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EXPERIMENTAL INVESTIGATION ON MECHANICAL AND TRIBOLOGICAL PROPERTIES OF MgO/ABS POLYMER COMPOSITES

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ABSTRACT

In this research paper, ABS as matrix material and MgO as a filler material to the matrix material. Composite specimens prepared with the use of an injection molding machine. Takes filler content, normal load, sliding distance and speed as input parameters with three levels for each parameter Taguchi's design of the experiment is carried out. Tensile and wear tests were conducted to investigate the mechanical and wear behavior of composites. The results show the impact of MgO nanoparticles in the ABS composite. It also shows the impact of other input process parameters for the enhancement of the mechanical properties. Using MgO as filler material to ABS, the properties are enhanced, which results in a wider application.

KEYWORDS: ABS, MgO, Tensile, Wear Test, Taguchi & Scanning Electron Microscope

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Original Article

INTRODUCTION

Nowadays, filler materials are used to improve the lubrication of the composite materials. Polymer alone cannot satisfy the required properties. The addition of the nanoparticles can do enhancement of the properties of the composite to the composite material. Sudeepan *et al*. [1] has taken three different levels of parameters, such as filler content, sliding speed and normal load with the help of Taguchi design experiments, which were conducted for ABS/$CaCO_3$ and micron-sized composites, which are prepared by the compression molding process through melt compounding and found normal load (B) was the most influencing factor affecting friction coefficient of the material. By the addition of Teflon nanoparticles to Nylon 6 matrix composite, there is an increase in the tensile strength along with hardness, and also, there is a reduction in ductility for polymer composites A. C. Reddy [2] and Yaping Bai *et al*. [3] studied the effect of Al_2O_3 nanoparticle reinforcement on the mechanical and high-temperature tribological behavior of Al-7075 alloy, and in this study, the tribological properties also indicated that 5 wt.% Al_2O_3 nanoparticle significantly improved the high-temperature wear resistance of 7075 alloys. Chandrashekar *et al*. [4] investigated the mechanical, structural and corrosion behavior of AlMg4.5/Nano Al_2O_3 Metal Matrix Composites. It discovered that the presence of 6% nano Al_2O_3 particles in AMMNC had displayed excellent tensile strength and hardness in correlation with the rest of the nano Al_2O_3 particles in a record of basic quality set up at 6% nano Al_2O_3 particles. The Statistical evaluation effect of the carbon nano fiber content on tribological properties of epoxy nanocomposites analyzed by Afroza Khanam [5].

Yijun Shi *et al*. [6] investigated tribological and Mechanical Properties of Carbon-Nano fiber-Filled Polytetrafluoroethylene Composites and found that the lubrication can be enhanced by addition of filler material to the matrix composite without any other external agents. Moreover, the mechanical properties are greatly influenced by the process parameters. M. Nikzad [7] using Fused Deposition Modeling rapid prototyping process ABS with copper particles composite was produced and found higher stiffness of the material after the injection process. Amritraj and Senthilvelan [8] by using twin-screw extrusion process ABS along with nano-zirconia and PTFE as reinforced material composite was prepared. By the addition of nano zirconia and PTFE, the wear resistance of the composites improved. Distance and load are the most significant factors. Karan Agarwal *et al*. [9] prepared the Nylon/Teflon Composites in addition to Nano Iron Oxide (γ-Fe_2O_3) and investigated the Mechanical behavior and found that Nylon 6/Teflon matrix doubles the tensile strength and also observed the flow lines in the Nylon 6/Teflon/Iron oxide. A. C. Reddy [10] concluded that by addition of the filler materials to Nylon 6, there is improvement of mechanical as well as wear resistance. Sa'ude *et al*. [11] prepared Copper-ABS Composites and studied Dynamic Mechanical Properties of FDM Feedstock and calculated storage modulus (E'), Tan Delta (δ) and loss modulus (E"). The results show the ABS with copper filler materials has better dynamic mechanical properties than ABS. Guralp Ozkoc *et al*. [12] investigated Short Glass Fiber Reinforced ABS and ABS/PA6 Composites and found that by an increase of 10 to 30 wt% of SGF (short glass fiber), the tensile modulus, tensile strength and flexural modulus improved.

