Coating of Oil Pipes Products with Erosion-Resistant Composite Materials Reinforced with Carbonates and Natural Wastes

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Abstract

Polymer - based components are exposed to many damage influences during their lifetime. One of these influences erosion, which is a crucial problem in many industrial applications such as pipes, boats, sewage…etc. Due to impingements of solid particles being suspended in the fluids flowing at high velocity. This work reports an investigation of erosion wear characteristics and their resistance to erosion wear after coated by using (spin coating) with rice husk ash – mixed (epoxy resin). Composites specimens have been prepared by (Hand lay-up) molding method. The composite specimens are composed of epoxy resin as the matrix, and 6% vf of glass fiber as reinforcing material and filler powders from natural wastes and industrial processed powders at 3% and 6% vf. The natural wastes are rice husk ash (RHA), carrot waste and sawdust (wood powder) while industrial processed powders are Na2CO3, CaCO3 and K2CO3. Solid particles erosion wear tests and coating after erosion are also carried out. The coating specimens with RHA-mixed epoxy resin at an optimized size of the particles 1.4-4.2 μm improvement erosion wear resistance. The optical microscope results of the coated specimens show those coatings are resistant to erosion parameters.

Keywords: Composites, natural materials, industrial materials, Erosion wear, glass fiber, Coating.

1. Introduction:

The composite is a multi-phase element, is artificially formed and chemically distributed by separate interface, one of the phases is termed "matrix" that is continuous and surrounds with other phase predominatinatingly, which is called the "reinforcement" [1]. Reinforced materials can be particles, fibers and structure that must be more powerful and stiffer than other "matrix" [2]. The composite polymer is estimated the initial kind of composite and employed in the high difference of composite enforcement as well as in the highest amounts in the illumination of appropriate ambient temperature characteristics, the efficiency of fabrication, good ductility, low density, and low cost [3].

Polymeric can be categorized according to the manner with rise temperature in to "Thermosets and thermoplastics") [4]. Polymer strengthened with fiber are closely utilized in designing because comparatively "low density and reliable tailoring" ability to prepare the required rigidity and strength [5]. Polymer composites have a low erosion impedance when compared with metals, and the neat polymer usually erodes faster than polymer reinforced with fiber and particles [6]. Therefore, the polymer composites strengthened with fiber could increase the intensity of, however reduced the erosion resistance of the composites [7].

There are many studies about composite materials, Alok (2013) studied the some mechanical properties (tensile strength, flexural property and hydrophilic behavior) of epoxy resin reinforced with 20% to 40% vf coconut shell filler. Tensile strength results display decreasing by 40% vf. Coconut shell filler, while flexural property improved by 30% vf coconut shell filler. Hydrophilic behavior, increase with an addition volume fraction of coconut shell filler [8]. Yilmaz (2008) studied the erosive wear of specimens, prepared from unsaturated polyester with glass fiber and 40%, 50%, 60% wf. CaCO3 at different particle sizes (1, 2, 3, 5 and 10 µm). The specimen reinforced with 60% wf. at 1 µm give erosion wear resistance when comparing with other weight fraction, also the peak erosion takes place at 90º impingement angle, therefore these specimens behaves in brittle manner [9]. Colombia (1996) studied the effect of the coat (spinning) process with polymeric (epoxy resin) strengthened by 7.5, 15, 30% wt iron particles for specimens steel. The thickness of the coating samples was about 70 pm thick. Results showed the existence of iron particles with epoxy resin in the coatings improved the behavior of steel specimen in the corrosive environment at 3.5% NaCl [10].

2. Objective Of This Work:

Prepare composites of epoxy resin resin reinforced with 6% vf glass fibers with 3% and 6% vf. rice husk ash, carrote powder, saw dust, Na_2CO_3, $CaCO_3$ and K_2CO_3), and comparing the erosion wear behavior of the specimens before and after coating.

3. Experimental Work:

The basic materials used in the preparation of samples consist of glass fibers (Woven E-Glass Fiber) from the (Tenax company), England, and epoxy resin Quickmast (105) base as the matrix of the (Don Construction products) made in Jordan with a density of (1.2 gm / cm3). The mean of natural powder was used for RHA (Rice Husk Ash) (61.6µm), Carrot powder (95.5µm), and wood powder (sawdust) (149.4µm) and industrial powder was used for calcium carbonates (0.71 µm), potassium carbonates (22.18 µm), and sodium carbonates (19.99µm) as shown in Figure (1). All the required molds for preparing the specimens were made from glass of dimensions of (150×150×5) mm. The inner face of the mold was covered with a layer of nylon (thermal paper) made from polyvinyl alcohol (PVA) so as to ensure no-adhesion of the resin with the mold. Specimens in order to complete the hardening process require thermal treatment by placing the specimen in the oven at 60 ° C for 55 minutes to remove remaining stresses in the specimens [11].

A. Chemical Compositions:

The chemical composition analyzer is used to find the element of the natural and industrial material as given in Tables 1 and 2.

4. Preparation Of Natural Materials:

A. Carrot Filer:

Carrot seeds were washed to remove any strange matter like sand, clay, dust and dirt. Solid waste from carrot juice is wealthy in fiber that is regarded as an effective fiber source. The fiber waste was dried in the air and then grinding by using a grinder then sieved to obtain fine and coarse fiber [12 &13].

