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Wear Behavior Performance of Polymeric Matrix Composites Using Taguchi Experiments

Reem Alaa Mohammed* **Ruaa Haitham Abdul Raheem****
Shaymaa Hasan Khazaal***
**, ** Department of Materials Engineering/ University of Technology / Iraq*
**** Department of Applied Science/ University of Technology/ Iraq*
*Email: 10904@uotechnology.edu.iq
** Email: lolo_ru1982@yahoo.com
*** Email: shaymaa8104@yahoo.com

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Abstract

This research estimates the effect of independent factors like filler (3%, 6%, 9%, 11% weight fraction), normal load (5N, 10N, 15N), and time sliding (5,7 , 9 minutes) on wear behavior of unsaturated polyester resin reinforced with jute fiber and waste eggshell and, rice husk powder composites by utilizing a statistical approach. The specimens polymeric composite prepared from resin unsaturated polyester filled with (4% weight fraction) jute fiber, and (3%, 6%, 9%, 11% weight fraction) eggshell, and rice husk by utilizing (hand lay-up) molding. Dry sliding wear experiments were carried utilizing a standard (pin on disc test setup) following a well designed empirical schedule that depends on Taguchi's experimental design L9 (MINITAB 16) with the determined (S/N) ratio and analysis of different (ANOVA) optimal factors to minimize the wear rate. Results exhibit that the presence the of 11% weight fraction eggshell and rice husk powder with 4% weight fraction jute fiber improves the wear resistance of unsaturated polyester composite materials significantly. The filler content was observed to be the major significant factor influencing the wear rate followed by time sliding and normal load. From the results of the S/N ratio, the optimization of wear parameters is obtained at specimens A3, A6, A7, and A10 as to minimize wear rate.

Keywords: *Unsaturated polyester resin, eggshell, rice husk, jute fiber, wear behavior, taguchi's method, ANOVA.*

1. Introduction

Recently there has been a rapid development in utilizing natural fibers like: jute, sisal, coconut...etc. with thermoset resin matrix materials in various industrial applications due to the fact these fibers are available in natural, non-toxic, low density, lightweight and has an ability combination between high performance and low cost [1 and 2]. There are various polymers that can be used as a matrix for composite materials like (thermoset and thermoplastics), the most frequently used thermoset polymers are epoxy resin, unsaturated polyester resins, and vinylester. A thermoset is a hard and interrelated material that loses mechanical and chemical properties and is non-modifiable when exposed to heat [3]. Unsaturated polyester resin is a type of thermosetting polymer that is formed by reacting with an unsaturated monomer or pre-polymer by having a carbon-to-carbon bond in its polymer chain and has a good mechanical and physical property so it is suitable for applications requiring high resistance, corrosion resistance, moisture resistance, thermal insulation and good electrical properties [4 & 5]. The wear behavior is divided into four types, which are erosive wear; abrasive wear; adhesive wear; and surface fatigue wear in this research study the adhesive wear and erosion wear [6]. Adhesive wear behavior can be defined as the process that occurs as a result of interaction among the surface of the solid material with the environmental conditions such as temperature, speed, impact loads and also various kinds of with be better such as solid or liquid or gas [7]. This kind of wear occurs in the case of sliding surfaces to each other under the influence of the load so that pressure high enough to cause local plastic deformation and adhesion [8]. There are many studies that have investigated the wear and erosive behavior and attempted to find the factors that have the most effect on the values of wear and erosive resistances. S.Majhi, et.al. [9] illustrated the wear behavior of composite polymer made from epoxy resin reinforced with (5%, 10%, 15%, 20% W.F) rice husk. The results show the specimen (Epoxy + 10% R.H) give better resistance to wear behavior than other weight fractions. S. Srinivasa and K. Manonmani [10] examine the wear behavior of hybrid composites constituents from (2%, 5%, and 9%wt.) titanium oxide filled with (30%, 4%, and 50% wt.) fiber at varying glass fiber lengths of 1, 2, and 3 cm into unsaturated polyester resin. Taguchi's test design procedure was applied to select a parametric analysis of the variable fiber content, fiber length and filler material content. Events prove the fiber content parameter was a major effect on wear rate and also with the increase in fiber content comes the increase in resistance wear rate. A.H. Majeed et.al. [11] studied the influence of varying ratios as 0%, 0.5%, 1%, 1.5 %, 2%, 2.5%, and 3% silica fume, glass powder, and carbon black filled with unsaturated polyester resin on impact test, hardness test, bending test, compressive strength and wear test. Results reveal the impact and hardness, improve with added SF, GP, CB, while the bending test improves with add GP associated with SF and CB. Compressive strength improves with SF compared with GP and CB, but the wear rate resistance improves with added GP and SF more than CB. Younis et.al. [12] studied the effect of 1%, 3%, and 5% wt. nano silica particles filled with 4% wt. glass fiber (chopped/woven) in a polyester resin matrix on the wear behavior, tensile strength, impact strength and hardness shore D. Load (3 N, 5N and 7N), sliding speed (2 m/s), sliding distance (7cm) and sliding time (15 minutes) are the factors influencing on the wear behavior rate were investigated. From these results it can be seen the presence 4% woven glass fiber with 5% Nano-silica in an epoxy resin matrix specimen improves wear behavior, tensile strength, impact strength and hardness shore D for polymer composite highly than specimens filled 4% chopped glass fiber with 5% Nano silica particles. The purpose of this research is to study the influence weight fraction of jute fiber, waste (eggshell and rice husk powder) reinforced with unsaturated polyester on dry sliding wear. Taguchi's experimental design (L9) was used and the ANOVA analysis in order to investigate the effect of factors (filler content, load applied, sliding time) on the dry sliding wear resistance. The resistance unsaturated polyester resins was improved by adding jute fiber with small amounts from waste eggshell and rich husk powder under the conditions for dry sliding wear behavior.

