

Effect of S-Glassfibre and Nanoclay Addition on the Tribology of Epoxy Composites: A Comparative Study

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ABSTRACT

The effect of S-glassfibre and nanoclay loading on the tribology of epoxy composites were carried out thus. 0, 10, 20, 30, 40, 50, 60, 70, 80 and 90 wt % of S-glassfibre were used to fabricate different E-glassfiber/epoxy composites while 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 wt % of nanoclay concentrations were used to fabricate nanoclay/epoxy composites using hand layout method. The wear properties of the composites were characterized using abrasion wear resistance testing machine manufactured by Taber Industries by ASTM D 958. Scanning electron microscopy (SEM) was used to study the distributions of S-glassfibre and nanoclay inside the composites. It was found out that nanoclay/epoxy composites have a better improvement on the wear resistant property of the composite when compared to the E-glassfiber/epoxy composites and control sample A. The results of tribology epoxy composites studied in this research proved that composites E with nanoclay to epoxy composition of 4:96 wt % were revealed as the overall best wear resistant materials with wear value of 2.94 wt % and improvement of 80 % recorded when compared to the control sample A. The control sample A (neat epoxy) is the least wear resistant material with wear value of 20 wt %. S-glassfibre enhanced the hardness property of epoxy composites with best resistance value found to be composite F 60:40 wt % epoxy to S-glassfibre with wear value of 4.41 wt % and improvement of 65 % when compared to the control sample A. Furthermore, SEM images show that the addition of both s-glassfibre and nanoclay independently into the epoxy matrix, gave better wear resistant values of the composites.

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INTRODUCTION

Abrasion wear resistant property of a material is the ability of the material to resist damage or gradual removal due to contact with another surface [1]. Wearing occurs when a hard rough surface slides across a softer surface, usually an adhesive material, causing the undesired removal of material from the weaker material's surface [2]. Wear behaviour of

composites can be studied using a pin-on-disc apparatus under dry sliding condition [3]. Weight loss of composites is measured using precision electronic balance with accuracy of 0.1 mg [4]. The specific wear rate (W_s) of the material is given by the equation 1.0 [5].

$$W_s = \frac{\Delta m}{P_c \cdot t \cdot V_s \cdot F_N} \dots\dots\dots 1.0$$

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Where,

Δ_m = Difference in mass of the samples before and after the test,

ρ_c = Density of composite (gm/mm³),

t = Duration of test (sec),

V_s = sliding velocity (m/s) and

F_N = Applied normal load (N)

It is worthy to note that when performing the weight loss experiment, loose particulate may adhere to specimens during testing [6]. It is crucial to clean off the test specimens to the best of one's ability prior to weighing [7]. This research publication X-rayed the tribology / wear properties of the epoxy/S-glassfibre composite and epoxy/nanoclay composites comprehensively and comparatively.

EXPERIMENTAL (MATERIALS, EQUIPMENTS AND METHODS):

Materials:

The test specimens for the tribology in this research work, were fabricated with the following materials and chemicals with specifications as follows: Montmorillonite nanoclay (≥ 20 nm, 10- 400 GPa, 1.72 gm/cm³, 682608-500G), S-glassfibre in fabric form (300 GSM Specific gravity 2.6 gm/cc), and epoxy resin (Araldite LY 506 Specific gravity 1.15-1.20 gm/cc). Others are epoxy resin hardner (Aradur HY 951 Specific gravity 0.97-0.99 gm/cc) and mould releasing agent (Poly vinyl alcohol PVA) all sourced from Zayo-Sigma Germany.

Equipment:

Table 1: list of equipment used for the research experiment

S/N	Instrument	Model / standard	Capacity
2.	Wear/Abrasion Tester	11884	230-1-50
4.	Open Glass Moulds	-	-
5.	Diamond cutter	-	-
6.	Motorized Stirrer	-	1000 rev/min

Methods:

The two different groups of composites glassfibre/epoxy composites and nanoclay/epoxy nanocomposites were prepared using the following methods:

Mould Design and Fabrication:

The moulds used for fabricating all the composites were prepared from silicate glass and have the same dimensions of 200 x 200 x 3 mm dimension. They were all fabricated in the locally.
Composites Formulation:

Table 2: The Compositions of Epoxy/S-glassfibre Composites Formulated

SN	Composite Name	Composite Code	Epoxy (wt %)	Glass Fibre (wt %)
1	EP100GF0	A	100	0.00
2	EP90GF10	B	90	10.0
3	EP80GF20	C	80	20.0
4	EP70GF30	D	70	30.0
5	EP60GF40	E	60	40.0
6	EP50GF50	F	50	50.0

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Table 3: The Compositions of Epoxy/nanoclay Composites Formulated

S/N	Composite Name	Composite Code	Epoxy (wt %)	Nanoclay (wt %)
1	EP100NC0	A	100	0.00
2	EP99NC01	B	99	1.00
3	EP98NC02	C	98	2.00
4	EP97NC03	D	97	3.00
5	EP96NC04	E	76	4.00
6	EP95NC05	F	75	5.00

As show in Table 2.0 nanoclay/epoxy composites of 99, 98, 97, 96 and 95-wt % epoxy with 1, 2, 3, 4 and 5-wt % nanoclay respectively were prepared by casting method, the ratios were mixed using high-speed motorised stirrer. Mould release agent PVA was applied on mould plates in order to have smooth removal of moulded composites after curing. Table 3.0 X-rayed the formulation compositions of epoxy/E-glassfibre composites as consisting mixtures of 90, 80, 70, 60 and 50-wt % epoxy with 10, 20, 30, 40, and 50-wt % E-glass fibre respectively made by hand layup method. The moulds were left undisturbed for 24 hours and the samples were removed and cut into rectangular shapes with diamond cutter according to ASTM standards.

