International Journal of Scientific & Engineering Research, Volume 7, Issue 2, February-2016
ISSN 2229-5518

Response Surface Methodology for The Optimization of Avocado Wood Filler (AWF)-high Density Polyethylene (HDPE) Composites Using Surface Modification

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ABSTRACT:

Response surface methodology was used to optimize the preparation of avocado wood filler (AWF)- high density polyethylene (HDPE) composites using surface modification. The effects of particle size and filler content on mechanical and water absorption properties were investigated. Central composite design was used to determine the optimum preparation condition of the composites to obtain the maximum tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water absorption. Regression models were developed for predicting the mechanical and water absorption properties based on central composite design. It was observed that the regression model developed by the properties of the composites exhibit a high coefficient of determination (R^2) value. The optimum process parameters were 100 mesh partcle size and 23.27wt% filler content. Under the optimum condition, the tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water absorption were 29.34671MPa, 3.542048%, 1.018416GPa, 76.2366MPa, 0.922318GPa, 1022.276Pa, 74.01456KJ/m^2 and 1.230679%, respectively.

Keywords: optimization, surface modification, HDPE, avocado wood flour, polymer composites, mechanical properties, response surface methodology

1. INTRODUCTION

In the world today, much emphasis has been given to natural filler for the replacement of inorganic fillers in the production of organic filler thermoplastic composites due to its comparative advantages; these natural fillers if properly harnessed will add significant value to the Nigeria economy as a result of her large vegetation and forest trees. These organic fillers have been used for polymer composites as a result of the following merits; low cost, renewability, low density and high specific mechanical properties [1]. However, the enormous advantages of the trees in sub-Sahara Africa have been under utilized for the provision of fillers for the production of composites which can be further used in the manufacturing of various products like; automobile parts and house-hold furniture.

Avocado pear wood has not been used by many researchers for the production of polymer composites as organic fillers. Apart from the aforementioned merits of organic fillers have in the production of composites, there are also some demerits associated with its applications, such as; high moisture absorption, weak adhesion between the filler and polymer matrix, thermal instability during processing and the low wet ability [2,3]. These poor bonding leads to incompatibility between the filler and polymer which is influenced by the intermolecular hydrogen bonding of the wood flour [4, 5]. These problems can be reduced by the chemical treatment of fillers.

Cellulose is the major constituent of organic fillers. It is a homo-polysaccharide that is mostly comprised of β-1,4- glocosidic which is joined by glucose monomers. It has a large degree of polymerization more than 10000, as it forms the largest component of natural fibers [6]. Due to its linear bond, it leads to the formation of entering and extra molecular hydrogen bonds. This hydrogen bond also leads to 36 glucose chains which are inside the crystalline constituent of the fibers. Almost 50-90% of the cellulose is crystalline which proportional to the source of natural

fibers [8]. In natural fibers, the nature of the structure and intermolecular hydrogen bonds provides high tensile strength, resistance to attack of micro-organisms and insoluble in several solvents. Other constituents of the organic filler such as; lignin, hemicelluloses and impurities have to be reduced by chemical treatment in order to boast the cellulose content. The chemical treatments are alkylation, cyanoethethylation and acetylation, treated with coupling agent such as maleated polyethylene further improves the bonding between the fillers and polymer to increase the mechanical properties of composites.

Thermoplastics are often used in the production of composites. These include; polyethylene, polypropylene, polyvinyl chloride and polystyrene [13]. These materials provide excellent matrix for the production of polymer-organic filler composites for various purposes.

The effect of input variable (filler content) on the mechanical and water absorption properties (tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water adsorption) was studied on a one factor plot. Also the optimization of the conditions of the input variable to maximize the mechanical and water absorption properties was carried out.

2. Material and Methods

2.1 Collection and Preparation of avocado wood flour.

The avocado palm wood was obtained in Federal Housing Estate Trans Ekulu in Enugu State of Nigeria. The fiber was sun dried for 14 days during the Harmattan season, after which the bark was removed. It was cut using a cutlass to small pieces to enable the grinding machine to take the feed. The fiber was later ground. The grinding operations were done in Kenyetta Timber market Agbani Road, Enugu. It was finally sieved using particle sizes of 100-20 mesh.