2. Materials Raw

2.1 Unsaturated Polyester Resin

The unsaturated polyester resin (PERPOL 111), which was used as matrix in this work has good tensile properties, flexural properties, good corrosion resistance and performs satisfactorily in water and sea-water. Table 1 shows the physical and mechanical properties of polyester resin used in this work and equipped by the United Arab Emirates Company.

Table 1,
Shows the physical and mechanical properties of polyester resin.

Properties	Values
Tensile Strength	55-65 Mpa
Tensile Modulus	3600-2800 Mpa
Flexural Strength	182-192 Mpa
Flexural Modulus	6500-6900 Mpa
Elongation at Break	1.9-2.3 %
Heat Deflection Temperature	63-71 C°
Water Absorption after 24 hrs at 23 C°	15-19 mg
Density	1.10-1.11 gm/cm^3

2.2 Jute Fiber

The mechanical properties of the jute fiber used in this work as reinforced materials are shown in Table 2 [13].

Table 2,
Shows the mechanical properties of jute fiber [13].

Properties	Values
Tensile Strength	400-800 MPa
Young Modulus	10-30 Gpa
Elongation at break	1.8%
Density	1.46 gm/cm^3

2.2 Waste Eggshell

In this research, eggshell waste will be used as a reinforcement material with unsaturated polyester resin. Eggshells were washed with water to remove membranes from the eggshell and dried at room temperature, later milling for 3 hours until the fine powder was obtained. Table 3 shows the chemical composition of eggshells after milling (examined by the XRF technique). The average particle size of eggshell powder is shown in Figure 1, where the average particle size of eggshell waste was (17µm).

Table 3,
Chemical composition of eggshell using X-Ray Fluorescence Spectrometer

Component	Ratio%	Component	Ratio%
CaO	50.25	Cl	0.029
SiO_2	0.020	K_2O	0.080
Al_2O_3	0.022	MnO	0.030
MgO	0.055	TiO_2	0.0043
Fe_2O_3	0.044	CuO	0.0088
Na_2O	0.55	V_2O_5	0.0014
P_2O_3	0.045	Cr_2O_3	0.0028
SrO	0.033	ZnO	0.0027
NiO	0.0020	I	0.0020
SO_3	0.64	BaO	0.0038

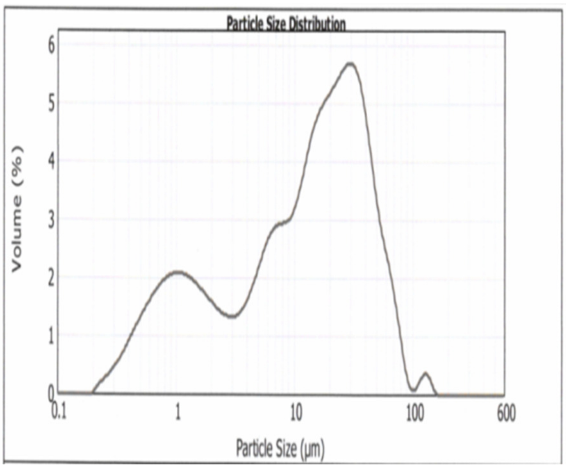


Fig. 1. Particle size analyzer of eggshell powder after milling.

2.3 Waste Rice Husk

The rice husk is the agricultural waste used in this research as a reinforcement material with unsaturated polyester resin. Rice husk consists of 20% silica, 30-40% cellulose, 25-30% lignin and 10-15% ash, and 5-10% humidity [14]. The rice husk was initially washed with water to remove dust and suspended materials, dried at room temperature and then grinded for 3 hours until the fine powder was obtained. Table 4 shows the chemical composition of the rice husk after milling examination by using (XRF) technique. The average particle size of rice husk is shown in Figure 2, where the average particle size of egg shells is (45µm).

Table 4,
chemical composition of rice husk by using an X-Ray Fluorescence Spectrometer)

Component		Ratio%	Component Ratio%
CaO	0.44	Cl	0.071
SiO_2	25.33	K_2O	0.47
Al_2O_3	0.075	MnO	0.022
MgO	0.038	TiO_2	0.0010
Fe_2O_3	0.98	CuO	0.075
Na_2O	0.25	V_2O_5	0.00060
P_2O_5	0.033	Cr_2O_3	0.0037
SrO	0.0035	ZnO	0.0093
NiO	0.0083	I	0.0023
SO_3	0.045	BaO	0.0036