MATERIALS AND METHODOLOGY

The filler material is approximately 100 nm taken along with ABS as a matrix material for preparation of composite specimens. MgO added to ABS by varying its percentage composition, such as 4%, 8%, 12%, 16% and 20% by weight in order. The main purpose of the addition of MgO nanoparticles is to improve the wear resistance of matrix material (ABS). With the help of ME100LA mixer, MgO mixed with ABS at a temperature of 190°C for 20 min with a speed of mixing blades of 200 rpm to make the mixture homogenous. After mixing ABS/MgO to make the composite injection, a molding machine was employed. The mixture of ABS and MgO was placed in the hopper and heated in the barrel, so that it became soft and molten. The combination of molten ABS/MgO was forced under pressure inside the mold cavity of injection mounding. During this process, the material was subjected to holding pressure for a specific time to compensate material shrinkage. For ABS, the melting point was 230°C, and its melt flow index was 12 g per 10 min. The injection pressure is 70 Mpa After injections, the material solidified, as the molding temperature decreased below the glass transition temperature (105°C) of the ABS. After sufficient time, the material was frozen into the mold shape and got ejected. For the tensile test, the standard tensile specimens were fabricated under different injection pressures and packing pressures. The standard specimens are shown in figure 1. For testing the tensile strength, Tensometer Model PC-2000 (Figure 2) was used. Later the samples were observed with a scanning electron microscope to study the fractured surfaces of the tensile specimens at room temperature.

To study the wear behavior of wear monitor (ASTM G99) and pin-on-disc type friction were employed. Polymer composites against emery paper (grade size of 400) fixed on a hardened ground steel (En32) disc. For the analysis of wear resistance, Taguchi's design of experiments was employed to identify the level of experiments and for fixing the input parameters, as shown in table 1. In the orthogonal array, L9 was preferred to carry out wear experiments (Table 2). For the experiments selected, the Rockwell micro hardness test was conducted to find the consequence of wear test of ABS/MgO polymer composite specimens. Scanning electron microscopy analyses were also carried out.

Figure 1: Tensile Specimens of ABS/MgO.

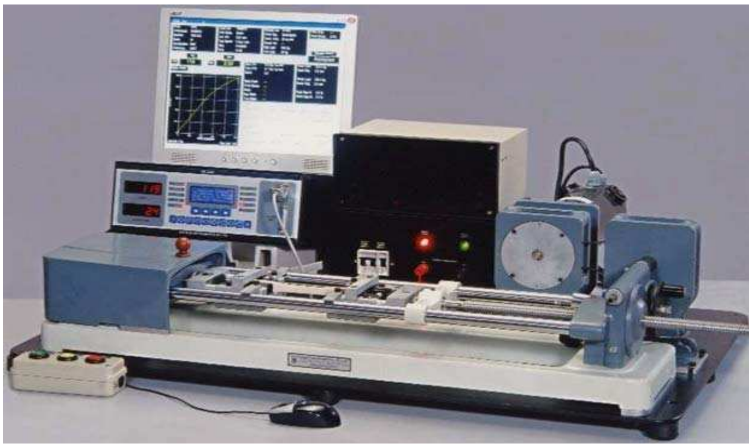

Figure 2: Tensometer.

RESULTS AND DISCUSSIONS

Tensile and wear tests are conducted for the specimens by varying compositions.

Mechanical Behaviour of ABS/MgO Polymer Composites

Stress–strain curves for ABS/MgO at different compositions are shown in Figure 3. 8%wt MgO exhibits the maximum stress and strain rate among other combinations of ABS/MgO polymer composites. From figure 4(a), the ultimate strength remains almost similar only with slight variations for compositions 4%wt, 8%wt and 12%wt of MgO with the highest ultimate strength of 29.874 MPa at 8%wt of MgO. There is a drastic decrease in the tensile strength from 12%wt to 16%wt resulting in the lowest ultimate strength of 16 MPa at 16%wt of MgO. It observed that the tensile strength gradually increases from 16%wt MgO to 20%wt MgO. From figure 4(b), it observed that the strain rate increases from 4%wt to 8%wt and gradually decreases between 8%wt to 16%wt MgO, followed by the only slight difference between 16%wt and

20%wt MgO.

Table 1: Design Factors with Different Levels

Factor	Symbol	Level 1	Level 2	Level 3
MgO %wt.	A	4	12	20
Normal Load, N	B	10	15	20
Sliding Speed, rpm	C	100	200	300
Sliding distance, m	D	500	750	1000

Table 2: Orthogonal Array (L9) and Control

Treat No.	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The hardness of composites was tested by the Rockwell hardness testing machine using the M scale. The indentation ball was 1⁄4-inch steel sphere and the load of 100 kgf. Figure 5 describes the Rockwell Hardness of different compositions of ABS/MgO polymer composites. ABS/MgO composites hardness increases with the increase in the MgO percentage. The material with 20%wt MgO shows a higher tensile strength of 84.66 HRM. ABS material without MgO shows less hardness. It explains that ABS's hardness can be increased by increasing the MgO percentage.