2.2 Collection and Preparation of Polyethylene

The HDPE was manufactured from Indorama Petrochemical Limited Eleme, Port Harcourt, Rivers State and bought at Awada, Onitsha in Anambra State of Nigeria.

2.3 Collection of Maleated Polyethylene

This was obtained from Sigma-Aldrich chemical corporation.

2.4 Collection of Sodium Hydroxide and Acetic Acid

These were obtained in Main Market, Enugu.

2.5 Treatment of the organic filler

The filler was soaked in a 6wt% sodium hydroxide solution for 16hrs and 4vol% acetic acid for 1hour. The filler was finally washed with distilled water, filtered and sun-dried for 10hrs. The treated filler was mixed with 5wt% maleated polyethylene.

2.6 Composite Preparations

The avocado wood filler at different weight percent were filled in HDPE. The treated filler was mixed with the HDPE.

The avocado wood filler was filled at 5, 10, 15, 20, and 25% by weight of the filler content. The various compositions of the filler and the HDPE were moulded using an injection moulding machine that was carried out in Ekenedilichukwu workshop Onitsha.The composites were prepared, cooled and cut to machine size in order to subject them for mechanical test for determination of tensile, flexural, hardness,impact and water absorption properties.

2.7 Testing of Tensile Properties of Composites

This test was carried in the University of Nigeria Civil Engineering Workshop, Nsukka Enugu State of Nigeria using a universal tensometer BSS1610 model no 8889 manufactured by Hounsfield tensometer limited. This test was carried using ASTM D638. The equipment has a cross-head speed between10-100cm.

The dimensions of tensile test sample size for ASTM used were 3.2mm x 19mm x 160mm. The samples were inserted into the griping chucks of the tensometer and placed firmly. A continuous load was applied to the sample and till fracture occurs. The ultimate tensile strength, elongation and modulus were calculated.

2.8 Testing of Flexural Sample Properties

The equipment used for this was universal tensometer used in a tensile test above. The dimension of flexural test sample size for ASTM D790 used were 3.2mm x 19mm x 300mm. The test sample was placed and fixed firmly on 3-point support span. A continuous load was applied in the centre of the sample until fracture and constant deflection occurred. The test was stopped at this condition. The flexural strength and modulus were obtained.

2.9 Testing of Hardness Properties Sample

The equipment used for this test was also universal tensometer. The dimension of hardness sample size for ASTM E103 used was 3.2 mm × 19mm× 19mm.The sample was clamped into the machine. A steel Brinnel bulb of diameter of 10mm was picked to obtain the indentation for this test. The sample was fixed in the equipment after which the indentation test connections were placed in the tensometer testing machine. The sample was subject to a specific load in the machine, the indentation which corresponded to the depth of indentation was measured. The Brinnel hardness was evaluated using this formula

$$BHN = \frac{2F}{\pi D\left[D-\sqrt{D^2-d^2}\right]} \quad (1)$$

Where BHN is the Brinnel Hardness Number (Pa), D is the diameterof the steel ball, d is the depth of indentation (m) and F is the load (N).

2.10 Testing of Impact Specimen

The equipment used for this test was impact tester machine located at the University of Nigeria, Nsukka, Mechanical Engineering Department Workshop, Enugu State.

The dimension of impact testing specimen size for ASTM D610-02M used was 3.2 mm × 19 mm×80mm. The specimen was clamped into the machine. The pendulum from the impact tester was released and allowed to strike through the specimen. The impact strength was determined.

2.11 Water Absorption Test

The test was carried out at Divine Chemical and Analytical Laboratory, Nsukka, Enugu state. The composite sample was cut to dimension of 3.2mm x 19mm x19mm oven dried for 50^{o}C for 30 minutes [14] according to ASTM specification and initially weighed (B_1). The sample was immersed in water for 12 weeks at room temperature using ASTM D96 – 06 and weighed again (B_2) after the left over water on the surface was removed. The percentage of water absorption was calculated using the formula:

$$M = \frac{B_2-B_1}{B_1} \times \frac{100}{1} \quad (2)$$

Where M is water absorption percentage of the composite, B_1 is the initial weight and B_2 is the weight after immersing in water.

