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ABS - $CaSO_4$ Polymer Composite: Experimental Studies On Mechanical And Tribological Properties

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Abstract

Objectives: The present study examines the effect of Calcium Sulphate ($CaSO_4$) microparticles as filler materials and ABS as matrix materials on mechanical properties and wear performance of composite materials, which are injected into molds for preparation of the specimens. **Methods:** The $CaSO_4$ microparticles are added at different weight fractions to the acrylonitrile butadiene styrene (ABS) polymer composites. Moreover, the reinforcement has improved tensile strength, wear properties, and hardness. Wear behavior was measured on ABS/ $CaSO_4$ by a wear monitor (ASTM G99) and pin-on-disc type friction. As part of this experiment, the cutting speed, loading, and sliding distance of composite materials are considered and optimized for their properties. To observe and analyze the characteristics of this material, tensile strength and wear tests were conducted. By analyzing SEM images, we were able to study the fractured material's morphology. In this study, an orthogonal array (L_9) and control parameters were used to examine wear debris that explored the flacks and grooves of the content. **Findings**: An increase in toughness and modulus of resilience (due to an increase in filler content) and the contribution of normal load to wear rate (37.44%) constitute the most important contribution to work. **Novelty :** we have evaluated the various tribological and mechanical properties of polymer composite specimens using the Taguchi method.

Keywords: ABS; Tensile strength; Pinondisc; SEM; Taguchi

1 Introduction

The goal of composite materials is to enhance mechanical properties. Due to the unique properties of strength and stiffness, they are rapidly replacing many traditional engineering materials. Materials derived from composites are also resistant to oxidation, corrosion, and wear, as well as a wide range of operating temperatures. New composite materials are primarily designed to increase mechanical qualities. ABS is a three-monomer polymer made up of acrylonitrile, butadiene, and styrene.

Acrylonitrile is a propylene and ammonia-based polymer. ABS's corrosion resistance and thermal stability are improved by this substance. Butadiene is a by-product of the steam cracker's ethylene production process. As a result of this component, the ABS polymer develops hardness and impact strength

A polymer nanocomposite consists of polymer materials with nanoparticles dispersed in a polymer matrix that can take on divergent shapes are studied. This polymer can be tested mechanically in different ways, such as impact strength, tensile strength, wear behavior and tribological behavior using various nanostructures[(1)]. The Addition of metallic fillers improves the mechanical properties of thermoplastic polymers. Wear resistance can be improved by using fillers such as TiO2[(2)], CuO[(3)], CuS[(4)] in various polymers. Thermoplastic PEEK / PTFE composites combined with alumina nanowires have been studied in mechanical and tribological tests. It has been observed that the permittivity increases by 20% at higher frequencies and temperatures[(5)]. Hybrid Alumina Metal Matrix is combined with different weight percent SiC and carbon nanotubes. Composites are manufactured and have different tests such as hardness and X-ray diffraction. Carbon nanotubes in sintered metal matrix composites have been found to have a significant impact on wear properties[(6)]. Styrene is formed when ethylbenzene has been dehydrogenated. It improves ABS material rigidity and processability[(7)]. Several notable improvements in this study include the fact that ultimate strength decreases with increasing SiO_2 concentration in composites and sliding speed explains 45.51% of the wear rate variation. Further research into the mechanical and wear characteristics of ABS/SiO2 nanoparticles polymer composites was conducted[(8)]. Supersaturated solutions cannot reliably form solubility equilibria due to the extremely slow crystallization kinetics of anhydrite in aqueous solutions at temperatures below70^0C[(9)]. The solubility of gypsum diminishes initially at lower temperatures in dilute sulphuric acid concentrations. At 298.15 K, the effect ceases[(10)]. In differential thermal analysis curves of the component sulfates KLa(SO4)2 and $CaSO_4$, this peak is not seen. The endotherm with the largest magnitude at 900°C corresponds to a eutectic with 70 mol% $CaSO_4$[(11)] . Perovskites are promising catalysts for oxidizing NO to NO2 under conditions comparable to those in seen in nitric acid factories, according to this research. Because of their low cost, ease of production, and high catalytic activity, perovskites are a promising alternative to noble metal catalysts[(12)]. $CaSO_4$:Terium(Tb),ytterbium(Yb) had the maximum intensity, with both Tb and Yb concentrations of 0.1 mol percent. The TL response was proportionate to the absorbed dosage in all samples.