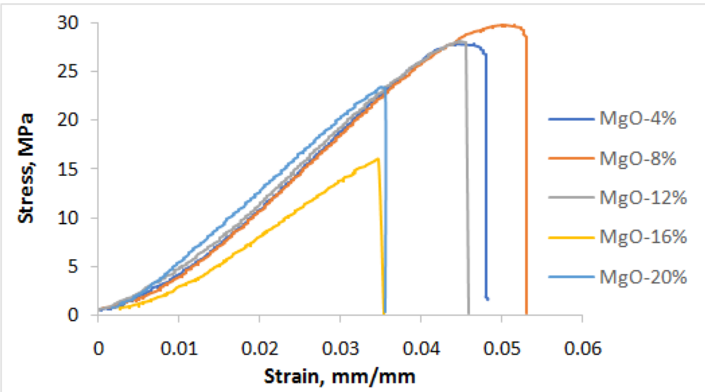

Figure 3: Stress–Strain Curves of ABS/MgO Polymer Composites.

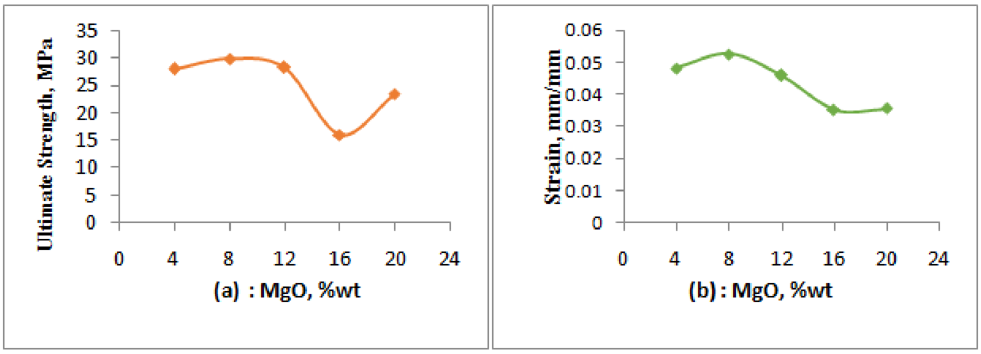

Figure 4: **Ultimate Strength (a) and Corresponding Strain (b) as a Function of MgO**.

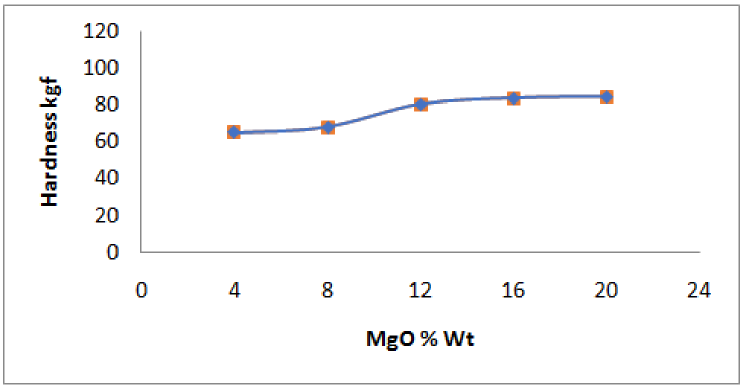

Figure 5: Hardness is a Function of %wt MgO.

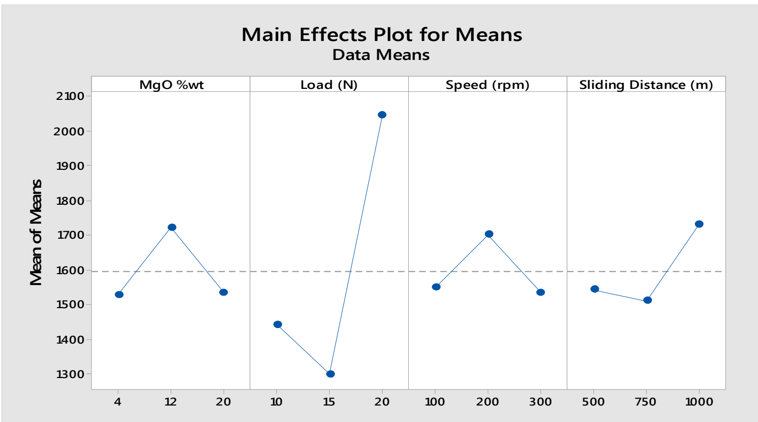

Figure 6: Wear Rate Variation with (a) Weight Fraction of MgO (b) Normal Load (N) (c) Speed (RPM) (d) Sliding distance (M).

