Enhancement of Mechanical and Wear Behavior of ABS/Teflon Composites

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Abstract

In the present investigations, Most of the engineering applications of metallic materials are replaced by polymeric based composite materials. Because of the low cost and accessible handling of polymer composite materials such as Acrylonitrile butadiene styrene (ABS) matrix materials are used to make the composites with additions of filler enhance the properties of the matrix materials. In the present study, ABS matrix material is used to make the composite materials by adding the Teflon materials. Investigations are carried out to find the enhancement of the composites' mechanical properties. Optimizing the process parameters is done to identify the composite's most optimum used to get composite with better mechanical properties. SEM analysis and wear Debris are investigated to study the microscopic surface nature and behavior of the composites.

Keywords: ABS, Teflon, Tensile strength, Pin-on-disc, SEM, Taguchi

Introduction

Mechanical industries are always under pressure to develop creative material well at mechanical strength and tribological performance. Polymer and its composites are increasingly being used in many industrial applications, such as rollers, cams, seals, wheels, gears, and clutches. The addition of nanoparticles such as nano-silica into polypropylene composite (PP) using grafting polymerization creates both toughening and reinforcing effects. This influences the tensile strength of composites with a function of load [1]. By adding the 2nd phase, nanoparticles are used to improve tribological properties (such as wear and coefficient of friction) of the thermoplastic polyamides (PA). A common reason for adding fillers to polymers is to increase the modulus or stiffness via reinforcement mechanisms described by theories of composites. Fillers may also be used to lower material costs by reducing the volume of matrix resin required. Fillers are used to enhance or modify properties such as thermal conductivity, friction, electrical resistivity, wear resistance, and flame resistance. This results in obtaining the smooth surface of nanocomposites, showing well-functioning tribological properties [2,3]. During curing, tensile strength also increases, which is due to better interfacial adhesion. For high-performance applications, glass fiber is a significant reinforcement for epoxy resin. There is a dynamic increase in mechanical properties [4,5]. Anionic ring-opening polymerization of e-caprolactam by rotational molding technique untreated and surface-treated TiO_2 prepared. Untreated and surface-modified TiO_2 decrease the average molecular weight, degree of conversion, melting temperature, and water observation [6]. The extrusion and injection molding process carried out, and carbon power filed ABS composite is processed. There is a minimum coefficient of friction, and during dry sliding, condition exhibits inferior wear properties [7]. Hardness of the composites increases with an increase in the percentage of MgO; as the load increases, the micro-cracks and wear rate also increase [8]. For, 1% of filler content are both changes in flexural strength and flexural modulus. When camphor soot filler content concentration was increased, Hardness increase, and melt flow index, i.e., the flow ability decreases [9]. ABS/BN polymer composite shows the symptoms of radially propagating crack growth directional lines during brittle cracking [10]. The wear rate of the composite increase with an increase in load [11]. Hybrid effect of micro fillers such as PA66/PTFE blends. Noticed to be an increase in hardness and density of PA66/PTFE blend. SEM images reveal the synergistic effect of compatibility with the thermoplastic matrix [12]. SEM pictures show the synergic effect of the hybrid fillers and compatibility with the thermoplastic matrix composites [13,14]. silica nanoparticles (SNPs) in glass-fiber-reinforced epoxy nanocomposite (GFRENC) or carbon fiber-

reinforced epoxy nanocomposite (CFRENC) improve mechanical properties such as fracture toughness, tensile strength fatigue and impact properties [15]. Introducing the graphite increases the storage modulus of the composite. As the graphite [16] is a brittle material, flexural strength is sensitive to defects [17]. Increase of Hbn content, the friction force increases, the coefficient of friction increases. The percentage of filler material in the composite can help to improve the tribological behavior[18]. The friction coefficient is inversely proportional to load as the contact area increases, the coefficient of friction increases [19].

Materials and methods

ABS matrix material composites most widely in industrial and scientific applications due to Stability, impact resistance, good surface finish, and the toughness of ABS material. ABS material has good flow ability, easy to prepare using injection modeling. ABS polymer composite is taken as the matrix material, and the Teflon nanofiller composite is added to the composites to increase the composite's binding properties. The filler material is added to the matrix material in various propositions, and during preparation, other parameters such as sliding speed, distance, and load are considered (**Table 1**). To optimize the all-input parameters, the Taguchi L9 design of experiments is adopted. This model is used to conduct the experiments; with that result, optimum solutions can be predicted. Investigations are conducted as per the Taguchi orthogonal array model are shown in **Table 2** below.