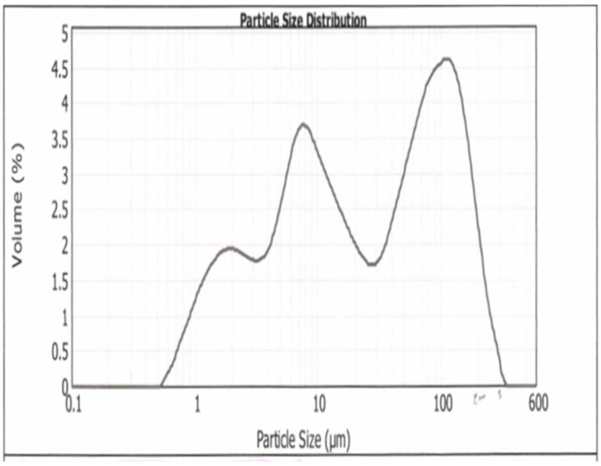


Fig. 2. Particle size analyzer of rice husk powder after milling

3. Experimental Work
3.1 Preparing of Test Specimens

The Preparation of samples of polymer composite matrix materials was done by hand lay up method. Initially, the preparing mold from the glass with a dimension of (20 × 20 × 0.5 cm), as shown in figure 3 and must be covered together with a layer of nylon until adherence between specimens and mold is prevented. Then the jute fibers are cut according to mold dimensions and calculate the weight fraction of the jute fiber and filler (eggshell and rice husk) depending on the role of mixture [15]. Next, the unsaturated polyester resins is mixed with a filler (3%, 6%, 9% and 11% weight fraction eggshell and rice husk) by using a glass rod until homogenous mixing is obtained and then adds the hardener to the mixture and the mixing process continues for 15 minutes. Part of the mixture was poured into the mold and layer jute fiber (4% weight fraction) was put and the remaining amount of mixture was poured and left for 24 hours at room temperature. Samples will be set in the oven at 55 degrees celsius for 1 hour in order to remove the remaining stresses and get better bonding [16&, 17]. The specimens were sliced according to ASTM (wear G99-04) tests. Table 5 shows the detailed composition of the specimens.

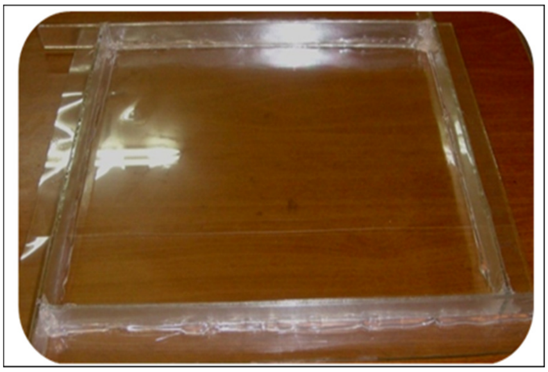


Fig. 3. Sample preparation mold.

Table 5,
Detail composition of the specimens

Specimens	Composition
A1	UP
A2	UP+4% J.F
A3	UP+4% J.F +3% E.S
A4	UP+4% J.F +6% E.S
A5	UP+4% J.F +9% E.S
A6	UP+4% J.F +11% E.S
A7	UP+4% J.F +3% R.H
A8	UP+4% J.F +6% R.H
A9	UP+4% J.F +9% R.H
A10	UP+4% J.F +11% R.H

3.2 Wear Test

A dry sliding wear test is carried according to pin-on-disc. The wear device consists of a flat metal arm containing holder that was installed in the specimen and a rotating iron disc connected to an electric motor. The hardness of the iron disc is 269 HB and the velocity is 950 rpm as shown in Figure 4, is located in the Materials Engineering / Department, Technology University. The specimen dimensions in this test were (10 mm width, 25mm length, and 5mm thickness) according to ASTM (G99-04) [18] as shown in Figure 5. The wear behavior rate can be calculated from equations 1and 2 [19].

$$W.R = \frac{\Delta W}{S.D} \quad \ldots(1)$$

where:

W.R: Wear rate (gm/mm)

ΔW: The difference weight (gm)

S.D: distance of sliding can be calculated from equation 2

$$S.D = S * T \quad \ldots(2)$$

where:

S: Speed of sliding (mm/min)

T: Time (min)

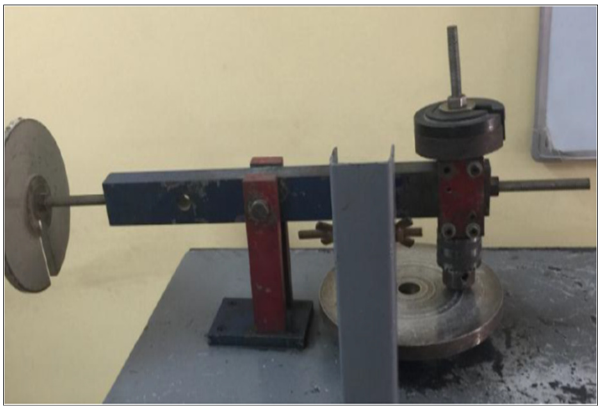


Fig. 4. Device used in wear test.

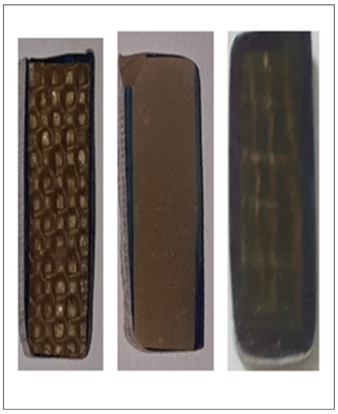


Fig. 5. Models for specimens wear test.

3.3 Taguchi Experimental Design

The Taguchi design has traditionally been adopted to improve design standards because this systematic approach can greatly reduce overall experimental costs and test time. Using the Taguchi L9 orthogonal array design, the optimal experimental state can be easily determined based on the S/N analysis required to estimate experimental results. In general, there are three types of signal-to-noise analysis applicable: 1, lower is better, 2 nominal is better, and 3 higher is better. In this current work, the main objective is to reduce the wear, so it was used the lower is better, according to equation 3 [20]. Table 6 shows the levels of the factors used in the experiments of the wear test.

$$\frac{S}{N} = -10\log\frac{1}{N}\left(\sum Y2\right) \qquad \ldots(3)$$

where;

N = Number of observations.

Y = Erosive wear rate.