The commercial colorless glass was found to be suitable for combining with phosphors to produce dosimeters in the shape of pellets. As you can see, $CaSO_4$: Tb, Yb could be used as a thermoluminescence dosimeter because of its features and low cost[(13)]. As a result, increasing the volume percentage of tin nanoparticles in the AA3003/Tin composites made them harder and more resistant to wear. The effects of Si_3N_4 nanoparticles on the wear parameters of aluminum alloy composites were investigated by[(14)]. The mechanical properties of ABS combined with micro-sized ZnO are evaluated. It is found that the filler content increases flexural strength and tensile strength[(15)]. A nylon6 filling of different types of nano-sized Caco3 is molded by injection molding, and tensile and wear tests are performed. In conclusion, the normal load is more important than sliding speed or filler content[(16)] .

The abrasive behavior of the micro-sized calcium sulfate ($CaSO_4$) filled ABS compounds have been studied by varying the cutting speed, filler content, and sliding distance at three levels of each parameter. Numbers of experiments are conducted in line with Taguchi's experiments. Using SEM microstructure analysis, initial and optimal parameters of the track structure were determined after multi-choice tests were performed

2 Methodology

ABS polymer is the primary ingredient in the compound (acrylonitrile-butadiene-styrene). To increase the binding capabilities of an ABS matrix composite, $CaSO_4$ microparticles are utilized as filler material. Because of its high surface polish and impact strength, ABS material composite is frequently used in industrial applications. A variety of $CaSO_4$ amounts have been added to ABS, such as 4%, 8%, 12%, 16%, and 20% by weight, to improve the polymer's tensile strength and wear. Other factors (Table 1) like load and speed are taken into account during manufacture and testing. To archive better mechanical qualities, it is critical to first analyze the key contributing parameter. Table 2 shows the experimental design used by Taguchi (L_9) and how it was carried out. A composite Rockwell hardness test was performed to measure the ABS/ CaSO4 hardness.

Table 1. Different levels of design factors.

Factor	CaSO4, (%wt).	Normal Load, (N)	Sliding Speed, (rpm)	Sliding distance, (m)
Symbol	A	B	C	D
Level–1	4	10	100	500
Level–2	12	15	200	750
Level–3	20	20	300	1000

Table 2. Orthogonal array (L9) and control parameters

Treat	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

2.1 The Composites Fabrication

At the initial stage, a ME100LA blender set to 190°C with mixing blades at 200 rpm was used to obtain ABS/CaSO4 composite in various quantities for 20 minutes. The primary goal of heating is to make the material homogeneous & uniform throughout the mixture. In the second stage, molten material is pumped into the injection and molded under high pressure. High pressure is mostly used to relieve internal tension. After the material hardened, it was progressively chilled before being released from the molding. Tensometer PC2000 type (Figure 1) is used for the tensile test**.** The dimensions of the tensile test pieces are shown in Figure 2. The mechanical and wear parameters of the materials were then determined by testing them under various normal load and speed conditions. The hardness of polymer composites was assessed using Rockwell indenters. The morphology of the fracture was studied using a scanning electronic microscope (S-3000N Toshiba SEM). A wear screen (ASTM G99) with a disc spindle and 400-size sanded paper was used to determine the wear rate.

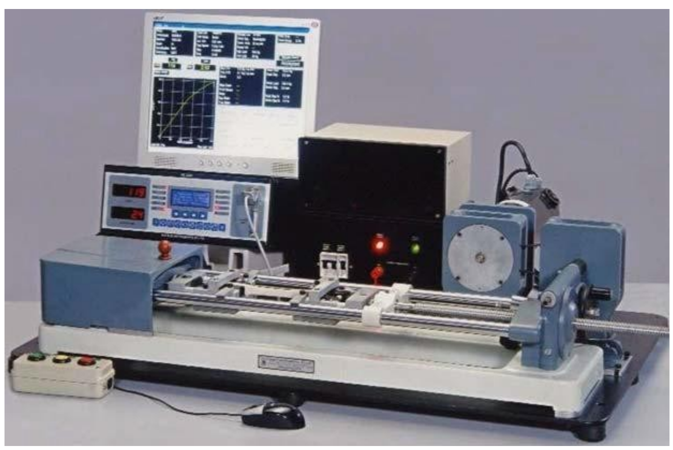

Fig 1. Tensometer

2.2 Impact of filling content on tensile properties

$CaSO_4$ has a considerable influence on the material's tensile strength, according to the composites' characterization. The ultimate strength peaks at 4%, and the tensile strength decreases as the filler percentage increases (Figure 3), as do the strain values. In the curve that shows necking, it shows a proportional limit followed by a maximum. The tensile strength decreases as the filler content increases, implying that less filler has better tensile characteristics

2.3 The Hardness of the filler varies with the filler content

For a 16 percent $CaSO_4$ filler percentage, the maximum hardness value is 69.3 HRM.