From table 3, it was clear that the percentage contribution of the load is higher than other input parameters. The percentage contribution of the load is 81.7%. Other parameters show less impact. The percentage contribution of MgO(%) is 6.9%. The Sliding displacement is 7.89%, and the percentage contribution of the speed is about 4.46%, which is very less as compared to another process parameter. From figure 6, the optimum solution was found, and the values of an optimum solution are MgO with 12% load with 20 N, speed of 200 rpm and sliding distance of 1000 m.

Table 3: ANOVA Summary of the Wear Rate

Parameter	Symbol	SUM 1	SUM 2	SUM 3	SS	v	V	P
MgO (%)	A	4584	5169	4605	73539	2	36769	6.39%
Load(N)	B	4326	3897	6135	939675	2	469837	81.7%
Speed(Rpm)	C	4647	5106	4605	51281	2	25640	4.46%
Sliding Distance(M)	D	4629	4533	5196	85691	2	42845	7.45%
Error	E	1076647				1		0%
Total	**T**				**1150186**	**9**		**100**

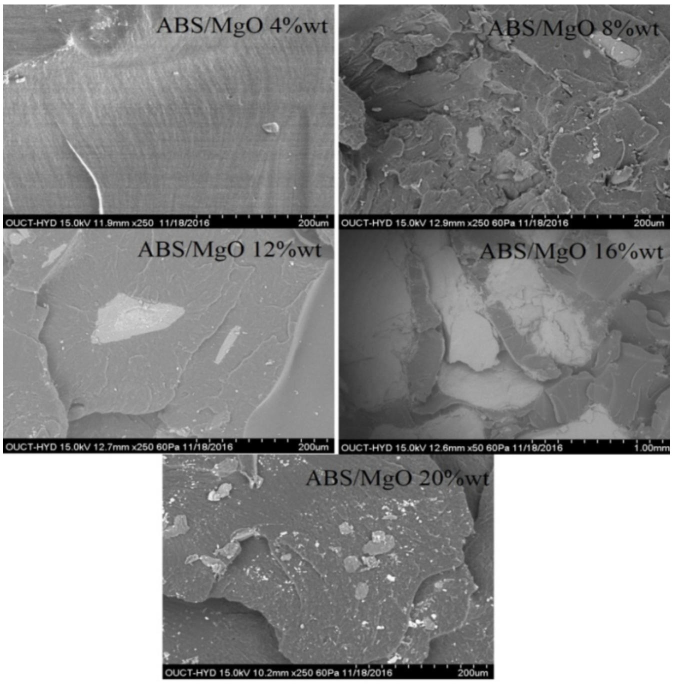

Figure 7: Fractography of ABS/MgO Polymer Composites.

The fractographic of ABS/MgO polymer composites are shown in figure 7. The micro damages are less for 4% MgO, but the micro damages are increasing with the increase of filler material. MgO nanoparticles are present at micro damages. For 8% MgO, there are multilayer cracks found during the deboning of the matrix, which results in higher tensile strength. The compact of MgO with ABS was also homogenous for 8% MgO composition. For 16% MgO, the MgO Slacks are present on the layers of ABS. These MgO particles are creating a bond with ABS composites.

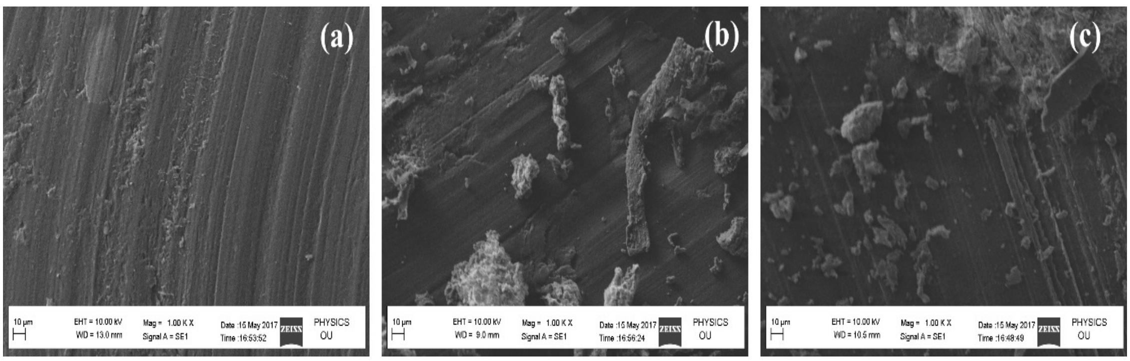

Figure 8: Worn Surfaces of Specimens for Trial Conditions of 1, 2 and 3.