2.12 Experimental Design

Response surface methodology was utilized to determine the optimum conditions for the preparation of the composites. The design of experiments was carried out using the software design expert 7.0. version. Two independent variables were applied using central composite design. The variables used were particle size (X_1) and filler content (X_2). The design consisted of 13 runs. The five levels (lowest, low, centre, high, highest) and the coding (-α, -1, 0, +1 and +α), and factors: particle size (100-20 mesh) and filler content (5 to 25%) were shown in Table 1. The response surface functions measured were tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water absorption. These can be represented by the equation, as a function of X_i and X_j as follows:

$$Y_i = B_O + \sum_{i=1}^{n} B_i X_i + \sum_{i=0}^{n} B_{ii} X_i^2 + \sum_{i=1}^{n}\sum_{i=i+1}^{n} B_{ij} X_i X_j + \varepsilon \quad (3)$$

Where Y_i is the predicted response, B_o is the constant coefficient, B_i the linear coefficients, B_{ii} is the quadratic coefficients, Bij is the interactive coefficients, X_i X_j are the coded values of the variables, n is the number of independent test variables and ε is the random error.

Table 1 level and code of variable for central composite design

Variables	Factors	unit	Range and levels				
			Lowest	Low	Center	High	Highest
			-α	-1	0	+1	+α
Particle Size	X_1	mesh	9.32	20	60	100	110.68
Filler Content	X_2	%	2.33	5	30	25	27.67

3. Results and Discussion

3.1 Optimization of Mechanical and Absorption Properties of HDPE/AWF Composite

Table 2: Design Matrix and Responses of HDPE/AWF composite

	Factors		Responses							
	mesh	%	MPa	%	GPa	MPa	GPa	KJ/m2	Pa	%
Run	X_1	X_2	Y_{TS}	Y_E	Y_{TM}	Y_{FS}	Y_{FM}	Y_{IM}	Y_{BH}	Y_W
1	-1	1	27.55	3.25	0.963	62.61	0.875	1008	60.6	1.72
2	1	-1	31.87	4.32	0.909	74.11	0.79	398	76.48	0.85
3	0	-1.2671	31.5	4.23	0.88	69.64	0.757	339	73.73	0.87
	0	0	29.88	3.48	0.945	71.6	0.853	772	72.86	1.08
5	1	1	29.17	3.52	1.023	76.43	0.926	1074	73.46--	1.3
6	-1	-1	29.07	4.01	0.865	59.23	0.743	351	64.15	1.24
7	-1.2671	0	27.71	3.4	0.87	56.69	0.797	697	60.72	1.56
8	1.267103	0	30.41	3.83	0.955	75.46	0.88	789	75.3	0.97
9	0	0	29.88	3.48	0.945	71.6	0.853	772	72.86	1.08
10	0	1.267103	28.59	3.33	1.06	72.7	0.929	1091	70.04	1.53
11	0	0	29.88	3.48	0.945	71.6	0.853	772	72.86	1.08
12	0	0	29.88	3.48	0.945	71.6	0.853	772	72.86	1.08
13	0	0	29.88	3.48	0.945	71.6	0.853	772	72.86	1.08

Table 3: ANOVA for the eight responses of HDPE/AWF composite: Y_{TS}, Y_E, Y_{TM}, Y_{FS}, Y_{FM}, Y_{BH}, Y_{IM} and Y_W

Y_{TS}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	19.03121	5	3.806242	1143.66	< 0.0001	Significant
	A-Particle Size	8.52631	1	8.52631	2561.896	< 0.0001	
	B-Filler Content	8.670649	1	8.670649	2605.265	< 0.0001	
	AB	0.3481	1	0.3481	104.5934	< 0.0001	
	A^2	1.450583	1	1.450583	435.8558	< 0.0001	
	B^2	0.03557	1	0.03557	10.68758	0.0137	
	Residual	0.023297	7	0.003328			
	Lack of Fit	0.023297	3	0.007766		+-	
	Pure Error	0	4	0			
	Cor Total	19.05451	12				
	R-Squared	0.998777					
	Adj R-Squared	0.997904					
	Pred R-Squared	0.991004					