B. Rice Husk Ash Filler:

Filler rice-husk include about (50% cellulose), (25–30% lignin), and (15–20% of silica) [13]. First step the cellulose and lignin are extracted at burning, but dismissed behind silica ash. The environment of burning and temperature affect the particle size and a specific surface area of rice husk ash [14 &15]. To provide the greatest pozzolanas, the burning of the rice husk requirement accurately managed to maintain the heat under 700°C and to assure that the production of carbon is retained to a least by providing a sufficient amount of air. At temperatures below 700°C amorphous silica is created, which that less reactive, while at the temperatures above 700°C crystalline silica is created, which that more reactive, the second step was milling the RHA by using a grinder to obtain a fine powder [16].

C. Wood Fiiler (Sawdust):

Wood powder is a product of cut, milling, drill, sand, or on the other hand crushing wood with a saw or other tool formed of the finest wood particle, also the product by several animals, birds, and insects which live in wood, like the woodpecker and builder ant which that can perform a risk in construction industries, particularly in terms of its flammability [17].

5. Results and Discussion

A. Erosion Wear:

The consequence of erosion wear for the pure epoxy and (natural, industrial) composites is illustrated in tables 3&4 and figures 2&3. Particle collisions with the specimen surface lead to an increase in the temperature and this causes the material to easily distort the matrix (resin) [18]. Thus, this deformation causes the formation of a hole and loss of weight in the specimens [19]. Results show, the natural and industrial composites give the lower erosion wear when they are compared with the other patterns (pure EP. and EP. +6% G.F) composite. The reason is that the presence of reinforcement and filler in the matrix (resin) assistance in employing dynamic power produced through impacted particles erodent, therefore making the power possible of the flexible deformation of the matrix (resin) to become smaller, this agrees with [19]. The improvement of erosion resistance in specimens supported with fibers and natural powders can be attributed to advancement the hard surface of these specimens with addendum of this reinforcement and the imbibition of a perfect amount of kinetic energy correlated with erosive by filler. From tables 3&4 and figures 2&3 it is clear that there is a pronounced effect of the addition of 6% glass fiber with 3% volume fraction from (natural and industrial powder) on the erosion wear, it is reported that specimens (epoxy +6% glass fiber +3%, 6% RHA, $CaCO_3$) give greater erosive wear strength than specimens reinforced with (3%,6% carrot sawdust, Na_2CO_3, K_2CO_3) because RHA has a high hardness value with small particle size and water absorption. One of the most important observations is that as the fiber and powder reinforcement increases the erosion wear rate decreases in composite material exposed to impingement of particles [20]. In this study the increase content of fiber and filler materials leads to improved erosion resistance because of the bonding between the base material and the reinforcing material which leads to improve mechanical properties, these results agree with [21]. Which may be related to its lower grain size with a good distribution and bonding and since RHA and $CaCO_3$ is harder, rise strength and stiffness than other filler. The impingement angle is one of the generality significant parameters on the erosion behavior. Peak erosion takes place at (15° to 20° angle) for ductile materials, while peak erosion takes place at (90°angle) for brittle materials [22]. The erosion wear peak takes place at 30◦ and 90°, this behavior can be termed as (semi-ductile). The erosion wear rate high in the specimens reinforced with sawdust and K_2CO_3 may be related to the poor linkage between matrix material and fillers with the matrix.