Tribology Testing:

The scratch wear resistance test were carried out on all the composites samples using abrasion wear resistance testing machine with serial number 01554, supply number 230-01-50, manufactured by Taber Industries, ASTM D 958 was employed. The test specimens were prepared in rectangle of 50 mm x 10 mm x 3 mm similar to flexural properties test specimen.

RESULT AND DISCUSSION

Wear Property Analysis of the Composites:

Comparative studies on the effects of fillers loading on abrasion wear properties of epoxy/S-glassfibre composites and epoxy/nanoclay composites were carried out and reported thus;

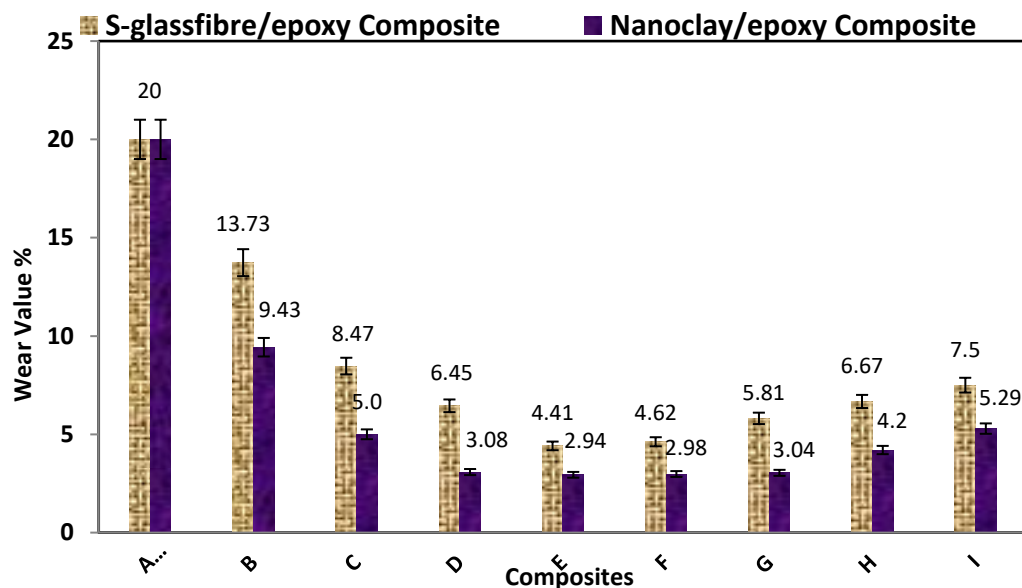


Figure 1: Wear Behaviour of Various Composites Fabricated

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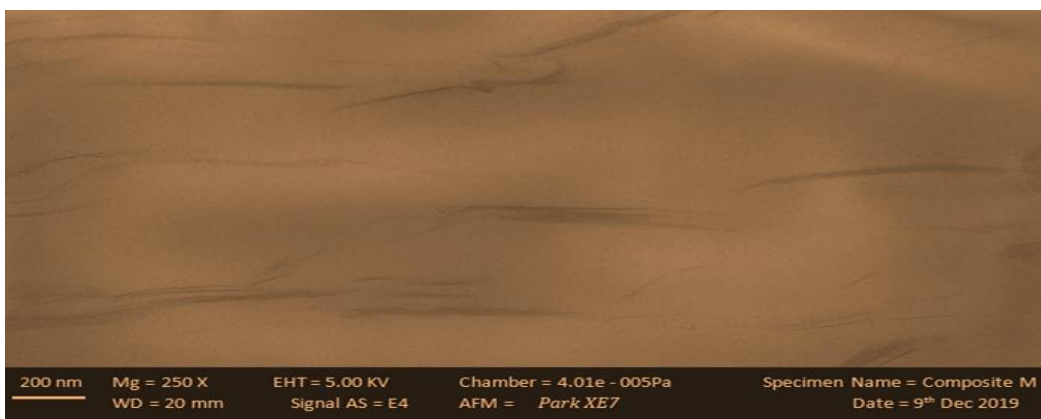


Plate I: SEM Image of Control Sample A (100 wt % epoxy)



Plate II: SEM Image of S-glass/epoxy Composite F (5 wt % nanoclay & 95 wt % epoxy)



Plate III: SEM Image of Epoxy/nanoclay Composite F (5 wt % epoxy & 95 wt % nanoclay)

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The percentage wear varies from 20 to 2.94 % for all the composites fabricated i.e. S-glassfibre/epoxy composites and nanoclay/epoxy nanocomposites. The highest wear value of 20 % was obtained for the control sample A with 100 wt % epoxy while the least wear value of 2.94 % recorded for epoxy/nanoclay composites F with 96 wt % epoxy & 4 wt % nanoclay. In general the decrease in percentage wear from sample A (control) to composite E were because of fillers ability to reinforce the wear resistance capacity of the composites and good interaction (mixing) between the reinforcement (nanoclay particles and S-glassfibre) with the epoxy [8,9, 10,11 and 12].