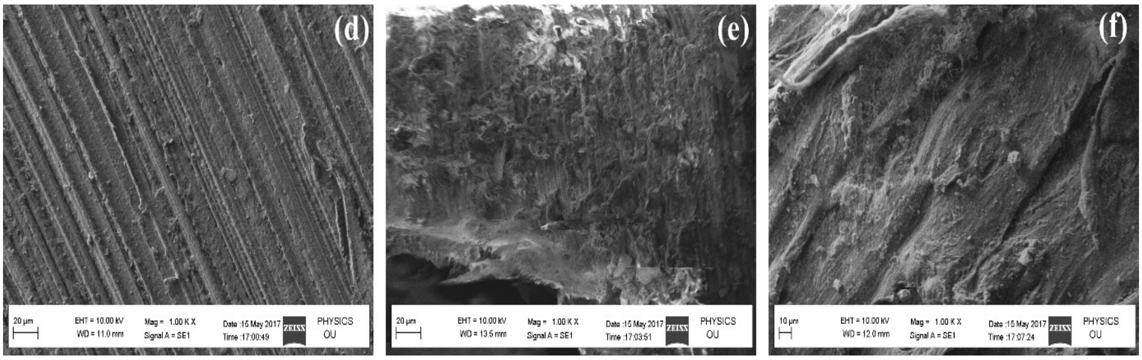

Figure 9: Worn Surfaces of Specimens for Trial Conditions of 4, 5 and 6.

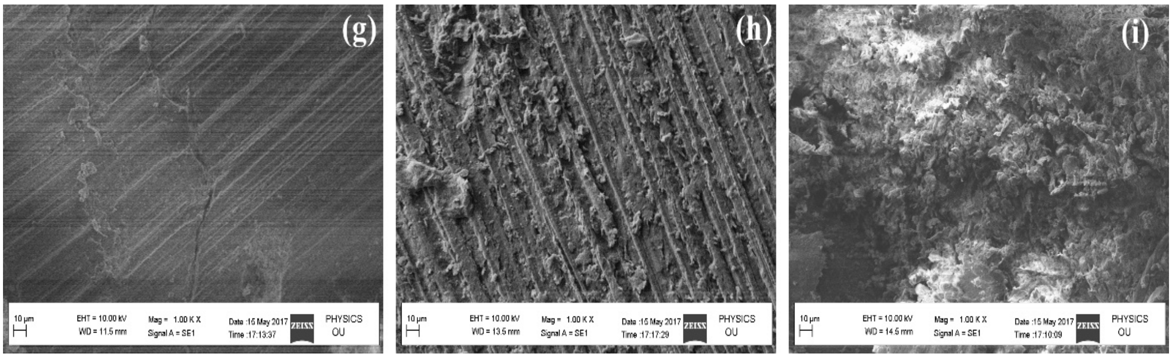

Figure 10: Worn Surfaces of Specimens for Trial Conditions of 7, 8 and 9.

Figures 8 to 10 show the SEM images of the ABS/MgO composite of 9 samples after the wear test. The micrograms on the surface are visible in the images. These micro cracks are distinct for various experiments. It observed that the grooves are perpendicular to the sliding surface. In figure 8(a), the micro-cracks are uniform and the surface is smooth, but as compared with other experiments, the micro cracks are less. In figure 8(b), the MgO percentage is the same as figure 8(a), but we have increased the other process parameters, which result in the wear rate. In figure 8(c), we have increased the load, as the load shows higher contribution than other parameters, the wear rate is high, which increases the micro cracks. In figures 9(d)-9(f) MgO percentage is 12% and other parameters are varying. For figure 9(d), the load is less than figures 9(e) and 9(f), the micro cracks are less for 8(d). As the load increased, the micro cracks are increasing, and the wear rate is also increasing. In figures 10(g)–10(i) MgO percentage is higher than other experiments. As the load increases, the wear rate is increasing, which increases micro cracks.