B. Coating:

The results of coating and erosion wear after coating for the pure epoxy and (natural, industrial) composites are illustrated in table 5. It is proposed to use the RHA with (particle size 1.4-4.2 μm) natural waste in the industry as an additive for epoxy resin as coating of thermosetting specimen. Erosions characteristics of uncoated samples are depicted in tables 3 & 4 the experiment (epoxy+6% glass fiber + 6% RHA) showed the best resistance to erosion among the natural-based materials. The (epoxy+6% glass fiber + 6% $CaCO_3$) experiment showed the best resistance to erosion among the industrial-based materials. The (pure epoxy) has been characterized by the following parameters; erosion time of (15 hours), a distance of (20 cm), (90°) of impingement angle, (850 µm) grain size, (30 Ċ) temperature, (200 gm) salt in (2 liters) of water. The weight of the investigated sample before coating is equal to (7.5743 gm), after coating the total weight amounted to (7.9042 gm) which corresponds to a coat thickness of (16 ± 1µm). After erosion wear test, sample weight has been found equal to (7.9030gm) with a loss of (0.0012 gm) from the coating layer only. The specimen (epoxy+6% glass fiber) has been characterized by the following parameters; erosion time of (15 hours), a distance of (20 cm), (60°) of impingement angle, (850 µm) grain size, (25 Ċ) temperature, (300 gm) salt in (2.5 liters) of water. The weight of the investigated sample before coating is equal to (8.3234gm), after coating the total weight amounted to (8.6623 gm). After erosion, the sample weight is found equal to (8.6614 gm) with a loss of (0.0009 gm) from the coating layer only. The specimen (epoxy+6% glass fiber +3%RHA) has been characterized by the following parameters; erosion time of (15 hours), a distance of (30 cm), (60°) of impingement angle, (850 µm) grain size, (25 Ċ) temperature, (200 gm) salt in (3 liters) of water. The weight of the investigated sample of experiment (17) before coating is equal to (8.4530 gm), after coating the total weight amounted to (8.7915 gm). After erosion, the sample weight is found equal to (8.7913 gm) with a loss of (0.0002 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +6% RHA) before coating is equal to (8.7432 gm), after coating the total weight amounted to (9.0725 gm). After erosion, the sample weight is found equal to (9.0724 gm) with a loss of (0.0001 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +3% carrot powder) before coating is equal to (8.7630 gm), after coating the total weight amounted to (9.1025 gm). After erosion, the sample weight is found equal to (9.1020 gm) with a loss of (0.0005 gm) from the coating layer only. The weight specimen (Epoxy+6%G.F+6% Carrot powder) before coating is equal to (9.0170 gm), after coating the total weight amounted to (9.3468 gm). After erosion, the sample weight is found equal to (9.3464 gm) with a loss of (0.0004 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +3% sawdust) before coating is equal to (8.2200 gm), after coating the total weight amounted to (8.5589 gm). After erosion, the sample weight is found equal to (8.5581 gm) with a loss of (0.0008 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +6% sawdust) before coating is equal to (8.5590 gm), after coating the total weight amounted to (8.8885 gm). After erosion, the sample weight is found equal to (8.8879 gm) with a loss of (0.0006 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +3% Na2CO3) before coating is equal to (9.7650 gm), after coating the total weight amounted to (10.1031 gm). After erosion, the sample weight is found equal to (10.1026 gm) with a loss of (0.0005 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +6% Na_2CO_3) before coating has been equal to (10.2600 gm), after coating the total weight amounted to (10.5981 gm). After erosion, the sample weight is found equal to (10.5977 gm) with a loss of (0.0004 gm) from the coating layer only. The weight specimen (ep+6% g.f + 3% $CaCO_3$) before coating is equal to (7.6400 gm), after coating the total weight amounted to (7.9599 gm). After erosion, the sample weight is found equal to (7.9596 gm) with a loss of (0.0003 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +6% $CaCO_3$) before coating is equal to (8.1760 gm), after coating the total weight amounted to (8.5139 gm). After erosion, the sample weight is found equal to (8.5137 gm) with a loss of (0.0002 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +3% K_2CO_3) before coating is equal to (8.1450 gm), after coating the total weight amounted to (8.4746 gm). After erosion, the sample weight is found equal to (8.4739 gm) with a loss of (0.0007 gm) from the coating layer only. The weight specimen (epoxy+6% glass fiber +6 %K_2CO_3) before coating is equal to (8.4650 gm), after coating the total weight amounted to (8.8025 gm). After erosion, the sample weight is found equal to (8.8019gm) with a loss of (0.0006 gm) from the coating layer only.

6. Optical Microicopy

Figure 4 shows the microscope images of the samples before and after erosion. In each figure four images were captured. The first and second images belong to uncoated samples before and after erosion respectively, thus showing the effect of erosion on the uncoated samples. The third and fourth images belong to the coated samples before and after erosion respectively, thus showing the effect of erosion on the coating layer. Comparison of the third and fourth images in most of the coated samples shows identical features despite 15 hours of erosion.

Conclusions:

The (natural and industrial) composites give the lower erosion wear than (pure epoxy and (epoxy +6% glass fiber) composite material. Composites with (epoxy +6% glass fiber +6%RHA) give better erosion resistance at (30 cm) stand – off distance, (60^o) angle, (425µm) size of sand, (30Ċ) temperature, (300) gm salt content with (2liter) water and (15hours) time, while the higher erosion wear is for the (epoxy +6% glass fiber+6% sawdust) composite. Composites with (epoxy +6% glass fiber +6% $CaCO_3$) give better erosion resistance at (30 cm) stand – off distance, (60^o) angle, (425µm) size of sand, (30Ċ) temperature , (300) gm salt content with (2liter) water and (15 hours) time while the higher erosion wear is for (epoxy +6% glass fiber +6% K_2CO_3) composites.

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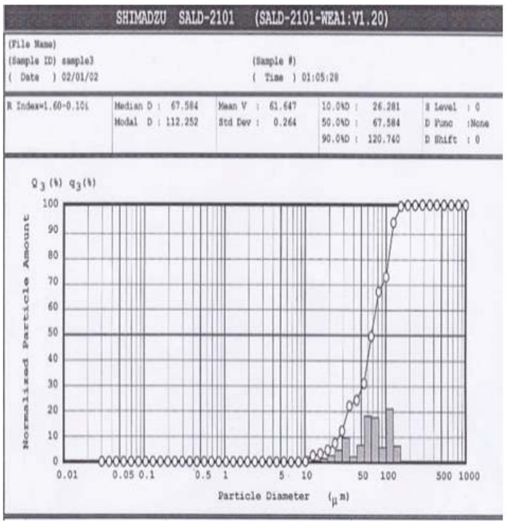
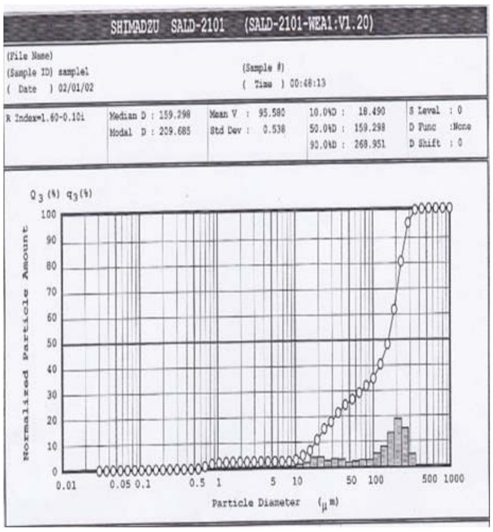
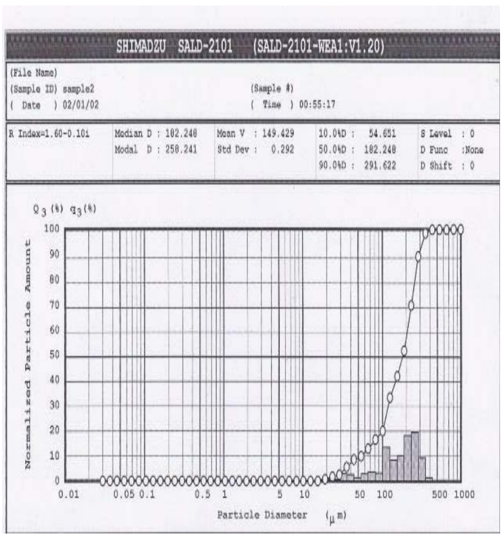