**Table 1** Different levels of design factors.

Factor	Teflon, (% 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	1,000

Table 2 Orthogonal array (L9) and control parameters.

Treat No.	A Teflon, (% wt)	B Normal Load, (n)	C Sliding Speed, (rpm)	D Sliding distance, (m)
Experiment model 01	4	10	100	500
Experiment model 02	4	15	200	750
Experiment model 03	4	20	300	1,000
Experiment model 04	12	10	200	1,000
Experiment model 05	12	15	300	500
Experiment model 06	12	20	100	750
Experiment model 07	20	10	300	750
Experiment model 08	20	15	100	1,000
Experiment model 09	20	20	200	500

Fabrication of the composites

ABS/Teflon nanocomposites are mixed in the ME100LA mixer at 190° Temperature for 20 min maintaining a speed 200 rpm of mixing blades. The mixture is heated to make the material smooth. The mixture is injected into an injection molding machine at high pressure (70 Mpa). By maintaining high pressure, the internal pressures are removed. The material is then cooled. When mold is cooled to remove temperature. Material get solidifies. After some time, the material is ejected from the mold. The specimen is then inspected to determine the mechanical properties of the material. For every test, average of 4 readings is taken for each specimen. The hardness of the polymer composite was investigated using Rockwell Hardness. Later, the specimens' surface was examined using the scanning electron microscope.
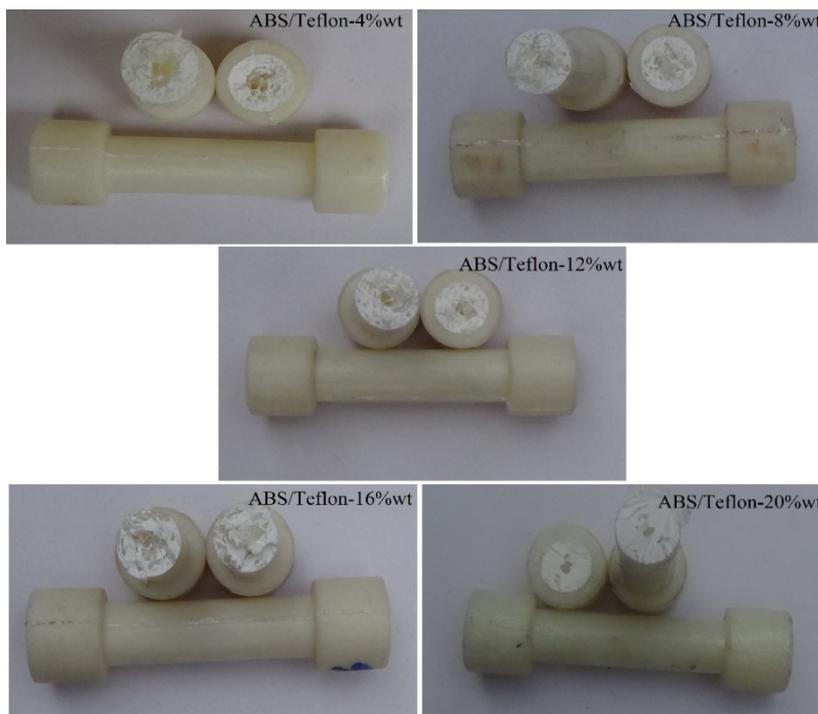
Figure 1 Tensile tested specimens of ABS/Teflon polymer composites.

Wear test is conducted using a wear monitor (ASTM G99) with pin-on-disc type friction on a hardened ground steel (En32) disc emery paper (grade size of 400) was fixed. To determine the hardness of the ABS/Teflon composite Rockwell hardness test is conducted. The composition of fabricated composites is given in **Figure 1**.

Mechanical characteristics of composites

For each experiment model, an average of 4 Rockwell hardness readings is recorded. The composite of different compositions poses different mechanical characteristics. To determine the influence of process parameters wear, tensile, hardness and microscopic study conducted.