Table 6,
Levels of variables utilized in the experiment of wear behavior

Variable	Level			
	I	II	III	Unit
	A1	A2	A3	
Weight fraction	A4	A5	A6	W.F %
	A1	A2	A7	
	A8	A9	A10	
Normal Load applied	5	10	15	N
Sliding time	5	7	9	min

4. Results and Discussion
4.1 Wear Test

The results wear rate for all experiments was carried out according to the predetermined design on specimens composites are presented in tables (7-10), also these tables present the experimental wear rate along with the signal-to-noise ratio for each single test run. Clearly from the tables (7-10) the wear rate values decrease with add weight fraction from waste (eggshell and rice husk powder reinforced with jute fiber into unsaturated polyester), where the lowest wear rate was found in the specimen (UP+4%jute fiber+11% eggshell and rice husk) (0.2×10^{-4} gm/mm, 1.2×10^{-4}gm/mm) respectively compared with the other specimens, due to the content of the fiber and filler acts as an obstacle to shear deformation during the sliding conditions, also the wear behavior can be based on both abrasion and adhesion, this agrees with [12&21]. Figure 6 shows the main effects plot for (S/N) ratios on wear rate, clear from the main effects of the S/N measurements that the incorporation factor of A3, A6, A7, A10, B1, and C3 gives a lower wear rate. It is clear through the Taguchi experimental that the lowest wear rate can be obtained when the filler content (A) with the sliding time (C) is at the highest level, while the load (B) is at the lower level. These results indicated in the change in sliding conditions has a direct effect on the wear rate of the composite polymer specimens. Figure 7 shows the relationship between the filler content and wear behavior rate, where the specimens reinforced with eggshell powder give wear resistance better than specimens reinforced with a rice husk powder, due to the natural chemical composition of eggshells compared to chemical composition of the rice husk where the presence of calcium oxide is (50.25%) in eggshell powder gives a better correlation with the resin matrix material, also the eggshells powder increases surface hardness of the polymeric composite thus improving the natural bond between the matrix material and filler materials. Figure 8 shows the effect of the load applied on the wear behavior rate, this figure shows a decrease in wear resistance with increasing applied load from (5 N to 15 N), from the Taguchi experiment on the specimens reinforced with 11W.F% (eggshell and rice husk powder) give better wear resistance at 5 a load. Due to that increasing the applied load increases friction on the surface of composite polymeric thus causes a higher weight loss, this agrees with [22]. Also the nature of interdependence between the resin matrix and the reinforcing material depends on several factors, including the particle size and the chemical composition of the reinforcing materials[23], where the particle size of waste eggshell was (17μm), which is smaller than waste rice husk (45μm), therefore the specimens reinforced with eggshell powder and jute fiber in unsaturated polyester resin give resistance wear rate better than reinforced with a rice husk powder. Figure 9 displays the effect of time sliding on the wear behavior rate. The Taguchi, experiments show that the increased time sliding from (5 to 9 min) leads to thermal softening and weakness in the typical polymer composite material, thus increasing the wear rate these results agree with [24]

Table 7,
Results of wear rate with the output results using L9 orthogonal array of specimens (pure polyester, 4% jute fiber, 3% eggshell powder)

Exp.	Filler (A)	Load (N) (B)	Time (C)	Wear Rate gm/mm	S/N
1	A1	5	5	$9.8 \times^{10-4}$	-19.8245
2	A1	10	7	$8.5\times^{10-4}$	-18.5884
3	A1	15	9	$7.7\times^{10-4}$	-17.7298
4	A2	5	7	$7.6\times^{10-4}$	-17.6163
5	A2	10	9	$7.2\times^{10-4}$	-17.1466
6	A2	15	5	$8.7\times^{10-4}$	-18.8897
7	A3	5	9	$4.1\times^{10-4}$	-12.2557
8	A3	10	5	$5.7\times^{10-4}$	-15.1175
9	A3	15	7	$5.2\times^{10-4}$	-14.3201

Table 8,
Results of wear rate with the output results using L9 orthogonal array for specimens (6%, 9%, 11% eggshell powder)

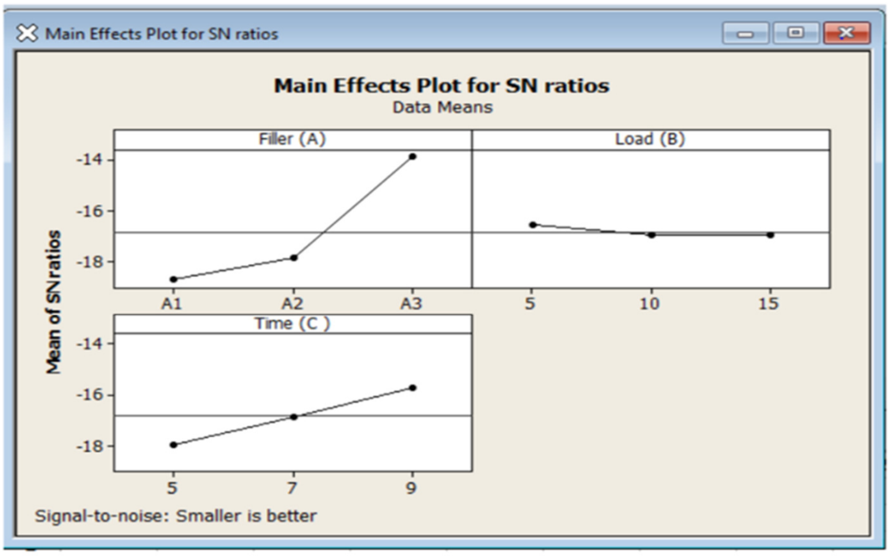
Exp.	Filler (A)	Load (N) (B)	Time (C)	Wear Rate gm/mm	S/N
1	A4	5	5	$3.6\times^{10-4}$	-11.1261
2	A4	10	7	$3.4\times^{10-4}$	-10.6296
3	A4	15	9	$3.1\times^{10-4}$	-9.8272
4	A5	5	7	$1.1\times^{10-4}$	-13.9794
5	A5	10	9	$1.5\times^{10-4}$	-3.5218
6	A5	15	5	$1.8\times^{10-4}$	-5.1055
7	A6	5	9	$0.2\times^{10-4}$	-0.8279
8	A6	10	5	$0.5\times^{10-4}$	-6.0206
9	A6	15	7	$0.4\times^{10-4}$	-7.9588