Y_E	Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
	Model	1.427491	5	0.285498	482.7017	< 0.0001	Significant
	A-Particle Size	0.175465	1	0.175465	296.6652	< 0.0001	
	B-Filler Content	1.011236	1	1.011236	1709.731	< 0.0001	
	AB	0.0004	1	0.0004	0.676294	0.4380	
	A^2	0.044015	1	0.044015	74.41733	< 0.0001	
	B^2	0.196375	1	0.196375	332.0182	< 0.0001	
	Residual	0.00414	7	0.000591			
	Lack of Fit	0.00414	3	0.00138			
	Pure Error	0	4	0			
	Cor Total	1.431631	12				
	R-Squared	0.997108					
	Adj R-Squared	0.995042					
	Pred R-Squared	0.978722					

Y_{TM}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	0.036504	5	0.007301	75.11491	< 0.0001	Significant
	A-Particle Size	0.006215	1	0.006215	63.945	< 0.0001	
	B-Filler Content	0.026857	1	0.026857	276.3184	< 0.0001	
	AB	6.4E-05	1	6.4E-05	0.658462	0.4438	
	A^2	0.002136	1	0.002136	21.97896	0.0022	
	B^2	0.001232	1	0.001232	12.67368	0.0092	
	Residual	0.00068	7	9.72E-05			
	Lack of Fit	0.00068	3	0.000227			
	Pure Error	0	4	0			
	Cor Total	0.037185	12				
	R-Squared	0.981703					
	Adj R-Squared	0.968634					
	Pred R-Squared	0.864054					

Y_{FS}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	453.761	5	90.75221	2604.671	< 0.0001	Significant
	A-Particle Size	381.9834	1	381.9834	10963.27	< 0.0001	
	B-Filler Content	12.72002	1	12.72002	365.0763	< 0.0001	
	AB	0.2809	1	0.2809	8.062087	0.0251	
	A^2	58.57597	1	58.57597	1681.184	< 0.0001	
	B^2	0.200772	1	0.200772	5.762344	0.0474	
	Residual	0.243895	7	0.034842			
	Lack of Fit	0.243895	3	0.081298			
	Pure Error	0	4	0			
	Cor Total	454.0049	12				
	R-Squared	0.999463					
	Adj R-Squared	0.999079					
	Pred R-Squared	0.996056					

Y_{FM}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	0.039348	5	0.00787	366.5063	< 0.0001	Significant
	A-Particle Size	0.005724	1	0.005724	266.5904	< 0.0001	
	B-Filler Content	0.032747	1	0.032747	1525.09	< 0.0001	
	AB	4E-06	1	4E-06	0.18629	0.6790	
	A^2	0.000568	1	0.000568	26.45274	0.0013	
	B^2	0.000305	1	0.000305	14.21169	0.0070	
	Residual	0.00015	7	2.15E-05			
	Lack of Fit	0.00015	3	5.01E-05			
	Pure Error	0	4	0			
	Cor Total	0.039498	12				
	R-Squared	0.996195					
	Adj R-Squared	0.993477					
	Pred R-Squared	0.971962					

Y_{BH}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	742358.5	5	148471.7	389.905	< 0.0001	Significant
	A-Particle Size	7308.73	1	7308.73	19.19363	0.0032	
	B-Filler Content	724599.9	1	724599.9	1902.889	< 0.0001	
	AB	90.25	1	90.25	0.237008	0.6412	
	A^2	2439.852	1	2439.852	6.407353	0.0392	
	B^2	7919.725	1	7919.725	20.79818	0.0026	
	Residual	2665.526	7	380.7894			
	Lack of Fit	2665.526	3	888.5086			
	Pure Error	0	4	0			
	Cor Total	745024	12				
	R-Squared	0.996422					
	Adj R-Squared	0.993867					
	Pred R-Squared	0.973497					

Y_{IM}	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	338.5645	5	67.71291	442.5728	< 0.0001	significant
	A-Particle Size	264.3947	1	264.3947	1728.088	< 0.0001	
	B-Filler Content	17.53737	1	17.53737	114.6246	< 0.0001	
	AB	0.070225	1	0.070225	0.458992	0.5199	
	A^2	53.25809	1	53.25809	348.0959	< 0.0001	
	B^2	3.304167	1	3.304167	21.5961	0.0023	
	Residual	1.070988	7	0.152998			
	Lack of Fit	1.070988	3	0.356996			
	Pure Error	0	4	0			
	Cor Total	339.6355	12				
	R-Squared	0.996847					
	Adj R-Squared	0.994594					
	Pred R-Squared	0.977048					