Results and discussions

Effect of filler content on tensile properties

The composites' characterization reveals Teflon filler content has a very much significant effect on the mechanical properties of composites. The influences of filler content on the composite's tensile strength are shown in **Figures 2** and **3**, respectively-tensile strength of the specimen with 4 Wt.% filler material shows greater tensile strength than others. Ultimate tensile strength is decreased with an increase in the filler content of the Teflon. The strain was decreasing with growth in the filler contain. Further, with an increase in filler content, there is a decrease in ultimate tensile strength. Composite material with filler content decrease both tensile strength and strain.
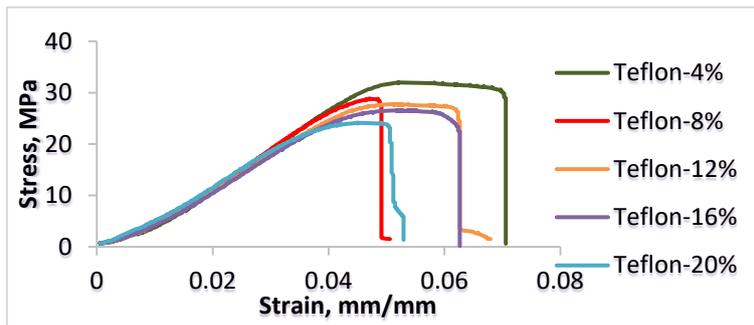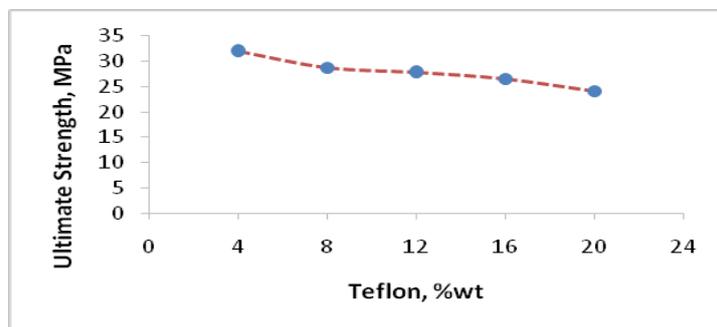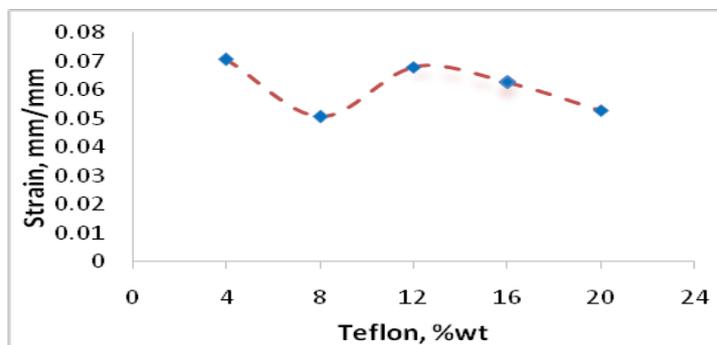
**Figure 2** Stress-strain curves of ABS/Teflon polymer composites.

(a)

(b)

Figure 3 Ultimate strength (a) and corresponding strain (b) as a function of Teflon.

Effect of filler content on the hardness

In this investigation, there was a slight increase in hardness of Teflon based filler content composite material. **Figure 4** would show the influence of filler content on the micro hardness of Teflon filled ABS composite. From the figure, it was shown that the micro hardness value increases from 4 to 8 Wt.% of filler composite, and then there is a decrease in the Micro hardness value. Maximum hardness value is 65 HRM for 8 Wt.% filler composites. By adding of filer material there is an increase in hardness value up to specific filler content, then there is a decrease in hardness overall by adding very less filler content there will process high hardness to material with low tensile strength.
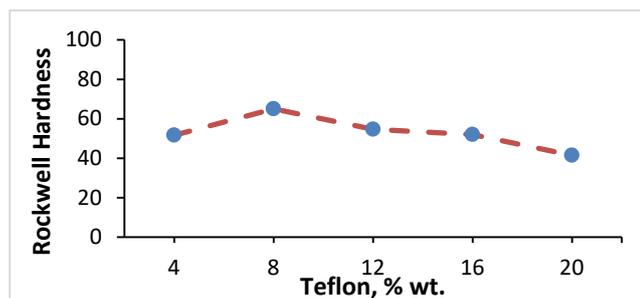
Figure 4 Hardness is a function of% Teflon.