Table 9,
Results of wear rate with the output results using L9 orthogonal array of specimens (pure polyester, 4%jute fiber, 3% RHA)

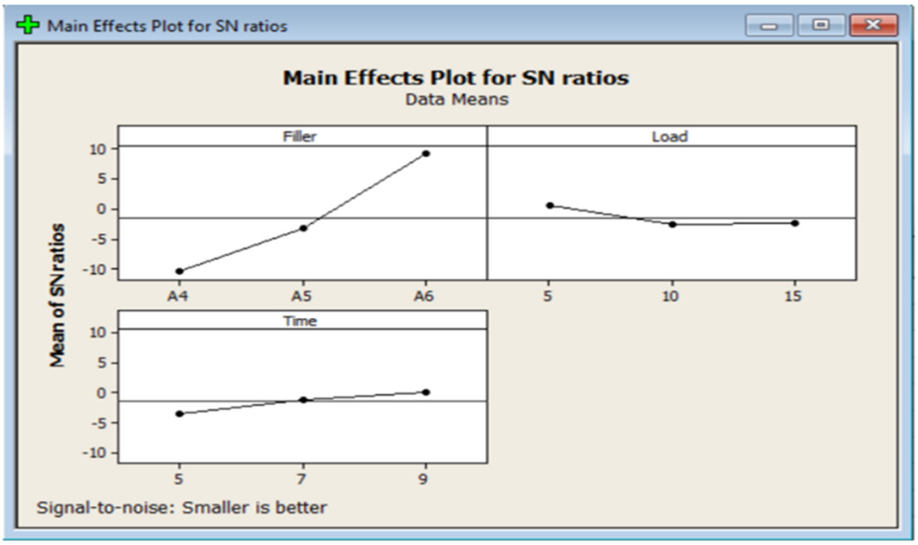
Exp.	Filler (A)	Load (N) (B)	Time (C)	Wear Rate gm/mm	S/N
1	A1	5	5	$9.8\times^{10-4}$	-19.8245
2	A1	10	7	$8.5\times^{10-4}$	-18.5884
3	A1	15	9	$7.7\times^{10-4}$	-17.7298
4	A2	5	7	$7.6*^{10-4}$	-17.6163
5	A2	10	9	$7.2\times^{10-4}$	-17.1466
6	A2	15	5	$8.7\times^{10-4}$	-18.7904
7	A7	5	9	$5.0\times^{10-4}$	-13.9794
8	A7	10	5	$6.6\times^{10-4}$	-16.3909
9	A7	15	7	$6.5\times^{10-4}$	-16.2583

Table 10,
Results of wear rate with the output results using L9 orthogonal array of specimens (6%, 9%, 11% RHA)

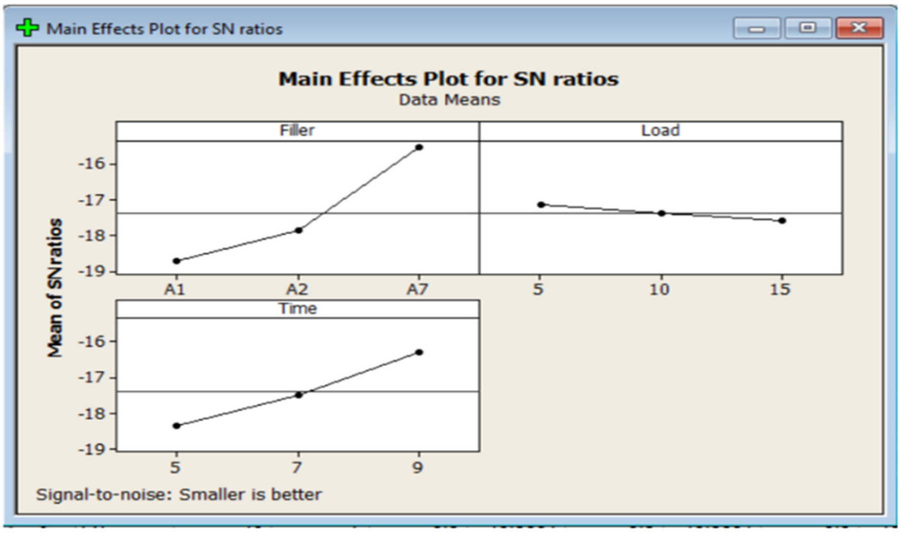
Exp.	Filler (A)	Load (N) (B)	Time (C)	Wear Rate gm/mm	S/N
1	A8	5	5	$4.4\times^{10-4}$	-12.8691
2	A8	10	7	$4.1\times^{10-4}$	-12.2557
3	A8	15	9	$3.8\times^{10-4}$	-11.5957
4	A9	5	7	$2.1\times^{10-4}$	-6.4444
5	A9	10	9	$2.5\times^{10-4}$	-7.9588
6	A9	15	5	$2.7\times^{10-4}$	-8.6273
7	A10	5	9	$1.2\times^{10-4}$	-1.5836
8	A10	10	5	$1.5\times^{10-4}$	-3.5218
9	A10	15	7	$1.4\times^{10-4}$	-2.9226