Y_W	Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
	Model	0.871716	5	0.174343	391.868	< 0.0001	significant
	A-Particle Size	0.336438	1	0.336438	756.2055	< 0.0001	
	B-Filler Content	0.432635	1	0.432635	972.425	< 0.0001	
	AB	0.000225	1	0.000225	0.505728	0.5000	
	A^2	0.071578	1	0.071578	160.8834	< 0.0001	
	B^2	0.030841	1	0.030841	69.32056	< 0.0001	
	Residual	0.003114	7	0.000445			
	Lack of Fit	0.003114	3	0.001038			
	Pure Error	0	4	0			
	Cor Total	0.874831	12				
	R-Squared	0.99644					
	Adj R-Squared	0.993897					
	Pred R-Squared	0.973583					

The design matrix and the experimental values of responses (tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water absorption) for HDPE/AWF composites is shown in Table 2 .The predicted values of the response were quadratic model fitting. The statistical model was generated by a regression analysis process using experimental data for the mechanical and absorption properties of HDPE/AWF composites. These were given as:

$$Y_{TS} = 28.22772+0.078030X_1-0.090323\ X_2-7.37500E\text{-}004\ X_1X_1-3.31522E\text{-}004\ X_1^2+8.30616E\text{-}004X_2^2 \quad (4)$$

$$Y_E = 4.43043-2.65508E\text{-}003\ X_1-0.094497X_2\ +5.77484E\text{-}005\ X_1^2+1.95166E\text{-}003X_2^2 \quad (5)$$

$$Y_{TM} = 0.80742+2.11064E\text{-}003\ X_1+8.65569E\text{-}004X_1\ -1.27224E\text{-}005\ X_1^2+1.54574E\text{-}004\ X_2^2 \quad (6)$$

$$Y_{FS} = 50.05079+0.44469X_1\ +0.23177X_2\ -6.62500E\text{-}004\ X_1X_1\ -2.10669E\text{-}003X_1^2-1.97339E\text{-}003X_2^2 \quad (7)$$

$$Y_{FM} = 0.67130+1.45408E\text{-}003X_1\ +8.89683E\text{-}003X_2-6.56012E\text{-}006X_1^2-7.69342E\text{-}005\ X_2^2 \quad (8)$$

$$Y_{BH} = 123.12046+2.24934\ X_1\ +42.74480X_2\ -0.013596X_1^2-0.39194X_2^2 \quad (9)$$

$$Y_{IM} = 57.42403+0.38746X_1\ +0.064343X_2-2.00879E\text{-}003X_1^2-8.00556E\text{-}003X_2^2 \quad (10)$$

$$Y_W = 1.45828-0.013956X_1\ +2.41592E\text{-}003X_2\ +7.36426E\text{-}005X_1^2+7.73436E\text{-}004X_2^2 \quad (11)$$

3.1.1 ANOVA Analysis for HDPE/AWF composite

It was observed in From Table 3 , that the model displayed high F-value(F models = 1143.66, 480.7, 75.11, 2604.67, 366.51, 389.9, 442.57 and 391.87) for tensile strength (Y_{TS}), elongation (Y_E), tensile modulus (Y_{TM}), flexural strength (Y_{FS}), flexural modulus (Y_{FM}), hardness (Y_{BH}), impact strength (Y_{IM}) and water absorption (Y_W), respectively. The probability values were low (P models = 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001 and 0.0001) for tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, Brinell hardness, impact strength and water absorption, respectively. The linear, the second order particle size and the filler content were the significant model terms. The interactive term (AB) shows no significant effect on, Y_E, Y_{TM}, Y_{FM}, Y_{BH}, Y_{IM} and Y_W, respectively.

The fitting of the models was checked by the determination coefficient values (R^2 values = 99.88%, 99.71%, 99.17%, 99.95%, 99.62%, 99.64%, 99.68% and 99.64%), for tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength, and water absorption, respectively. The value of R^2 and adjusted R^2 are not significantly different as shown in Table 3.

These also gave the high significance of the models [15]. These showed that there is good precision and reliability of the experiment [16].