Effect of filler content on sliding wear

From **Table 3**, the wear rates of all specimens are investigated. By increase, the sliding distance from 500 to 1,000 m, wear loss of the composite increase. ABS/Teflon polymer composite with 20% wt. of Teflon exhibits a higher wear rate. As the load increase from 10to 15n with constant Teflon percentage that is 20% wt., there is an increase in the wear rate. For Teflon 20% wt. with increase of load from 15to 20n, there is a decrease in the wear. From **Figure 7**, wear rate increase from 100 to 200 rpm with tremendous difference, and later there is a slight increase from 200 to 300 rpm. For optimization, this parameter and percentage contribution of the process parameters Taguchi method is used. From **Table 4**, Sliding distance and speed show higher contribution-Teflon shows significantly less contribution to wear rate. From the **Figure 5**, optimum process parameters for low wear are Teflon (%) of 12%, load (n) of 15 Speed (rpm) of 100 rpm, sliding distance (m) of 500 m wear/μm.

Table 3 Design factors with different levels.

Trial	Teflon (%)	Load (n)	Speed(rpm),	Slidingdistance (m)	Wear/μm
1	4	10	100	500	950
2	4	15	200	750	2,035
3	4	20	300	1,000	2,024
4	12	10	200	1,000	2,033
5	12	15	300	500	1,453
6	12	20	100	750	1,307
7	20	10	300	750	1,986
8	20	15	100	1,000	2,037
9	20	20	200	500	1,349

Table 4 ANOVA Summary of the wear rate.

Parameter	Symbol	DOF	SS	MSS	P%
% Teflon	A	2	57074	28537	4.01
Load	B	2	122965	61482.33	8.64
Sliding Speed	C	2	292201	146100.3	20.54
Sliding Distance	D	2	950611	475305.3	66.81
Error	e	0	0.002	..	0
Total	T	8	1422850		100

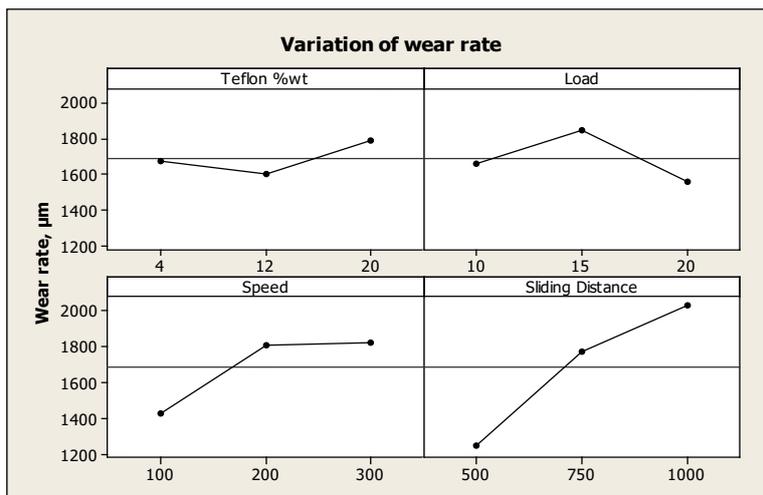(DOF; Degree of freedom, SS: sum of squares, MSS: means of squares and P%: Percentage contribution)

Figure 7 Variation of wear rate.

Surface morphology of the composites

The SEM pictures confirm many variations in composite in micro scale as an increase in the filler content, the material becoming smoother **Figure 8**. As a result, inter bond strength decreases, resulting in a decrease in the composite's tensile strength.