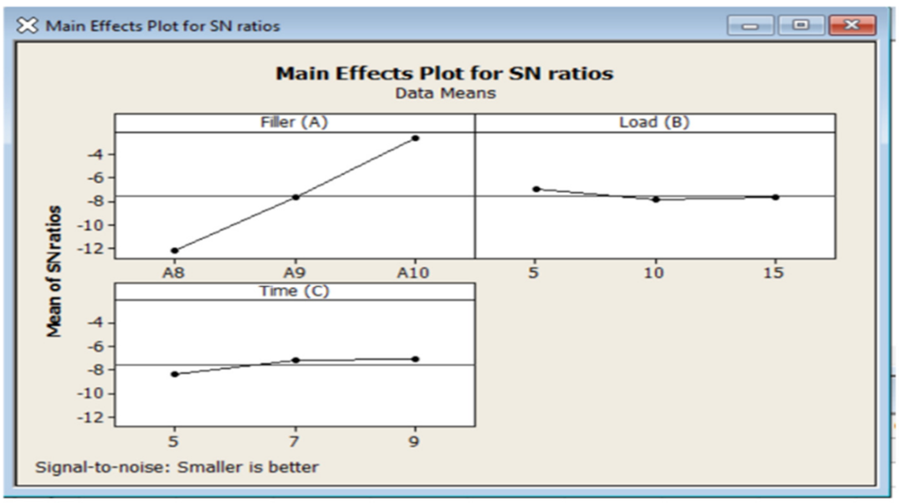
(A) (UP, 4% J.F, 3% E.S)



(B) (6%, 9%, 11% E.S)



(C) (UP, 4% J.F, 3% R.H)



(D) (6%, 9%, 11% R.H)

Fig. 6. (A, B, C, D) Represent the main effects plot for S/N ratios on the wear behavior rate for all specimens.

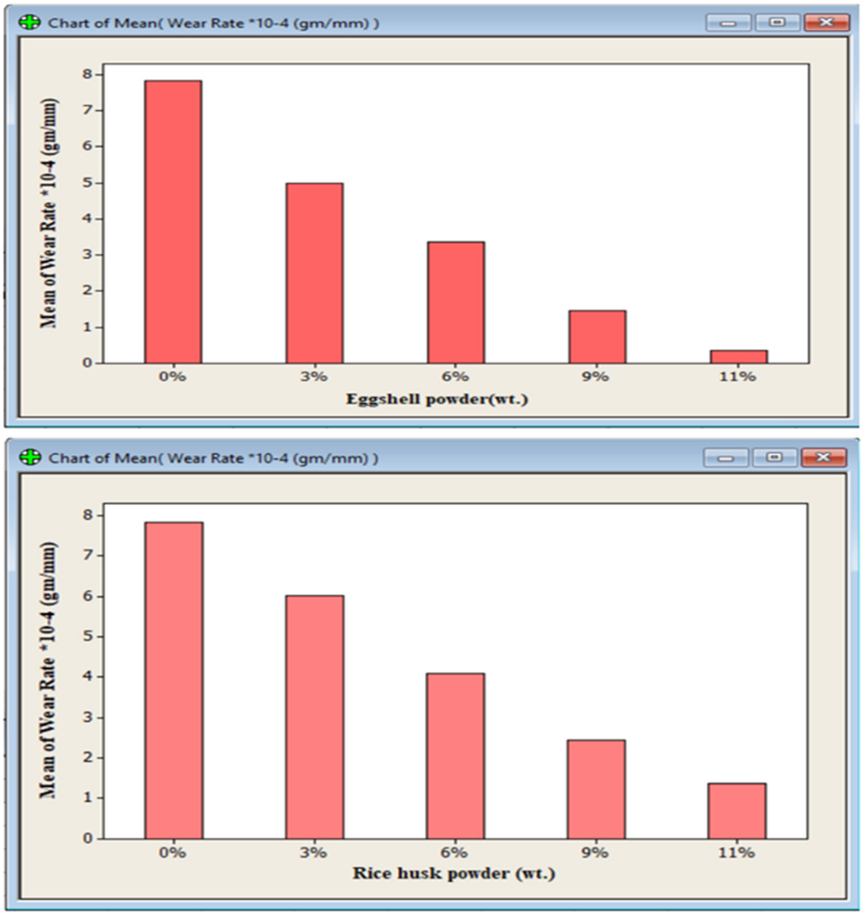


Fig. 7. Represent the effect filler content on the wear rate for all specimens (eggshell and rice husk).

