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Aluminum Matrix Composites for Industrial Use: Advances and Trends

S.T. Mavhungu*[a], E.T. Akinlabi[b], M.A Onitiri[b], F.M. Varachia[a]

[a]Metal Casting Technology Station, Faculty of Engineering and the Built Environment, University of Johannesburg. P.O. Box 524, Auckland Park 2006, South Africa.

[b]Department of Mechanical Engineering Science, Faculty of Engineering and the Built Environment, University of Johannesburg. P.O. Box 524, Auckland Park 2006, South Africa.

Abstract

Composites material, plastics and ceramics have been the dominant emerging materials in many industries over the last decade. The motive behind the use of metal matrix composite components in the automotive, agriculture and mining sectors is based on requirements for weight reduction and in pursuit of high efficiency and performance in the material. The automotive industry is subjected to increasingly restrict fuel economy requirements by consumers, demanding improved comfort and safety. To meet these requirements, automotive manufacturers are turning to light weight and improved efficient products. Aluminium metal matrix composites (AMMC's) with high specific stiffness and high strength could be used in long-term application in which saving weight is an important feature, such applications include robots, high speed machinery, high-speed rotating shafts, and automotive engine and brake parts. This research paper presents a review on advances and trends of aluminium matrix composites for industrial uses. Composite materials are high strength-lightweight components and popular in the automobile and industrial sectors and this ultimately leads to the development of advance material parts with improved performance and efficiency.

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* Corresponding author
Email address: stmavhungu@uj.ac.za

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1. Introduction

Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for variety of applications owing to their lower weight, excellent thermal conductivity properties [1]. It has been discovered recently that the need for the use of lightweight materials in the automobile industry for production of components and parts can be over emphasized. This is due to the stringent air pollution regulations and the insatiable demand by consumers for improved and sophisticated automobile interiors with electronic components, multimedia gadgets, etc., which imposes additional weight culminating to increased overall weight. This, in turn, leads to increased fuel consumption and environmental pollution. The use of lightweight materials for the production of automobile components and parts would help in achieving the ever stringent air pollution regulations and also improve efficiency [2, 3].

The aforementioned led to the adoption of Aluminium matrix composites (AMCs) which are interesting group of advanced materials. AMCs possess improved physical and mechanical properties such as superior strength to weight ratio, good ductility, high strength and high modulus, low thermal expansion coefficient, excellent wear resistance, excellent corrosion resistance, high temperature creep resistance and better fatigue strength [2]. They are widely used for high performance applications such as automotive, industrial, military, aerospace and electricity industries [2]. Various kinds of ceramic materials, e.g. Al_2O_3, SiC, MgO and B_4C, are extensively used to reinforce aluminium alloy matrices. Superior properties of these materials such as refractoriness, high hardness, high compressive strength, wear resistance, etc. make them suitable for use as reinforcement in the matrix of composites [5]. This paper focuses on the advances and trends in the fabrication and industrial applications of aluminium matrix composites.

2. Properties of particles reinforcements

Aluminium oxide particles are a low-cost alternative most commonly used for casting application, but the most common discontinuously reinforced metal-matrix composite materials system being currently used in aerospace structural application being Silicon Carbide and boron carbide particles [6].

Table 1: Mechanical and physical properties of various ceramic particles reinforcements, [6].

Ceramic	Density, g/cm^3	Elastic modulus		Knoop hardness	Compressive Strength		Thermal conductivity		Coefficient of thermal expansion		Specific thermal conductivity. W · m^2/kg · K
		Gpa	**10^6 psi**		**Mpa**	**ksi**	**W/m · K**	**Btu · Ft/h · Ft^2. ^{0}F**	**10^{-6} / K**	**10^{-6} / ^{0}F**	
SiC	3.21	430	62.4	2480	2800	406.1	132	76.6	3.4	6.1	**41.1**
B_4C	2.52	450	65.3	2800	3000	435.1	29	16.8	5.0	9.0	**11.5**
Al_2O_3	3.92	350	50.8	2000	2500	362.6	32.6	18.9	6.8	12.2	**8.3**
TiC	**4.93**	**345**	**50.0**	**2500**	**2500**	**362.6**	**20.5**	**11.9**	**7.4**	**13.3**	**4.2**

Table 1 shows a lists the mechanical and physical properties of various ceramic reinforcements commonly used in the manufacture of modern discontinuously reinforced metal-matrix composites material systems. For operation of toughening mechanisms, the microstructure should be homogeneous. It means that metal particles should be uniformly distributed in the ceramic matrix [7]. In the particulate reinforced composite the size of the particulate is more than 1 μm, so it strengthens the composite in two ways. First one is the particulate carry the load along with the matrix materials and another way is by formation of incoherent interface between the particles and the matrix; so a larger number of dislocations are generated at the interface, thus material gets strengthened. The degree of strengthening depends on the amount of particulate (volume fraction), distribution, size and shape of the particulate [7].