Material with less filler content has better tensile strength than others. Also, there are large micro-cracks gradually, so there is a decrease in strain rate because of the material becoming brittle (plastic stress is decreasing). The friction coefficient of the composite increase because of large micro-cracks results in the wear rate as surface area increases.
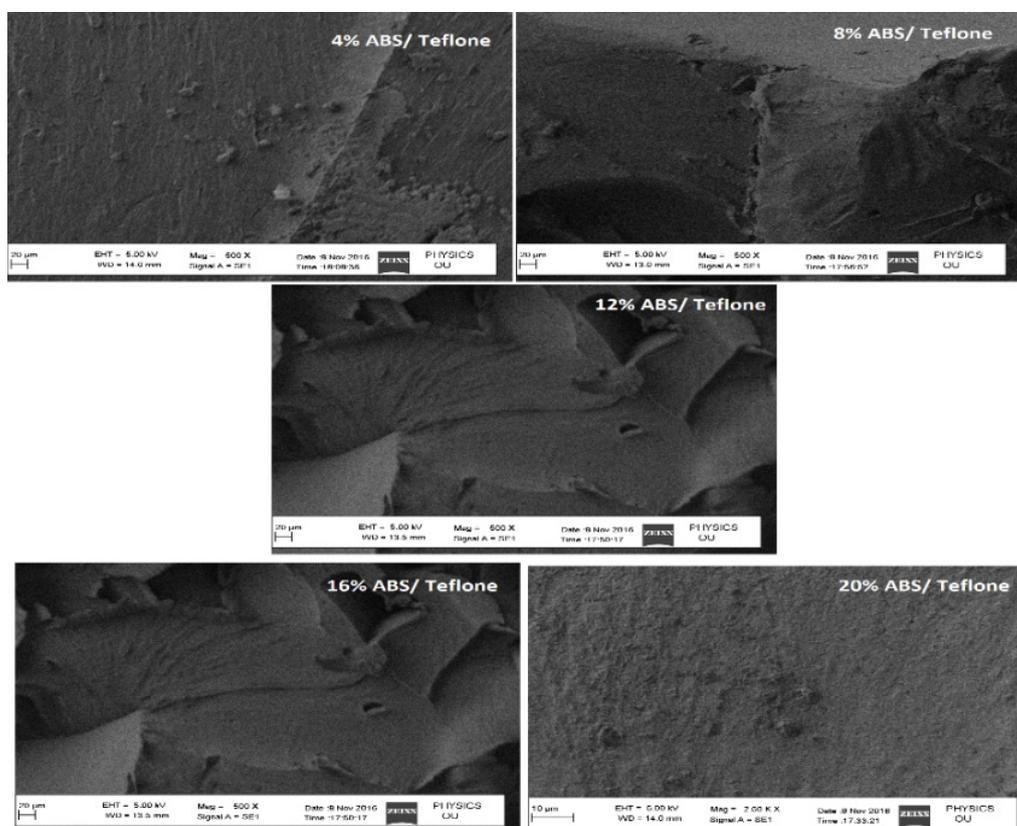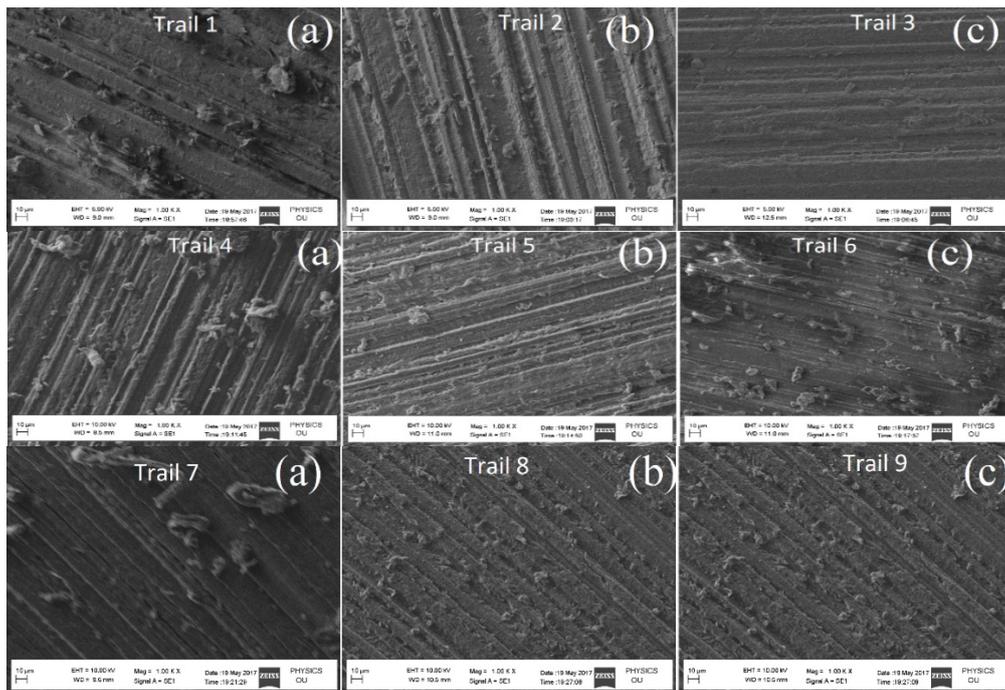