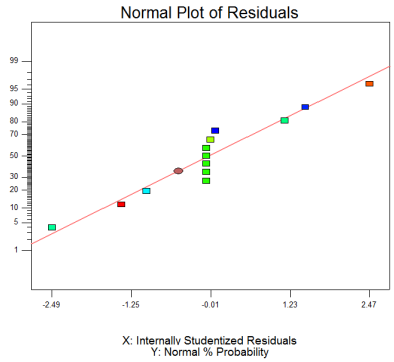

Fig 1

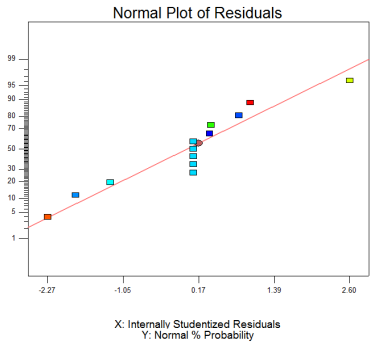

Fig 2

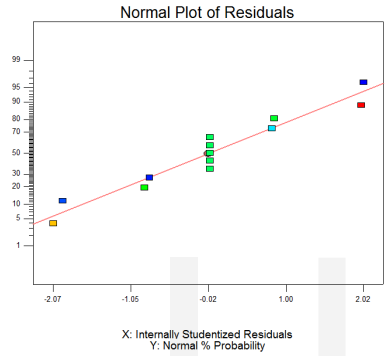

Fig 3

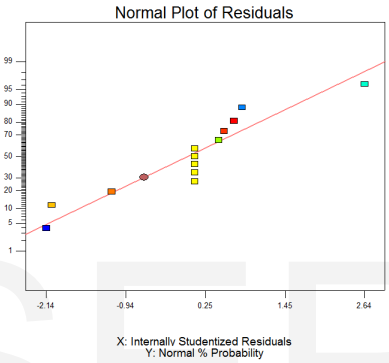

Fig 4

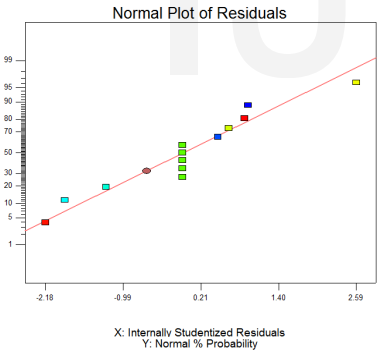

Fig 5

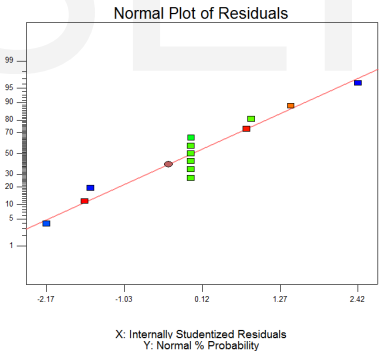

Fig 6

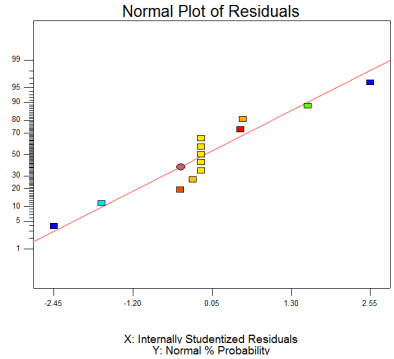

Fig 7

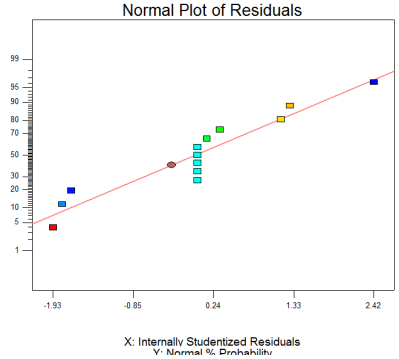

Fig 8

Fig(1-8): normal probability plots of residual for Y_{TS}, Y_E, Y_{TM}, Y_{FS}, Y_{FM}, Y_{BH}, Y_{IM} and Y_W of HDPE/AWF composite.