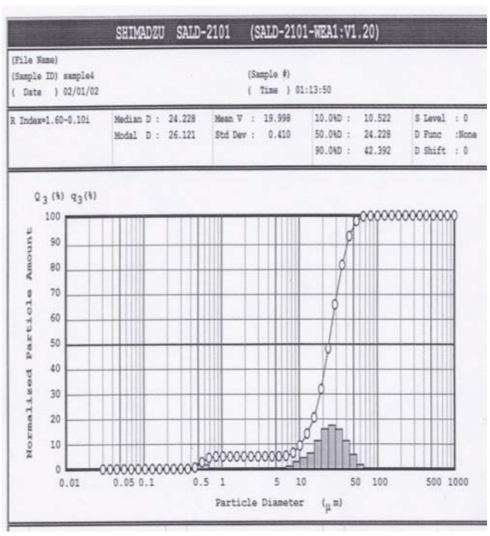
A- RHA (Rice Husk Ash



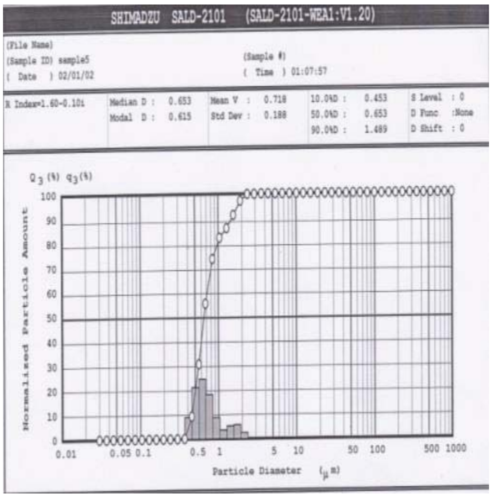
B- Carrot powder



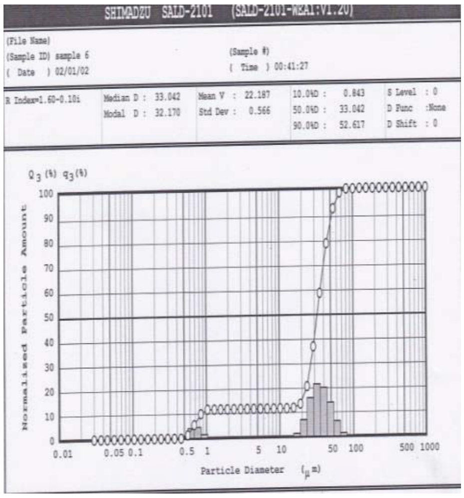
C- Sawdust



D- Na_2CO_3



E- $CaCO_3$



F- $CaCO_3$

Fig. (1) Particle size of natural and industrial powder (A-Rice Husk Ash, B-Carrot powder, C- Sawdust, D-Na_2CO_3, E-$CaCO_3$, F-K_2CO_3)

Table (1) Chemical composition of RHA, carrot powder and sawdust.

A (RHA)		B (Carrot powder)		C (Wood powder) Sawdust	
Chemical Composition	**(Content %)**	**Chemical Composition**	**(Content %)**	**Chemical Composition**	**(Content %)**
SiO_2	94.41%	Al	3.82%	Cellulose	47%
Al_2O_3	0.15%	B	0.30%	Lignin	21%
Fe_2O_3	0.99%	Ca	31.27%	Hemi- Cellulose and other compounds	30%
CaO	0.52%	Cr	0.086%	Extractives	2%
MgO	0.70%	Cu	0.06%	Ash	0.4%
K_2O	2.27%	Fe	6.05%		
Na_2O	0.26%	K	35.55%		
P_2O_5	0.62%	Mg	3.87%		
TiO_2	<0.01%	Mn	0.403%		
MnO	0.08%	Na	6.08%		
		Ni	0.059%		
		P	12.85%		
		Se	0.005%		
		V	0.184%		
		Zn	0.281		

