Composites: Part A 92 (2017) 70–96

Contents lists available at ScienceDirect

Composites: Part A

journal homepage: www.elsevier.com/locate/compositesa

Review

Carbon fiber reinforced metal matrix composites: Fabrication processes and properties

Kamyar Shirvanimoghaddam[a,*], Salah U. Hamim[b], Mohammad Karbalaei Akbari[c], Seyed Mousa Fakhrhoseini[a], Hamid Khayyam[a], Amir Hossein Pakseresht[d], Ehsan Ghasali[d], Mahla Zabet[e], Khurram Shahzad Munir[f], Shian Jia[g], J. Paulo Davim[h], Minoo Naebe[a,*]

[a] Institute for Frontier Materials, Carbon Nexus, Deakin University, Geelong, Victoria 3216, Australia
[b] School of Mechanical and Aerospace Engineering, Oklahoma State University - Stillwater, OK, USA
[c] University of Ghent Global Campus, Department of Applied Analytical & Physical Chemistry, 119 Songdomunhwa-ro, Yeonsu-Gu, Incheon, South Korea
[d] Department of Ceramics, Materials and Energy Research Center, P.O. Box 31787-316, Karaj, Iran
[e] Dave C. Swalm School of Chemical Engineering, Mississippi State University, USA
[f] School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Victoria 3000, Australia
[g] Secat, Inc., Lexington, KY 40504, USA
[h] Department of Mechanical Engineering, University of Aveiro Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

ARTICLE INFO

Article history:
Received 1 July 2016
Received in revised form 23 September 2016
Accepted 31 October 2016
Available online 1 November 2016

Keywords:
Metal matrix composites
Carbon fiber
Reinforcement
Mechanical properties

ABSTRACT

This paper reviews the research and development works conducted over the past few decades on carbon fiber reinforced metal matrix composites (CFR-MMC). The structure and composition of carbon fiber and its bonding to metal matrix have an impact on the properties of the resulting CFR-MMC remarkably. The research efforts on process optimization and utilizing of carbon fibers are discussed in this review. The effect of carbon fiber on structural, physical and mechanical properties of metal matrix composite are studied as well. This review also provide an overview of the research to date on various fabrication methods that is used for production of CFR-MMC.

Contents

* Corresponding authors.
E-mail addresses: kshirvan@deakin.edu.au (K. Shirvanimoghaddam), minoo.naebe@deakin.edu.au (M. Naebe).

http://dx.doi.org/10.1016/j.compositesa.2016.10.032
1359-835X/

1. Introduction

The advent of technological era has brought the need for new materials to tackle everyday challenges of current materials for different applications. In the quest for new advanced materials, researchers have innovated various material systems. One of the most prominent material systems in the past few decades is Metal Matrix Composites (MMCs), where two or more constituents are used to fabricate a new material [1]. By formulating a composite, it is possible to use the unique advantages of different constituents in a complementary manner to suppress the limitations of each constituent. For example, the need for lightweight structural material for the applications in automotive and aerospace industry is paramount these days. This is partly due to enforcement of new emission regulations and the rising fuel costs. Traditional materials such as aluminum or titanium are failing to overcome current challenges of ordinary materials are facing today. Properties of materials significantly deteriorates at relatively low temperatures and in turn limits their usability in critical components [2]. However, by combining inherent ductility of matrix and toughness with high stiffness and high specific strength materials, such as ceramic filaments or carbon fibers, it is possible to fabricate materials that can overcome performance issues and also being used in high-tech applications like nanoelectronic, structural and medical applications [3–12]. The incorporation of such reinforcements into metal matrices significantly improves the hardness, tensile strength, elastic modulus and other mechanical properties. Few other properties, such as thermal conductivity (TC), coefficient of thermal expansion (CTE), coefficient of friction, wear resistance, corrosion and fatigue resistance can also be tailored according to application requirements in metal matrix composites [13,14].

As an example, a heat sink material needs to have high heat dissipation rate in order to provide effective cooling to the electronic chip. At the same time the CTE of the material has to be low so that it generates less thermal stress while undergoing thermal cycles. Pure copper and aluminum has relatively high CTE of 17×10^{-6} and 23×10^{-6}/K respectively; thus, generates high thermal stresses [15,16]. Studies show that silicon carbide (SiC) reinforced MMCs can provide high heat dissipation rate and minimal thermal stresses due to low CTE mismatch [17–20]. Diamond particle reinforced copper MMCs has also been studied to replace bulk metal heat sinks [21–23]. Although, these MMCs were found to have improved thermo-mechanical properties, the required volume fraction of the reinforcement for property enhancement is as high as 60%. This in turn makes the diamond and SiC reinforced MMCs very difficult to machine for industrial applications. In search of the balance between machinability and thermo-mechanical properties, Carbon fibers (CFs) reinforced MMCs have also been explored for heat sink application. Lalet et al. [24] reported that only 30% carbon fiber reinforcement could reduce the CTE of aluminum and copper. Owing to the very low CTE in the longitudinal direction (-1×10^{-6}/K) CF reinforced aluminum and copper MMCs has been found to offer great promise as heat sink material [24–29]. As mentioned earlier, carbon fiber reinforced metal matrix composites also possesses high wear resistance, and thus found application in bearings and wear parts [30]. Liu et al. [31] reported that, 40 vol% of short CFs not only improves the wear resistance of Cu, but also improves the friction coefficient. Owing to the high temperature strength and self-lubricating effect of CFs [32–34], other chemical and physical properties such as, modulus, strength, toughness, electrical conductivities of these MMCs also tend to be superior [30,35–40]. As a result, CF-MMCs has received great

Table 1
Review papers in the field of metal matrix composites (since 2000).

Author	Topic discussed	Literature
Kaczmar et al.	Fabrication methods of different types of MMC	[178]
Tjong and Ma	Fabrication techniques, microstructure and mechanical properties	[179]
Torralba et al.	Powder metallurgy based different MMCs and their properties	[180]
Ye and Liu	Fabrication techniques, microstructures, interfacial characteristics, mechanical properties	[181]
Miracle	Properties and fabrication techniques of MMCs for different applications	[182]
Chawla and Chawla	Use of MMCs for automotive and railroad applications	[183]
Ye et al.	Material systems, fabrication methods, material properties and microstructures	[184]
Mortensen and Llorca	Fabrication techniques, deformation and fracture mechanism	[185]
Bakshi et al.	Processing techniques, mechanical properties, dispersion and interfacial characteristics	[186]
Qu et al.	Advances in manufacturing process, thermal properties of SiC/metal, carbon/metal and diamond/metal composites	[19]
Kumar et al.	Mechanical and wear properties of particulate reinforced Al matrix	[187]
Saheb et al.	Properties of spark plasma sintered metals and MMCs	[188]
Silvestre	Fabrication and mechanical properties of CNT based MMCs	[189]
Das et al.	Microstructural, optical, physical and mechanical properties of ceramic-reinforced Al MMCs	[190]
Kala et al.	Stir cast particulate reinforced Al MMC's mechanical and tribological properties	[191]
Jain et al.	Effect of different machining parameters on Al MMCs	[192]
Munir et al.	Mechanical properties of CNT/Ti MMCs fabricated by powder metallurgy	[193]
Ramnath et al.	Mechanical properties of particulate and fiber reinforced Al MMCs	[194]
Casati and Vedani	Strengthening mechanism, fabrication, and properties of nanoparticle reinforced MMCs	[195]