Figure 8 Fractography of ABS/Teflon polymer composites.

Figure 9 Worn surfaces of specimens for trial conditions of 1 to 9.

The maximum wear rate observed at trail 2, 4, 8, and the minimum wear rate is observed at trail 1. From the SEM picture, the intensity of micro cracks is high for trails with the maximum wear rate, and edges of cracks are sharp for the maximum wear rate composite. Trail 1 composite, the material crack intensity is less.
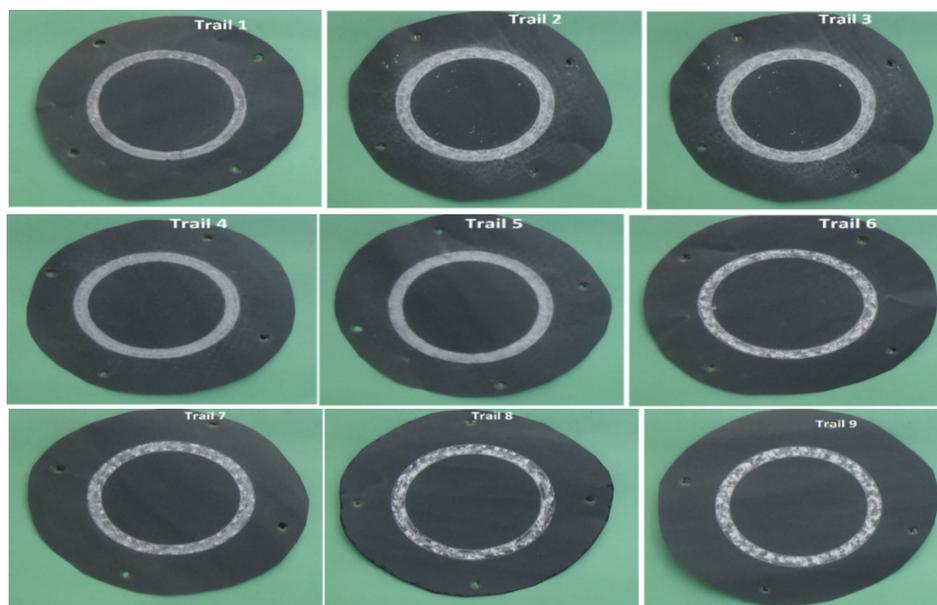
Figure 10 Debris of specimens for trial conditions of 1 to 9.

Wear debris produced during the wear test examined and found as a percentage of composition increases (Trail 1, 3, 7); there is an increase in the size of flakes. Similarly, when the load increased (Trail 7, 8, 9), there is an increase in flakes.

Conclusions

The present investigations of the mechanical behavior of ABS filled with Teflon nanoparticle composites lead to the following.

- ABS composite with Teflon nanoparticle composites is fabricated using the injection molding Technique. I have noticed that the mechanical properties of the composite, such as hardness, tensile strength, wear rate, are also influenced by the filler content.
- That micro hardness value increases from 4 to 8 Wt% of filler composite, and then there is a decrease in the micro hardness value.
- Optimum process parameters for low wear are Teflon (%) of 12 %, load (n) of 15 Speed (rpm) of 100 rpm, sliding distance (m) of 500 m wear/μm.
- The increase in the filler content, the material becoming smoother; thus, inter bond strength decreases, resulting in a reduction of the composite's tensile strength.
- The intensity of micro cracks is high for trails with maximum wear rate.
- Increase in the percentage of filler material and load; there is an increase in flakes' size.

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