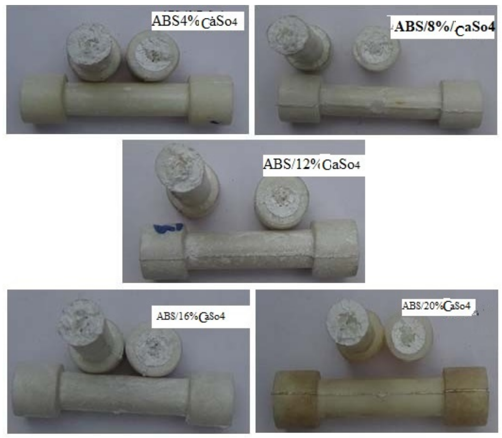

Fig 2. Tensile specimens ABS-CaSO 4

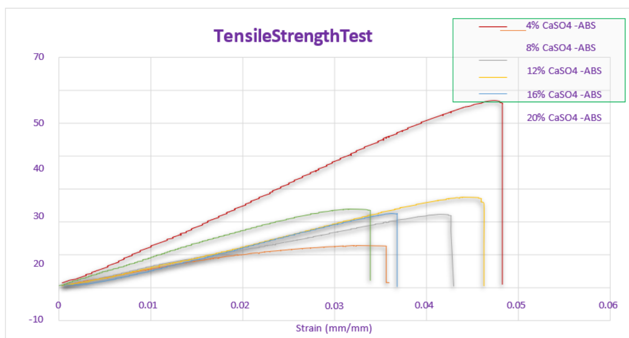

Fig 3. Stress-strain curves of CaSO4/ABS polymer composites.CaSOfiller content from 4% to 12% wt.however, when filler percentages increased from 16% to 20%, the material's hardness decreased.

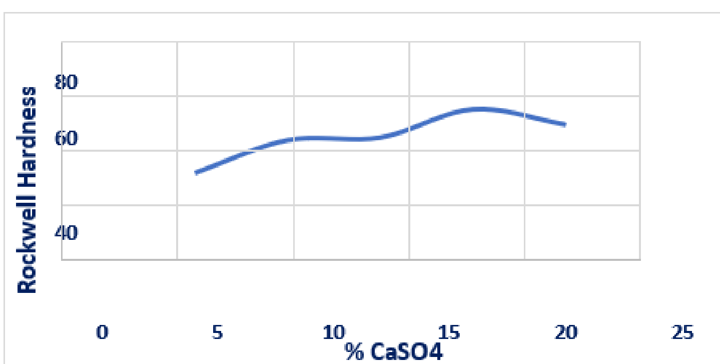

Fig 4. Hardness is a function of CaSO4

2.4 Impact of filling content on sliding wear

Taguchi's orthogonal L_9 series was used to measure the rate of wear on all samples. Figure 5 shows that as the filler content increases, so does the wear rate. $CaSO_4$ contributes much more than other input process elements in terms of weight percent. Load makes for 37.44 percent of the composite's total contribution (Table 3).

Table 3. Summary of ANOVA wear levels.

Source	DOF	Sum1	Sum2	Sum3	Adj SS	Adj MS	F- Value	P- Value	Percentage contribution
$CaSO_4$(% Wt.)	2	1421	1899	1662	343694	171847	1.04	0.408	25.82%
Load (N)	2	1879	1770	1334	498348	249174	1.8	0.245	37.44%
Speed (Rpm)	2	1690	1781	1511	112923	56461	0.28	0.766	8.48%
Sliding distance, (m)	2	1788	1822	1372	376135	188067	1.18	0.369	28.26%
Error	0				0				100.00%

(DOF; Degree of freedom, SS: the sum of squares, MSS: means of squares)

