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Effect of weight fraction and particle size of CRT glass on the tribological behaviour of Mg-CRT-BN hybrid composites

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ABSTRACT

The current research focuses on dry sliding wear behaviour of end of life CRT panel glass and BN reinforced hybrid magnesium matrix composite fabricated through powder metallurgy route. CRT panel glass percentage (5, 10 & 15 wt %) and particle size (10, 30 & 50 μm) are varied to find its effect on wear performance and BN solid lubricant is added at a fixed level of 2%. Increase in reinforcement content and particle size decreases the wear rate whereas the opposite trend is found for coefficient of friction. ANOVA results reveal that all of the considered parameters significantly influence the response parameters. Taguchi based GRA is used for multi objective optimization and the worn surface SEM analysis is also performed.

1. Introduction

The unpredictable weather changes in the environment forces the world to concentrate on the greenhouse gas emission that too mainly from the exhaust of automobiles. Along with the gas emission problems the instability over oil costs makes the researchers to go for alternative solutions. Use of eco-friendly lightweight materials like magnesium having high strength to weight ratio is supposed to be one of the simplest way to minimize the fuel consumption and carbon dioxide emission. Magnesium with a density of 1.74 g/cm^3 is one among the lightest material as it posses density values about one fifth of steel (7.9 g/cm^3), two third of aluminium (2.7 g/cm^3) and near to that of plastics (0.92–2.17 g/cm^3) [1]. Due to the attractive properties of magnesium materials wide range of applications in aerospace, automobiles, defence and sports industries were easily sought out. Despite its positive properties it also has some limitations like low ductility and stiffness, insufficient high temperature creep resistance and poor resistance to wear and corrosion which hinders its wider applications. Yet again, because industrial applications like bearings, bushes, electrical sliding contact and other antifriction applications requires materials that has increased strength with enhanced antifriction and anti-wear characteristics it is a necessary artefact to attain so. It was a proven fact that the addition of reinforcements and alloying elements with magnesium to make composites and alloys can eliminate its limitations [1,2]. Further, it was reported that the ceramic particle reinforcement in metal matrix increases the strength and hardness, effects in wear resistance improvement of material [4,5]. Generally, particle reinforced magnesium materials possess higher strength and improved wear properties when compared to monolithic counterparts [3].

Many researchers used ceramic reinforcements such as SiC, B_4C, Al_2O_3 and TiC to improve the mechanical and wear properties of the materials [6–20]. Nguyen QB et al. [6] reinforced Al_2O_3 ceramic particles with AZ31B alloy and found that the developed composites exhibits superior wear resistance than base alloy at high loads and sliding speeds. Coefficient of friction of the alloy and composites were in the range of 0.25–0.45 and got least at critical loads and speeds. Addition of reinforcement like TiC and MoS_2 also significantly improves the wear resistance of the magnesium hybrid composites [7]. Wear depth of the aluminium material decreased with addition of SiC and Graphite i.e. wear loss decreased [18]. It was identified that the wear resistance of the 2 and 4% Al_2O_3 reinforced copper is superior to that of unreinforced matrix [19]. Addition of SiC and B_4C reinforcements (5, 10 and 15%) with aluminium decreased the wear rate considerably and its contribution percentage over wear rate is found as higher than that of sliding time. However, it was identified that most of the wear behaviour researches are focused on aluminium based MMCs wherein only minimal number of researchers analysed wear behaviour of magnesium based materials. Further the studies on effect of reinforcement size on wear behaviour of magnesium are rare minimal and only very few studies were performed in aluminium Metal Matrix Composites (MMC). But, Song-

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Table 1
Chemical composition of CRT.

Composition	Si	O	Ba	K	Na	Al
%	36.93	34.88	11.27	9.49	5.53	1.90

Jeng Huang et al. [14] found that the particle size of reinforcement has influence on wear properties of magnesium composite and reveals that with increasing particle size of SiC_p, wear rate of the composite sets decreased for moderate sliding conditions at any sliding speed of 250 and 1000 rpm, apart from 10 to 50 N at the severe sliding rate of 1500 rpm. Jo SK et al. [15] stated that the large-sized reinforcements are being capable of effectively preventing severe abrasive wear by withstanding the load applied. Further, it was reported as the resistance to wear capacity of Al 2024 alloy is improved with increase in alumina particles size [8]. Similar findings that confirms for the improved wear resistance of aluminium alloy with increase in reinforcement particle size were detailed by some other researchers also [9–11]. On the other hand, few contradictory findings also obtained by other researchers. For instance, Roy et al. [12] report on wear rate of aluminium MMC showcased that when the size of ceramic reinforcement particles were altered from 1.9 to 7 µm there is no significant changes on wear rate. So it is understandable that the reinforcement and their sizes effects on wear behaviour is varies from material to material, therefore, it should be analyzed for every newer MMC.