Table (2): Chemical composition of $CaCO_3$, K_2CO_3 and Na_2CO_3

A		B		C	
Material	**Ca_2CO_3 (Content %)**	**Material**	**K_2CO_3 (Content %)**	**Material**	**Na_2CO_3 (Content %)**
$CaCO_3$	97.5%	K_2CO_3	97%	Na_2CO_3	98.5%
$MgCO_3$	0.87%	$MgCO_3$	0.71%	$MgCO_3$	0.89%
SiO_2	0.30%	SiO_2	0.25%	SiO_2	0.50%
Al_2O_3	0.14%	Al_2O_3	0.21%	Al_2O_3	0.17%
Fe_2O_3	o.12%	Fe_2O_3	0.15%	Fe_2O_3	o.15%
Na_2O	< 0.08%	Na_2O	< 0.07%	CaO	< 0.09%
K_2O	< 0.04%	Cao	< 0.05%	K_2O	< 0.05%
T.O.C.	0.025%	T.O.C.	0.031%	T.O.C.	0.027%
Absorption H_2O	0.18%	Absorption H_2O	98.6%	Absorption H_2O	99.19%

Tables (3) Erosion wear after (10 hours) for all samples prepared from epoxy resin reinforced with 6% vf. glass fibers and (3%, 6% vf.) natural and industrial powders under different variables

Filler content	Stand-off distance (cm)	angle	Grin size (sand) (µ m)	Temperature (C°)	Salt content (gm)	Water content (ml)	Total weight (Ws) (gm)	Weight after erosion (WL) (gm)	Erosion rate (€) $W_L/W_S*\rho_t$ (cm^3/gm)
Pure epoxy	20	30°	425 µ m	25	100	2	7.7006	7.6800	0.0022
Pure epoxy	25	60°	600 µ m	30	200	2.5	7.7006	7.6752	0.0027
Pure epoxy	30	90°	850 µ m	35	300	3	7.7006	7.6600	0.0043
Epoxy+6% GF	20	30°	600 µ m	30	300	3	8.3645	8.3534	0.0011
Epoxy+ 6% GF	25	60°	850 µ m	35	100	2	8.3645	8.3524	0.0017
Epoxy+6% GF	30	90°	425 µ m	25	200	2.5	8.3645	8.3540	0.0010
Epoxy+6%GF +3%RHA	20	60°	425 µ m	35	200	3	8.4597	8.4586	0.00011
Epoxy +6%G.F+3%RHA	25	90°	600 µ m	25	300	2	8.4597	8.4575	0.00022
Epoxy +6%GF +3%RHA	30	30°	850 µ m	30	100	2.5	8.4597	8.4564	0.00033
Epoxy+6%GF +6%RHA	20	60°	425 µ m	35	200	3	8.7495	8.7484	0.00010
Epoxy +6%G.F+6%RHA	25	90°	600 µ m	25	300	2	8.7495	8.7473	0.00021
Epoxy +6%GF +6%RHA	30	30°	850 µ m	30	100	2.5	8.7495	8.7462	0.00031
Epoxy+6%GF +3%Carrot	20	60°	425 µ m	35	200	3	8.8148	8.8000	0.0014
Epoxy +6%G.F+3%Carrot	25	90°	600 µ m	25	300	2	8.8148	8.7950	0.0019
Epoxy +6%GF +3%Carrot	30	30°	850 µ m	30	100	2.5	8.8148	8.7900	0.0024
Epoxy+6%GF +6%Carrot	20	60°	425 µ m	35	200	3	9.0497	9.0380	0.0011
Epoxy +6%G.F+6%Carrot	25	90°	600 µ m	25	300	2	9.0497	9.0300	0.0018
Epoxy +6%GF +6%Carrot	30	30°	850 µ m	30	100	2.5	9.0497	9.0270	0.0021
Epoxy+6%GF +3%Sawdust	20	60°	425 µ m	35	200	3	8.2750	8.2485	0.0028
Epoxy +6%G.F+3%Sawdust	25	90°	600 µ m	25	300	2	8.2750	8.2400	0.0037
Epoxy +6%GF +3 Sawdust	30	30°	850 µ m	30	100	2.5	8.2750	8.2375	0.0040
Epoxy+6%GF +6%Sawdust	20	60°	425 µ m	35	200	3	8.6127	8.6015	0.0011
Epoxy +6%G.F+6%Sawdust	25	90°	600 µ m	25	300	2	8.6127	8.6002	0.0013
Epoxy +6%GF +6%Sawdust	30	30°	850 µ m	30	100	2.5	8.6127	8.5985	0.0014
Epoxy+6%GF +3%Na_2CO_3	20	60°	425 µ m	35	200	3	9.8683	9.7900	0.0063
Epoxy+6%GF +3%Na_2CO_3	25	90°	600 µ m	25	300	2	9.8683	9.7800	0.0071
Epoxy+6%GF +3%Na_2CO_3	30	30°	850 µ m	30	100	2.5	9.8683	9.7750	0.0075
Epoxy+6%GF +6%Na_2CO_3	20	60°	425 µ m	35	200	3	10.3664	10.2980	0.0050
Epoxy+6%GF +6%Na_2CO_3	25	90°	600 µ m	25	300	2	10.3664	10.2800	0.0064
Epoxy+6%GF +6%Na_2CO_3	30	30°	850 µ m	30	100	2.5	10.3664	10.2780	0.0065
Epoxy+6%GF +3%$CaCO_3$	20	60°	425 µ m	35	200	3	7.6703	7.6586	0.0011
Epoxy+6%GF +3%$CaCO_3$	25	90°	600 µ m	25	300	2	7.6703	7.6550	0.0015
Epoxy+6%GF +3%$CaCO_3$	30	30°	850 µ m	30	100	2.5	7.6703	7.6500	0.0020
Epoxy+6%GF +6%$CaCO_3$	20	60°	425 µ m	35	200	3	8.2050	8.2000	0.00046
Epoxy+6%GF +6%$CaCO_3$	25	90°	600 µ m	25	300	2	8.2050	8.1900	0.0013
Epoxy+6%GF +6%$CaCO_3$	30	30°	850 µ m	30	100	2.5	8.2050	8.1850	0.0018
Epoxy+6%GF +3%K_2CO_3	20	60°	425 µ m	35	200	3	8.2664	8.1681	0.0096
Epoxy+6%GF +3%K_2CO_3	25	90°	600 µ m	25	300	2	8.2664	8.1651	0.0099
Epoxy+6%GF +3%K_2CO_3	30	30°	850 µ m	30	100	2.5	8.2664	8.1630	0.0101
Epoxy+6%GF +6%K_2CO_3	20	60°	425 µ m	35	200	3	8.5949	8.4990	0.0086
Epoxy+6%GF +6%K_2CO_3	25	90°	600 µ m	25	300	2	8.5949	8.4940	0.0091
Epoxy+6%GF +6%K_2CO_3	30	30°	850 µ m	30	100	2.5	8.5949	8.4900	0.0095

