide (Al_2O_3) are commonly used for automobile applications such as piston rings, diesel engine pistons, connecting rod, drive shafts, brake disc, cylinder liners etc. [9-10].Due to physical and chemical compatibility with alumina (Al) matrix and silicon carbide (SiC) is widely used, also the contribution of silicon carbide increases young's modulus and tensile strength of the composite and additionally promotes an increase in wear resistance of composites[11].[12]Experimental work on synthesis and characterization of aluminium silicon-silicon carbide composites and observation was density values are very close to theoretical ones that indicates the soundness of composites but marginal difference due to the presence of entrapped gases and shrinkage porosity. Along with hardness and ductility, composites should have sufficient compressive and tensile strength, the reinforcement constituents are one of the important factors controlling the strength Al-Si-SiC composites. [13]Silicon carbide (SiC) also known as carborundum it is a compound of silicon and carbon having formula SiC. It is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice and the result is a very hard and strong material having 16-100 grit size. This compound was originally produced by a high temperature electro-chemical reaction of sand and carbon. It has an excellent abrasive nature used in making grinding wheels and other abrasive products for over ten decades. Now the material has been developed with a high quality technical grade ceramic having excellent mechanical properties. [14] Composite hardness improved by increasing the size of the particles, the worked carried on Al/SiC/30p composite observed that the hardness of Al MMC was 120 Vickers Hardness Number (VHN) with fine reinforcement (65μm) and has a hardness of 100 Vickers Hardness Number (VHN) with reinforcement size (15 μm). [15]The resistance of materials against surface indentation is termed as hardness. The micro hardness of composites evaluates the interface bonding strength between reinforcing particles and matrix.[16]The addition of silicon carbide (SiC) particles in Al MMC enhances the hardness of AMC's when compared with unreinforced Al. When unreinforced Al has Vickers hardness value of (24.50±0.35), hardness value increases with increasing SiC content and maximum obtained hardness value is (45.40±1.06) for 20 Wt. % SiC reinforced AMC. The presence of harder and well bonded SiC particles in aluminium matrix that impede the movement of dislocations increases the hardness of AMC's. [17, 18, 19] It has been observed by investigation that the tensile strength of AMC's is greater than unreinforced aluminium (Al). Increase of tensile strength in aluminium metal matrix composites (AMMC's) can be due to applied tensile load transfer to the strongly bonded SiC reinforcements in aluminium matrix, increased dislocation density near matrix-reinforcement interface and grain refining strengthening effect. Composite having strong matrix and strong interface, the crack has to propagate across both matrix and reinforcements. [20, 21, 22, 23]The wear resistance of MMC's indicated that both the reinforcement size and matrix strengthening have a significant effect on the wear properties of composites. With increasing SiC particulate size sliding wear resistance of the composite increases. Composite consist of various particulate sizes, the wear properties of the composites cannot be directly correlated to the bulk hardness (HRB) of the composites. Wear mechanism has been explained on the nature of wear debris, wear cracks, its growth, propagation, and detachment and these factors contribute to wear loss. No direct relationship has been found between hardness and wear resistance and maximum wear resistance has been reported after over ageing. [24] Aluminium and silicon carbide have very different mechanical properties for example young moduli of 70 and 400 GPa, coefficient of thermal expansion of 24x 10^{-6} and 4 x 10^{-6}, and yield strengths of 35 and 600 MPa by combining these materials example A6061/SiC//17p (T6 condition) MMC with a young's modulus of 96.6 GPa and yield strength of 510 MPa can be produced.[25] As the increase of weight fraction of reinforcement from 5% to 20% increases composites hardness, elastic modulus, creep resistance, fatigue behavior, tensile strength, density, impact strength and wear resistance but its cooling rate, ductility, forge ability are decreased.

3. Conclusion

From literature survey it is concluded that:

- If there is addition of even small amount of silicon carbide it directly affects the mechanical properties of AMMC.
- Clustering of reinforcements in the matrix affect the ductility and strength of AMMC.
- The size of silicon carbide (SiC) greatly affects than that of volume fraction.
- Tensile strength of AMMC's decreased for a given volume fraction as reinforcement particle size increased.
- Mechanical property like stiffness of AMMC's increases with the increase of volume fraction of reinforcement particles.

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