Wear behaviour of glassfibre/epoxy composites varied from 20 to 4.41 wt %. The maximum wear value 20 wt % was obtained for control sample A with 0 wt % glassfibre reinforcement while the minimum wear value was 4.41 wt % for composite F with 50 wt % glassfibre reinforcement. The decreases in percentage wear experienced from composites B to F were because of improved wear resistant capacity of the composites due to the increase in S-glassfibre loading in the composites and the ability of the matrix to accommodate the reinforcing S-glassfibre between 0-40 wt percent. The S-glassfibre/epoxy composites with glassfibre content above 40 wt % i.e. composite F to J, witnessed reduction the wear resistant ability due to poor interactions between the matrix and S-glassfibre as the saturation point were exceeded [13-16].

The percentage wear of nanoclay/epoxy composites varies from 20 wt % to 2.94 wt %. The maximum wear value of 20 wt % was obtained for control sample A with 0 wt % nanoclay while the minimum wear value of 2.94 wt % were observed for nanocomposites E and F with 4 wt % and 5 wt % nanoclay. The enhanced wear resistant properties of the composites were experienced due to nanoparticle reinforcement special ability to occupy the intermolecular spaces and surface voids inherent in epoxy materials [17, 18, 19 and 20]. The increment in the nanoclay content beyond 4 wt % as in composite F, results to reduction in wear resistance of the composites as

seen in composite F - J. This is because nano particles do better reinforcement in minute quantity [21, 22, 23, 24 and 25] thereby improving the surface hardness and wear resistance of composite materials by occupying the inherent voids and fault in epoxy materials. The greater quantity of nano particles beyond 5 wt % causes the formations of cluster and agglomerations leading to weakening of the materials [26, 27 and 28].

Morphology Analysis of the Fabricated Composites:

The SEM image shown in plate I, reveals traces neither of nanoclay nor of E-glassfibre in the sample but random intermolecular void and surface fracture formations due to surface shrinking and entrapped air bubbles [5, 6 and 11]. During the fabrication process as the hardener was added, the reaction that took place was exothermic and as such, air bubbles were created [9]. Although much care was taken to remove these bubbles, small bubbles were still present and these showed up as voids at a later stage. The scattered lighter sections are the voids, which were created during the mixing process. Furthermore, as the neat epoxy cures, there exist shrinking (uneven reduction in the surface area) leaving the formation of cracks and faults on the surface of the control sample [1 and 3]. These intermolecular voids and surface cracks make the controls sample to be weak making it to wear out more than the reinforced composites.

Plate II shows uniformly distributed 40 wt % S-glassfibre in the composite E sample. The distribution of glassfibre reinforcements in matrix is even forming a uniformly topography [13, 14 and 15] although there exist little faults (voids) as shown in the black coloured circled area. The inherent voids in epoxy, which were created during the mixing and curing processes, were taken care of by the S-glassfibre reinforcement making the composite to better ability to withstand damage due to abrasion [8, 9, 10 and 11]. Plate III shows the structure of nanoclay/epoxy composite E sample. Here no clusters were seen but uniformly distribution of nanoclay particles in the matrix forming a homogenous mixture. The distance between the platelets is less than 8.8 nm,

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however there is little agglomeration as shown in the circle with white line. The nanoclay particles were able to fill up the inherent void and fault in the epoxy composite making the material more resistant to wear and tear due to abrasion [19, 22, 23 and 24].

CONCLUSION

The tribology on epoxy/glassfibre and epoxy/nanoclay composite were comprehensively and comparatively done and the following conclusion where made:

1. Epoxy/nanoclay composites are the overall best abrasion wear resistant composites with composites E recorded as the overall best abrasion wear resistant composite and the least abrasion wear resistant composite is control sample A.
2. In the other hand, the control sample A recorded the highest wear value of 20 wt % while Epoxy/nanoclay composites E recorded the least wear value of 2.94 wt %.
3. S-glassfibre reinforced epoxy composites have improved abrasive wear resistant ability with epoxy/S-glassfibre E having the best and the least wear value of 2.94 wt % and 4.41 wt % respectively.
4. SEM images reveals that the abrasion wear performance of the composites were due to their degrees of surface and intermolecular interactions between the matrix and the reinforcements as the epoxy/nanocomposites with 4 wt % nanoclay respectively possess the best surface interactions.
5. The composites produced can serve in engineering applications such as floor cover, shoe sole, pedals etc where materials with high surface wear (abrasion) resistant are required [9], [10], [11].

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