Conversely, the major problem associated with these high performance modern materials is high reinforcement cost and availability. So several authors tried low cost and easily available reinforcements such as fly ash, colliery shell ash and rock dust in order to produce economical composites and found better results [21,22]. As such the current research also aims to develop a novel and economical composite by utilizing low cost E-waste Cathode Ray Tube (CRT) glass as reinforcement with magnesium. CRT that consists of 85% glass is the major part of E-waste and occupies for about 65% of entire weight of a Tele Vision (TV) or Personal Computer (PC) monitor [23]. Panel and Funnel glass are the two major parts of CRT in which leaded funnel glass processing units are available and lot of researches were already done, however non-leaded panel glass is again used to make new CRTs. But, introduction of flat screen technologies like Liquid Crystal Display (LCD) and Light Emitting Diode (LED) reduces/almost ended the production of new CRTs and concurrently panel glass recycling also ended. Hence effective recycling and reutilization technologies have to be identified for the CRT panel glass which has rich amount of silica. In order to overcome many other such technical hitches, CRT panel glass is selected as reinforcement and due to its rich silica content it is believed that the addition of CRT glass powder particles will provide positive effect on magnesium.

Based on the aforementioned facts, the current research focuses on developing economical composite by reinforcing silica rich CRT panel glass powder with magnesium and also on analyzing the wear behaviour of developed MMC. Even though considerable number of researchers analyzed the wear behavior of magnesium MMCs in the past, studies on the wear parameter optimization and effect of reinforcement content on wear behaviour was not fully understood for different sliding conditions [7]. So the current investigation focuses on the study of optimization based on statistical design of experiments, so that the optimum tribological parameters, % reinforcement, reinforcement particle size, load, sliding speed and sliding distance for multiple responses such as wear rate and co-efficient of friction for the composites can well be predicted.

2. Materials and methods

2.1. Materials and processing

Commercially available pure magnesium is used as base metal whereas three different sizes of CRT panel glass particles and commercially available BN with average particle size of 10 µm is used as the reinforcement. CRT panel glass is separated from the dismantled CRT and the required particle size (10 µm, 30 µm and 50 µm) is obtained by processing the wrecked panel glass through ball mill for different time periods. The chemical composition of CRT panel glass is shown in Table 1 and its Energy Dispersive Spectroscopy (EDS) spectrum is shown in Fig. 1. Boron Nitride is a low dense solid lubricant material which has the combined properties of high strength, wear and corrosion resistance. Many studies suggested that the addition of solid lubricant in higher percentage reduces the mechanical properties of the composites even though it increases the wear resistance. And based on the preliminary experimental results, amount of boron nitride addition is fixed as 2%. Totally nine different composites were fabricated by varying the weight percentage and particle size of the CRT panel glass as shown in Table 2. The morphologies of the CRT panel glass and BN is illustrated in Fig. 2.

Table 2
Compositional plan for composite.

Sl.No	CRT Particle Size	CRT Weight %	Mg Weight %	BN Weight %
1.	10 µm	5	93	2
2.		10	88	
3.		15	83	
4.	30 µm	5	93	
5.		10	88	
6.		15	83	
7.	50 µm	5	93	
8.		10	88	
9.		15	83	

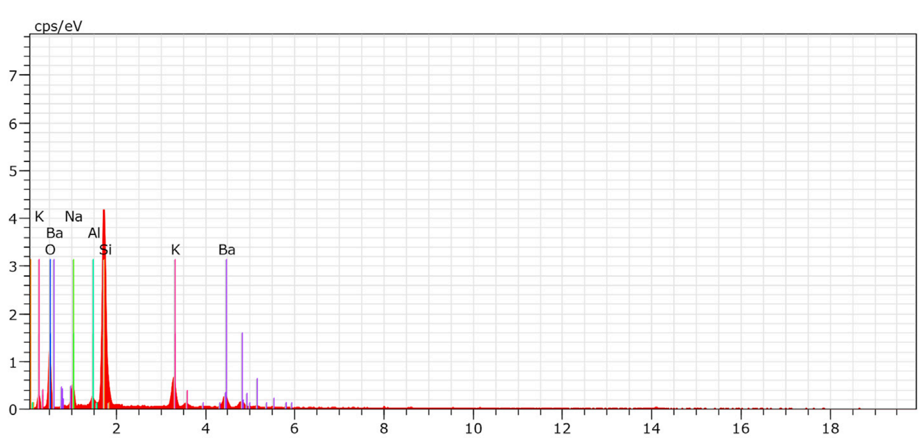

Fig. 1. EDS spectrum of CRT panel glass.