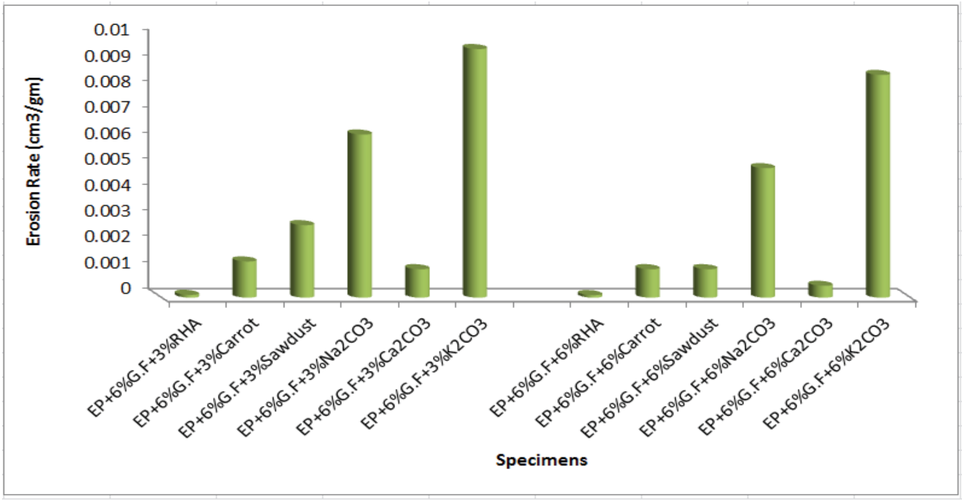


Fig. (2) Erosion wear after (10 hours) for all samples prepared from epoxy resin reinforced with 6% vf, glass fibers and (3%, 6% vf.) natural and industrial powders under different variables

Tables (4) Erosion wear after (15 hours) for all samples prepared from epoxy resin reinforced with 6% vf, glass fibers and (3%, 6% vf.) natural and industrial powders under different variables