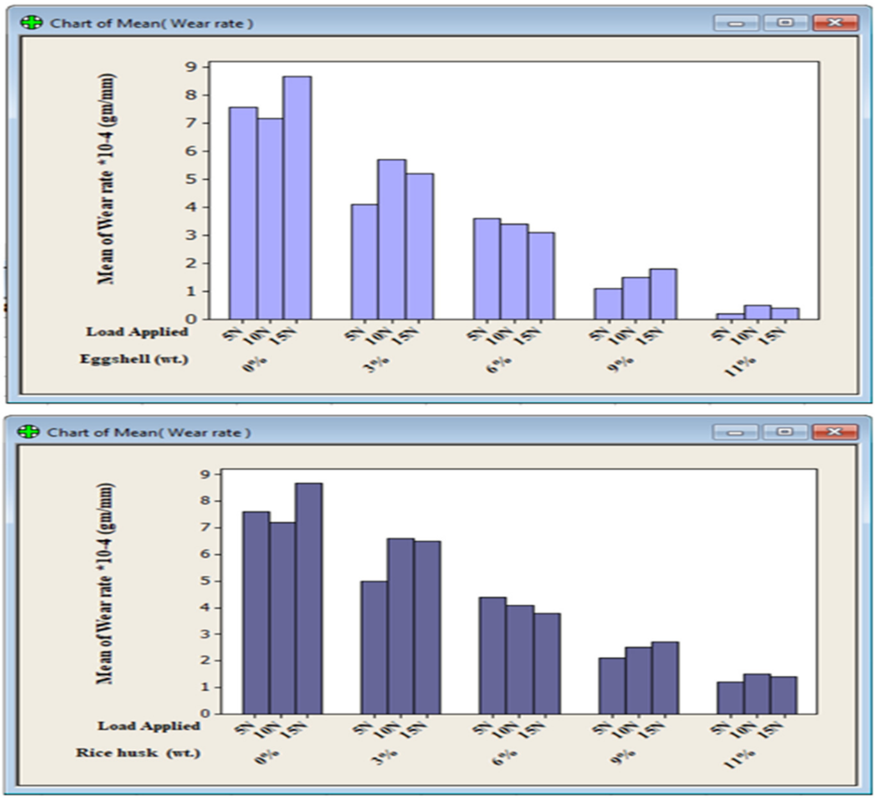


Fig. 8. Represents effect load applied on the wear rate for all specimens (eggshell and rice husk).

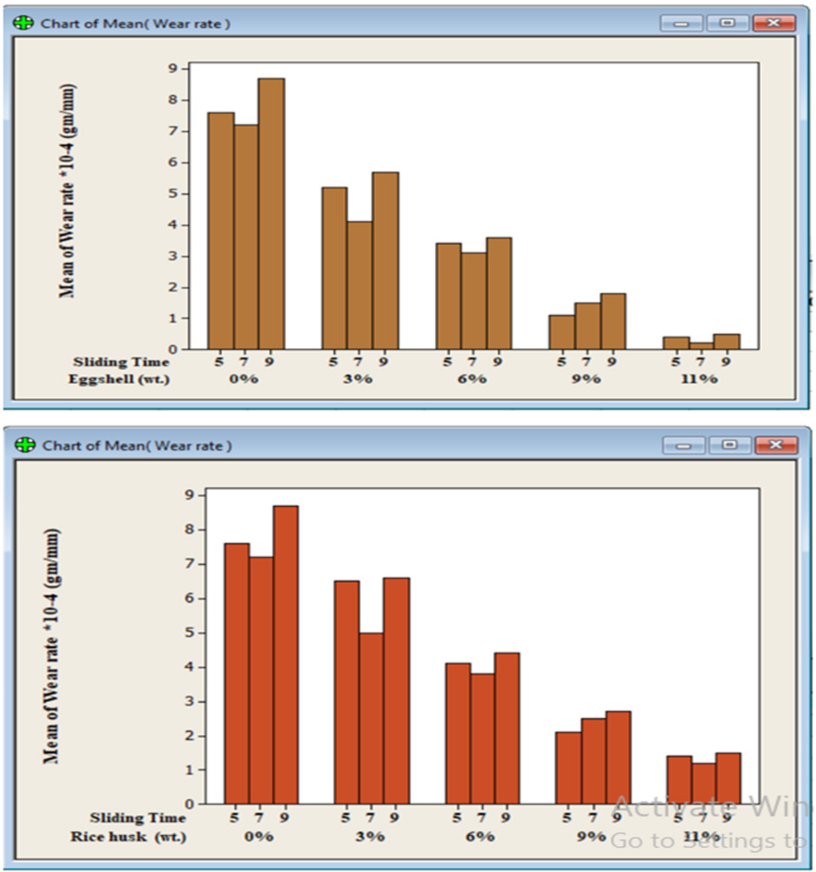


Fig. 9. Represents effect time sliding on the wear rate for all specimens (eggshell and rice husk).

4.2 Analysis ANOVA for Wear Rate Results

The ANOVA analysis is used to understand the effect of the factors and their interaction on the wear rate and allows determining the effect of each variable on the total difference of the results. Tables (11,12) offer ANOVA analysis results for specimens reinforced by eggshell powder, while Tables (13-14) offer ANOVA analysis results for specimens reinforced by rice husk powder. In the tables, the last column represents the contribution percentage P for each variable and determines the percentage of the effective factors on the wear rate. When P-value is less than 0.05, this factor has a significant influence on the wear behavior rate. Table 11 shows the P value of the filler (A) and time sliding (C) (0.012, 0.054) respectively, have a greater effect on the wear behavior rate, whereas the P value of the applied load (B) (0.875) have less influence on the wear behavior rate. Table 12 shows the P value of the filler (A) and load applied (B) (0.009, 0.053) respectively, which has more significance on the wear behavior rate, while the P value of the time sliding (C) (0.339) has less influence on the wear behavior rate. Table 13 shows the P value of the filler (A) (0.04) has more effect on wear rate, while P values (0.975, 0.097) of the load applied (B) and time sliding (C) respectively have less influence on the wear behavior rate. Table 14 shows the P value of the filler (A) and load applied (0.012, 0.054) respectively, have most significance on the wear behavior rate, while the P value of the time sliding (C) (P= 0.362) less influence on the wear behavior rate. From these results can be noted in the specimens (A1, A2, A3, A7) was the filler (A) and time sliding (C) more influence on the wear behavior rate while load applied (B) less influence on the wear behavior rate, but in the specimens (A4, A5, A6, A8, A9, A10) the filler (A) and time sliding (C) have more effect on the wear behavior rate while the load applied (B) has less effect on wear rate.