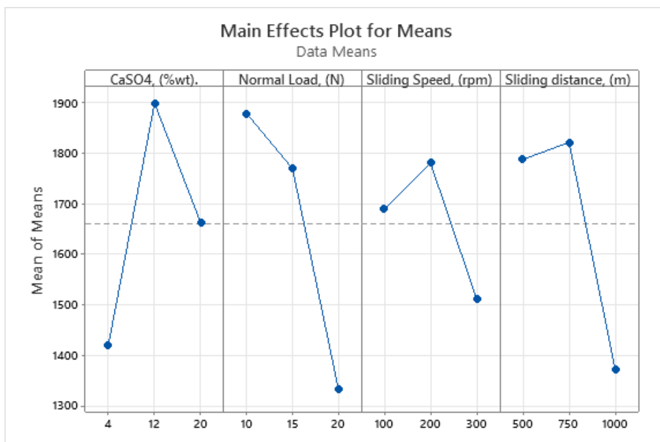

Fig 5. Changes in wear rate

As the load rises from 10N to 20N, the wear rate decreases and the load contributes 37.44 percent to the overall wear rate. Similarly, when the $CaSO_4$ percent Wt. increased, the wear rate climbed until it reached 12 percent, and then it decreased. $CaSO_4$ is the influential factor, accounting for 28.26% of the total contribution. Counters and surface plots of significant influencing factors for load and filler material are developed (Figure 6).

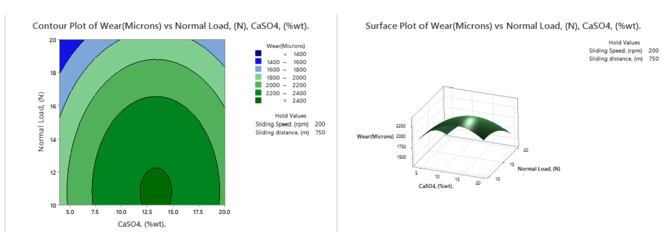

Fig 6. Counter and surface plot of wear vs Load (N)& CaSO4

2.5 Morphology of the surface of composes

Each Taguchi L9 array experiment was studied in detail using SEM, in which various parameters were varied such as load, composition, and speed. All of the photos were captured with data magnification of 20 micrometers. The sample filler content remained constant From test1,2 and 3, the load increased steadily and the severity of micro-cracks decreased. At trail 1 start-up

Table 4. Maximizing and minimizing wear with optimal process parameters.

	$CaSO_4$ (%wt)	Load (N)	Speed (rpm)	Sliding distance,(m)
Maximum wear (microns)	12	10	200	750
Minimum wear (microns)	4	20	300	1000

settings, the worn surface displays tiny Grooves. For tests1,2 and 3 with 4 % $CaSO_4$ microparticles (Figure 7). Less distortion is noticed because the load increases. At trails 5,6 and 7, the microcracks with 12 % $CaSO_4$ microparticles were identical, however, the worn surface is homogeneous and very intense. Due to an increase in the $CaSO_4$ filler material concentration, clustering was detected in the specimens of trials 7, 8, and 9 with 20% $CaSO_4$ microparticles.

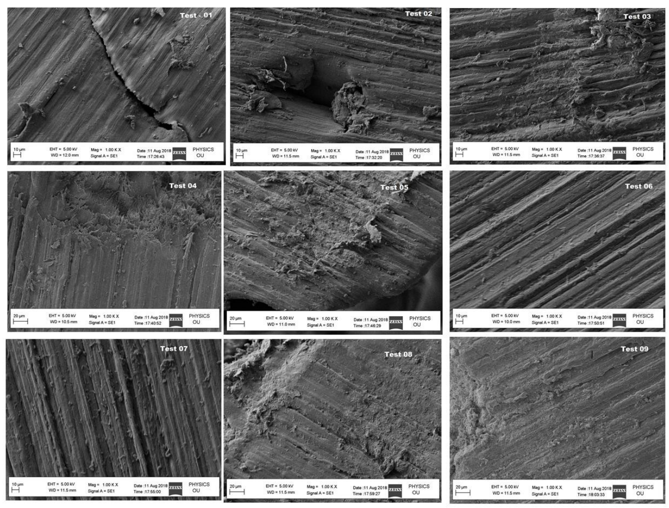

Fig 7. SEM images of specimens for trial conditions of 1 to 9.

3 Conclusion

The mechanical property and tensile strength increase for ABS/v composites with 4% $CaSO_4$ and decrease with 20% $CaSO_4$ when the filler content is increased further. The maximum Rockwell hardness can be identified at 16% $CaSO_4$. In an experiment using Taguchi's trails plan, the wear behavior of ABS loaded with $CaSO_4$ composite was evaluated for three different levels of speed, normal load, sliding distance, and three different levels of each parameter. To determine ABS/$CaSO_4$ polymer composite's wear behavior, we used pin-on-disc friction and wear monitoring (ASTM G99). In terms of wearing rate, the normal load affects 37.44% of variations. During extension of the load and sliding distance, the specimen exhibited extensive deformation and cracking of the surface. It may be beneficial to analyze dynamic mechanical analysis and temperature effects of this ABS/$CaSO_4$ material in the future to develop the best composite material

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