Filler content	Stand-off distance (cm)	angle	Grin size (sand) (μ m)	Temperature (C°)	Salt content (gm)	Water content (ml)	Total weight (Ws) (gm)	Weight after erosion (WL) (gm)	Erosion rate (€) $W_L/W_S*\rho_t$ (cm^3/gm)
Pure epoxy	20	90°	850 μ m	30	200	2	7.7006	7.5743	0.0136
Pure epoxy	25	30°	425 μ m	35	300	2.5	7.7006	7.5863	0.0123
Pure epoxy	30	60°	600 μ m	25	100	3	7.7006	7.5753	0.0135
Epoxy+6% GF	20	60°	850 μ m	25	300	2.5	8.3645	8.3234	0.0040
Epoxy+ 6% GF	25	90°	425 μ m	30	100	3	8.3645	8.3320	0.0032
Epoxy+6% GF	30	30°	600μ m	35	200	2	8.3645	8.3300	0.0033
Epoxy+6%GF +3%RHA	20	90°	600 μ m	35	100	2.5	8.4597	8.4542	0.00056
Epoxy +6%G.F+3%RHA	25	30°	850 μ m	25	200	3	8.4597	8.4530	0.00068
Epoxy +6%GF +3%RHA	30	60°	425 μ m	30	300	2	8.4597	8.4550	0.00048
Epoxy+6%GF +6%RHA	20	90°	600 μ m	35	100	2.5	8.7495	8.7440	0.00052
Epoxy +6%G.F+6%RHA	25	30°	850 μ m	25	200	3	8.7495	8.74320	0.00060
Epoxy +6%GF +6%RHA	30	60°	425 μ m	30	300	2	8.7495	8.7451	0.00042
Epoxy+6%GF +3%Carrot	20	90°	600 μ m	35	100	2.5	8.8148	8.7690	0.0045
Epoxy +6%G.F+3%Carrot	25	30°	850 μ m	25	200	3	8.8148	8.7630	0.0051
Epoxy +6%GF +3%Carrot	30	60°	425 μ m	30	300	2	8.8148	8.7720	0.0042
Epoxy+6%GF +6%Carrot	20	90°	600 μ m	35	100	2.5	9.0497	9.0190	0.0029
Epoxy +6%G.F+6%Carrot	25	30°	850 μ m	25	200	3	9.0497	9.0170	0.0030
Epoxy +6%GF +6%Carrot	30	60°	425 μ m	30	300	2	9.0497	9.0200	0.0028
Epoxy+6%GF +3%Sawdust	20	90°	600 μ m	35	100	2.5	8.2750	8.2260	0.0052
Epoxy +6%G.F+3%Sawdust	25	30°	850 μ m	25	200	3	8.2750	8.2200	0.0058
Epoxy +6%GF +3 Sawdust	30	60°	425 μ m	30	300	2	8.2750	8.2300	0.0048
Epoxy+6%GF +6%Sawdust	20	90°	600 μ m	35	100	2.5	8.6127	8.5650	0.0046
Epoxy +6%G.F+6%Sawdust	25	30°	850 μ m	25	200	3	8.6127	8.5590	0.0054
Epoxy +6%GF +6%Sawdust	30	60°	425 μ m	30	300	2	8.6127	8.5720	0.0041
Epoxy+6%GF +3%Na_2CO_3	20	90°	600 μ m	35	100	2.5	9.8683	9.7700	0.0079
Epoxy+6%GF +3%Na_2CO_3	25	30°	850 μ m	25	200	3	9.8683	9.7650	0.0083
Epoxy+6%GF +3%Na_2CO_3	30	60°	425 μ m	30	300	2	9.8683	9.7730	0.0076
Epoxy+6%GF +6%Na_2CO_3	20	90°	600 μ m	35	100	2.5	10.3664	10.2720	0.0070
Epoxy+6%GF +6%Na_2CO_3	25	30°	850 μ m	25	200	3	10.3664	10.2600	0.0079
Epoxy+6%GF +6%Na_2CO_3	30	60°	425 μ m	30	300	2	10.3664	10.2750	0.0067
Epoxy+6%GF +3%$CaCO_3$	20	90°	600 μ m	35	100	2.5	7.6703	7.6430	0.0027
Epoxy+6%GF +3%$CaCO_3$	25	30°	850 μ m	25	200	3	7.6703	7.6400	0.0031
Epoxy+6%GF +3%$CaCO_3$	30	60°	425 μ m	30	300	2	7.6703	7.6450	0.0025
Epoxy+6%GF +6%$CaCO_3$	20	90°	600 μ m	35	100	2.5	8.2050	8.1775	0.0025
Epoxy+6%GF +6%$CaCO_3$	25	30°	850 μ m	25	200	3	8.2050	8.1760	0.0026
Epoxy+6%GF +6%$CaCO_3$	30	60°	425 μ m	30	300	2	8.2050	8.1800	0.0023
Epoxy+6%GF +3%K_2CO_3	20	90°	600 μ m	35	100	2.5	8.2664	8.1500	0.0114
Epoxy+6%GF +3%K_2CO_3	25	30°	850 μ m	25	200	3	8.2664	8.1450	0.0119
Epoxy+6%GF +3%K_2CO_3	30	60°	425 μ m	30	300	2	8.2664	8.1553	0.0109
Epoxy+6%GF +6%K_2CO_3	20	90°	600 μ m	35	100	2.5	8.5949	8.4700	0.0113
Epoxy+6%GF +6%K_2CO_3	25	30°	850 μ m	25	200	3	8.5949	8.4650	0.0117
Epoxy+6%GF +6%K_2CO_3	30	60°	425 μ m	30	300	2	8.5949	8.4800	0.0104

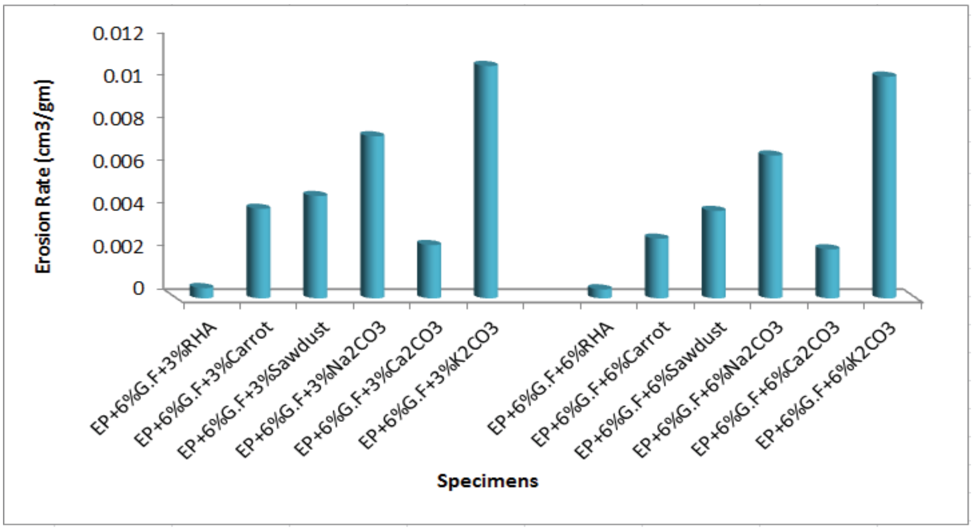


Fig. (3) Erosion wear after (15 hours) for all samples prepared from epoxy resin reinforced with 6% vf. glass fibers and (3%, 6% vf.) natural and industrial powders under different variables