Table 11,
ANOVA analysis of specimens (pure polyester, 4% jute fiber, 3% eggshell powder)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filler (A)	2	22.1667	22.1667	11.0833	85.26	0.012
Load (B)	2	0.0067	0.0067	0.0033	0.03	0. 875
Time sliding (C)	2	4.526	4.526	2.2633	17.41	0.054
Error	2	0.2600	0.2600	0.1300		
Total	8	26.9600				

Table 12,
ANOVA analysis of specimens (6%, 9%, 11% eggshell powder)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filler (A)	2	13.8200	13.8200	6.9100	109.11	0.009
Load (B)	2	0.0467	0.0467	0.0233	0.37	0.053
Time sliding (C)	2	0.2467	0.2467	0.1233	1.95	0.339
Error	2	0.1267	0.1267	0.0633		
Total	8	14.2400				

Table 13,
ANOVA analyses of specimens (pure polyester, 4% jute fiber, 3% rice husk)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filler (A)	2	10.8689	10.8689	5.4344	22.54	0.04
Load (B)	2	0.0689	0.0689	0.0344	0.14	0.975
Time sliding (C)	2	4.5089	4.5089	2.2544	9.35	0.097
Error	2	0.4822	0.4822	0.2411		
Total	8	15.9289				

Table 14,
ANOVA analysis of specimens (6%, 9%, 11% rice husk powder)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filler (A)	2	11.3867	11.3867	5.6933	81.33	0.012
Load (B)	2	0.0267	0.0267	0.0133	0.19	0.054
Time sliding (C)	2	0.2467	0.2467	0.1233	1.76	0.362
Error	2	0.1400	0.1400	0.0700		
Total	8	11.8000				

5. Conclusions

Below are the most important conclusion researches.

1. The presence of wastes eggshell and rice husk powder into unsaturated polyester resin with 4% weight fraction jute fiber can significantly reduce the wear loss. The optimal wear rate characteristic was obtained at 11% weight fraction.
2. The specimens (UP +4% J.F +11% E.S) and (UP +4% J.F +11% R.H) give wear rate resistance (0.2×10-4 gm/mm) and (1.2×10-4 gm/mm) respectively at load applied (5 N) and time sliding (9 min), while the specimen (UP) give higher wear rate (9.8×10-4 gm/mm) at load applied (15N) and time sliding (9 min).
3. Filler content was observed to be the major significant factor influencing the wear rate followed by (C) (time sliding) and (D) (normal load).
4. From analysis of variance (ANOVA) exhibit at the specimens (A1, A2, A3, A7) the filler and time sliding has most influence on the wear rate behavior and in the specimens (A4, A5, A6, A8, A9, A10) the filler, the load applied have most influence on the wear rate behavior.
5. The S/N ratio and, the optimization of wear parameters is obtained at specimens (A3, A6, A7, A10) as to minimize wear rate.

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أداء سلوك البلى للانسجة البوليمرية المركبة باستخدام تجارب تاكوجي

ريم علاء محمد* رؤى هيثم عبد الرحيم** شيماء حسن خزعل***
*،** قسم هندسة المواد / الجامعة التكنولوجية
*** قسم العلوم التطبيقية / الجامعة التكنولوجية
* البريد الالكتروني : 10904@uotechnology.edu.iq
** البريد الالكتروني : lolo_ru1982@yahoo.com
*** البريد الالكتروني : shaymaa8104@yahoo.com

الخلاصة

يقيم هذا البحث تأثير العوامل المستقلة مثل الحشو (٣%، ٦%، ٩%، ١١% كسر وزني) ، الحمل العادي (N٥، N ١٠، N١٥) ووقت الانزلاق (٥، ٧، ٩ دقائق) على سلوك البلى لمتراكبات راتنج البوليستر غير المشبع المدعم بألياف القنب ونفايات مسحوق قشور البيض وقشور التمن بوساطة استخدام نهج إحصائي. يتم تحضير العينات البوليمرية المتراكبة من راتنجات البوليستر غير المشبعة المحشوه مع ٤ % كسر وزني ألياف القنب و (٣٪ ، ٦٪ ، ٩٪ ، ١١٪ كسراً وزنياً) قشور البيض وقشور التمن باستخدام القولبة اليدوية واجريت تجارب البلى الانزلاقي باستخدام (دبوس على إعداد اختبار القرص) القياسي باتباع جداول تجريبية مصممة جيدا تعتمد على تصاميم تجارب تاكوجي (L9) (مني تاب ١٦) مع حساب نسبة الاشارة الى الضوضاء (S/N) وتحليل التباين (الانوفا) الامثل للمتغيرات لتقليل معدل البلى. أظهرت النتائج أن وجود ١١ % كسراً وزنياً من مسحوق قشور البيض وقشور التمن مع ٤ % كسراً وزنياً ليف القنب يحسن من مقاومة البلى للمواد المتراكبة من البوليستر غير المشبعة بشكل كبير. لوحظ أن محتوى الحشو هو العامل الرئيسي الهام الذي يؤثر على معدل البلى يليه (وقت الانزلاق) و (الحمل العادي). ايضا من نتائج نسبة الاشارة الى الضوضاء (S/N) تم الحصول على الأمثل لمتغيرات البلى عند العينات (A10, A7, A6, A3) لتقليل معدل البلى.