International Journal of Surface Engineering and Interdisciplinary Materials Science
Volume 10 • Issue 1

Effect of Reinforcements on the Sliding Wear Behavior of Self-Lubricating AZ91D-SiC-Gr Hybrid Composites

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ABSTRACT

This article statistically investigates the effect of various parameters such as material factors: silicon carbide (SiC) reinforcement, graphite (Gr) reinforcement, and mechanical factors: normal load, sliding distance, and speed on the sliding wear rate of vacuum stir cast self-lubricating AZ91D-SiC-Gr hybrid magnesium composites. The sliding wear tests have been performed on pin-on-disc tribometer at 10-50N loads, 1-3m/s sliding speed and 1000-2000m sliding distance. It has been examined that hybrid composites yielded improved wear resistance with reinforcement of SiC and solid lubricant graphite. ANOVA and signal-to-noise ratio investigation indicated that applied load was the most critical factor influencing the wear rate, followed by sliding distance. Further, the AZ91D/5SiC/5Gr hybrid composite has exhibited the best wear properties. From the SEM and EDS analysis of worn surfaces, delamination was confirmed as the dominant wear mechanism for AZ91D-SiC-Gr hybrid composites.

KEYWORDS

Hybrid Magnesium Composites, Sliding Wear, Solid Lubricant Graphite, Taguchi Experimental Design, Vacuum Sir Casting

1. INTRODUCTION

The energy crisis and change in environment due to global warming are the main challenges of the contemporary world. Being one of the major source of energy consumption and environmental pollution, for transport industries, there is growing worldwide demands of lightweight materials that are stronger and cheaper which can reduce the weight of automobile improving the fuel efficiency and reducing the harmful gas emission (Banerjee et al., 2019; Campbell, 2012). Moreover, light weight magnesium and its alloys possessing high stiffness and specific strength have become attractive materials to meet such demands in automobile, aerospace, medical, electronic, defense and sports industries (Li et al., 2019; Yu et al., 2018). Reduction in weight of V6, 3-cylinder car by replacing its engine block made of cast iron and aluminum by magnesium was 54.6 kg and 9 kg respectively, which

DOI: 10.4018/IJSEIMS.2022010103

further promotes fuel savings and emission reduction (Tharumarajah & Koltun, 2007). However, low creep resistance, low ductility; poor corrosion and wear resistance of magnesium restricts its wider applications (Dey & Pandey, 2015). These limitations can be eliminated by addition of reinforcement and alloying elements in magnesium in the form of alloy, composites and hybrid composites (Gopal et al., 2017).

AZ91D with high specific strength and good corrosion is the widely used magnesium alloy in aerospace and automobile industries; however, it has been mostly used for structural application (Zafari et al., 2012). Applications of AZ91D alloy can be further increase in other automobile and space satellite components such as engine cylinder, piston, stirline engine and high speed air foil bearing by improving its mechanical properties along with wear resistance. Over the past years, many researchers have improved the mechanical properties of AZ91D by reinforcing the hard ceramics particles such as silicon carbide (SiC), cerium oxide, aluminum oxide (Al_2O_3), yttrium oxide (Y_2O_3), boron carbide (B_4C) and titanium carbide (TiC) at micro and nano level (Khatkar et al., 2018). SiC was the most used reinforcement, due to its good wettability in magnesium. Good wettability of SiC in magnesium is due to low surface tension of magnesium (0.599N/mm), which is also lower than of aluminium (0.720N/mm)(Poddar et al., 2007). For AZ91D magnesium alloy presence of aluminum has tremendous influence in increasing the wettability of SiC (Aatthisugan et al., 2017). For the better tribological properties, graphite (hexagonal lattice crystal structure); due to its low cost and easily availability has been widely used as solid lubricant of various metal matrix and their alloys such as aluminum (Ravindran, Manisekar, Rathika et al, 2013), copper (Ram Prabhu et al., 2014), nickel (Li & Xiong, 2008) zinc (Babic et al., 2010), magnesium (Girish et al., 2015), silver (Feng et al., 2007), and bronze (Cui et al., 2013). Therefore, reinforcing the combination of hard ceramics SiC and solid lubricant graphite in AZ91D alloy as self-lubricating hybrid magnesium matrix composites (HMMCs) give opportunity to achieve improved mechanical and wear properties. Self-lubricating HMMCs are the important class of materials reinforced with solid lubricants as secondary reinforcement, find applications in harsh or vacuum environmental conditions where lubrication using liquid lubricant is difficult or impossible (Menezes et al., 2013; Moghadam et al., 2015; Reeves et al., 2013). Moreover, liquid lubricants emits harmful pollutants to environment, so the need of hour is to fabricate of green or environment friendly materials for these applications and self-lubricating HMMCs are one of the best options (Omrani et al., 2016).

Over the past decades, many techniques have been developed for fabrication of HMMCs such as, disintegrated melt deposition metal (DMD) technique, stir casting, squeeze casting, remelting and dilution technique, infiltration method, friction stir processing (FSP) and powder metallurgy (Khatkar et al., 2018). In present research work advanced vacuum assisted stir casting processing has been considered for fabrication of HMMCs reinforced with SiC and graphite due to its lower fabrication cost, simplicity, ability to cast complex shapes and less destruction to reinforcement particles. In advanced vacuum assisted stir casting, two blade stirring of melt has been followed by vacuum assisted bottom pouring which eliminated the drawbacks of conventional stir casting. Agglomeration of reinforcement particles, their inhomogeneous distribution and interfacial reactions with matrix are the major drawbacks of conventional stir casting. SiC and Gr as a hybrid reinforcement (where SiC is incorporated as primary reinforcement while Gr is added as secondary reinforcement) has been extensively used by several researchers for improving the mechanical and tribological properties of HMMCs of various matrix materials such as aluminium (Bodunrin, 2015; Guo & Tsao, 2000; Mosleh-Shirazi et al., 2016), Copper (Ramesh et al., 2009; Xiao et al., 2013), and iron (Ma et al., 2008).

Maamari et al. (Soorya et al., 2016) reinforced different content of solid lubricant graphite in pure magnesium by mechanical alloying to fabricate Mg-Gr self-lubricating composites and examined mechanical and wear behavior. It was reported that reinforcement of graphite in pure magnesium reduced the mechanical properties of composites while improving the wear resistance. The minimum wear rate and coefficient of friction for Mg-Gr composites was achieved with 5 wt.% reinforcement of graphite. Beyond 5 wt.% of graphite wear rate and coefficient of friction for Mg-Gr

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