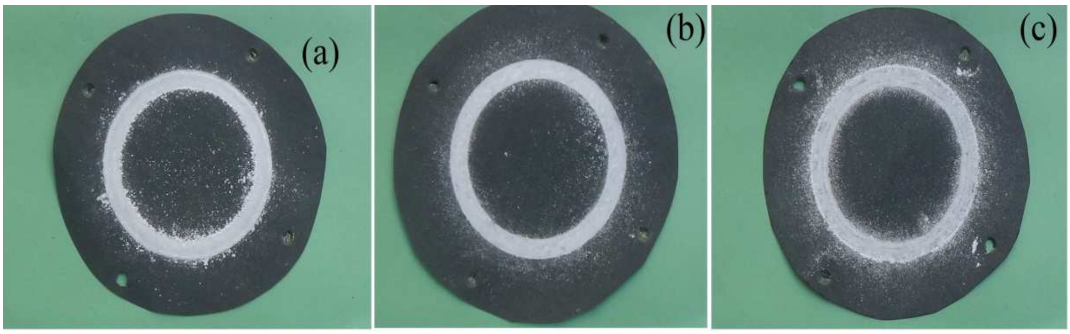

Figure 11: Debris of Specimens for Trial Conditions of 1, 2 and 3.

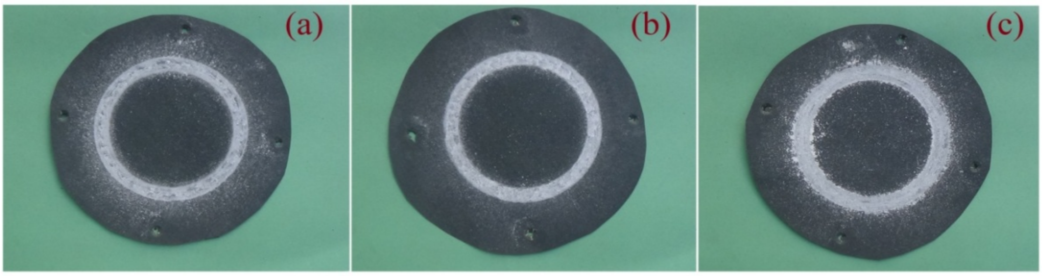

Figure 12: Debris of Specimens for Trial Conditions of 4, 5 and 6.

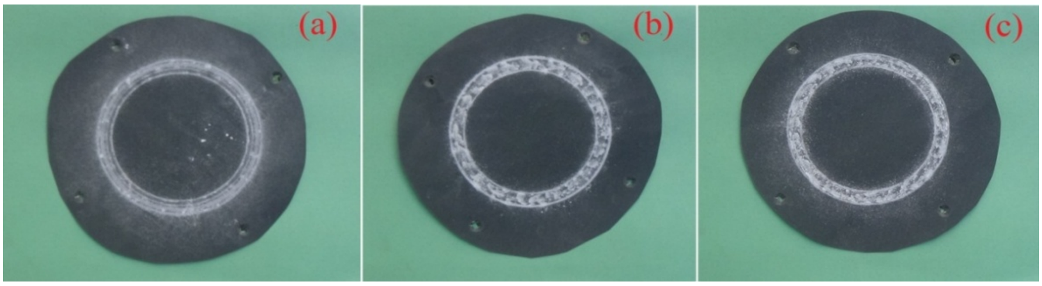

Figure 13: Debris of Specimens for Trial Conditions of 7, 8 and 9.

Figures 11 12 and 13 show the wear debris produced during the wear test. With the increase, the load of the wear debris is increasing. Wear debris are higher for figure 13. As the percentage of filler increases, the wear debris is increasing. The filler material and load show the impact on the wear debris.

CONCLUSIONS

ABS/Mgo composite specimens prepared through an injection molding, and the following conclusions were observed:

- Input process parameters such as sliding distance, sliding speed, normal load and filler content were considered, and the Taguchi method design was carried out, and composites prepared using an injection moulding machine.
- The load shows a higher percentage contribution (81.7%) than another input parameter.
- During the tensile test, ABS with 8% MgO shows higher tensile strength than other compositions. Ultimate tensile strength is low for composite without MgO. As a result, by addition, MgO the mechanical properties increases.
- The hardness of the composites increases with an increase in the percentage of MgO.
- The wear rate is higher when the input load is increasing.
- From the fractographic of ABS/MgO, it was observed that with the increase of the MgO , there are multilayer cracks due to the strong bonding of MgO with ABS,
- From the SEM image, it was found that with an increase in the load, micro cracks were high.

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