Table (5) Coating and erosion wear after coating for the pure epoxy and (natural, industrial) composites

Composites	Weight before erosion	Weight after erosion at 15 hour	Weight after coating	Weight after erosion at 15 hour
Pure epoxy	7.7006	7.5743	7.9042	7.9030
Epoxy+6% glass fiber	8.3645	8.3234	8.6623	8.6614
Epoxy+6% GF+3%RHA	8.4597	8.4530	8.7915	8.7913
Epoxy+6% GF+6%RHA	8.7495	8.7432	9.0725	9.0724
Epoxy+6% GF+3% Carrot powder	8.8148	8.7630	9.1025	9.1020
Epoxy+6% GF+6% Carrot powder	9.0497	9.0170	9.3468	9.3464
Epoxy+6% GF+3% Sawdust	8.2750	8.2200	8.5589	8.5581
Epoxy+6% GF+6% Sawdust	8.6127	8.5590	8.8885	8.8879
Epoxy+6% GF+3% Na_2CO_3	9.8683	9.7650	10.1031	10.1026
Epoxy+6% GF+6% Na_2CO_3	10.3664	10.2600	10.5981	10.5977
Epoxy+6% GF+3% $CaCO_3$	7.6703	7.6400	7.9599	7.9596
Epoxy+6% GF+6% $CaCO_3$	8.2050	8.1760	8.5139	8.5137
Epoxy+6% GF+3% K_2CO_3	8.2664	8.1450	8.4746	8.4739
Epoxy+6% GF+6% K_2CO_3	8.5949	8.4650	8.8025	8.8019

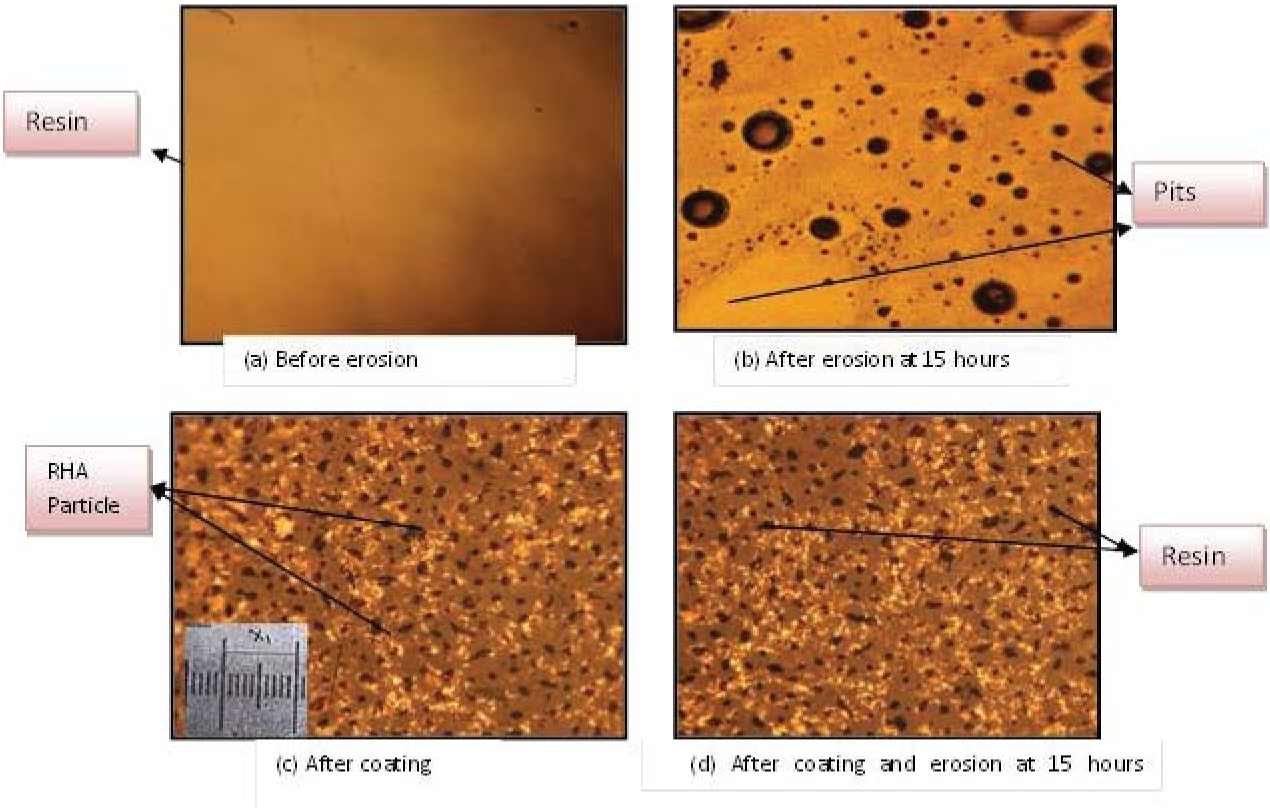


Fig. (4) Optical microscopy for pure epoxy (100X)