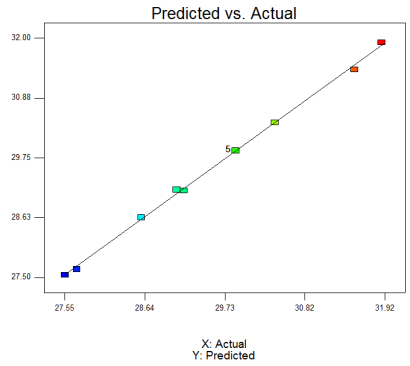

Fig 9

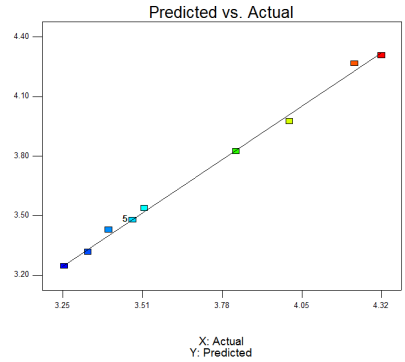

Fig 10

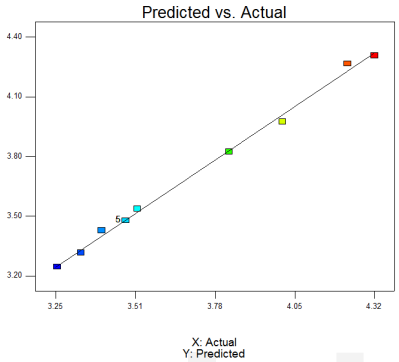

Fig 11

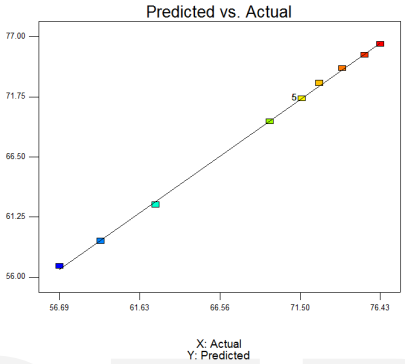

Fig 12

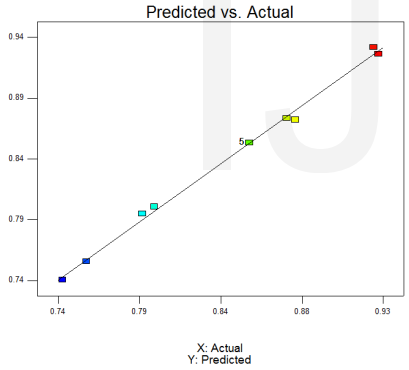

Fig 13

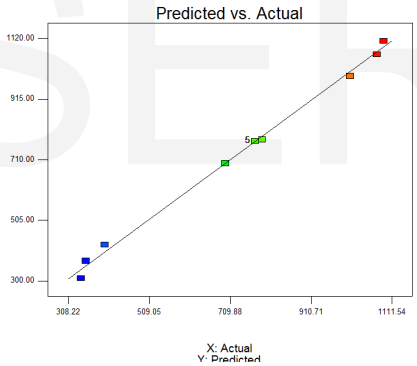

Fig 14

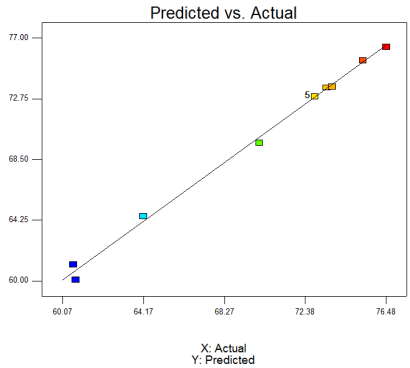

Fig 15

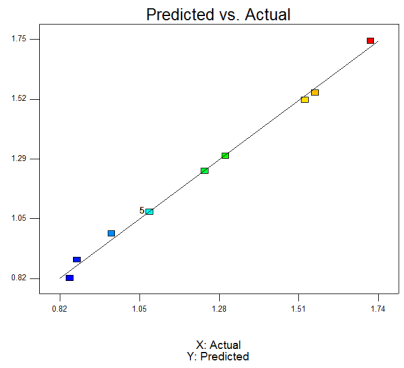

Fig 16

Fig(9-16): Predicted vs actual plots of residual for Y_{TS}, Y_E, Y_{TM}, Y_{FS}, Y_{FM}, Y_{BH}, Y_{IM} and Y_W of HDPE/AWF composite.

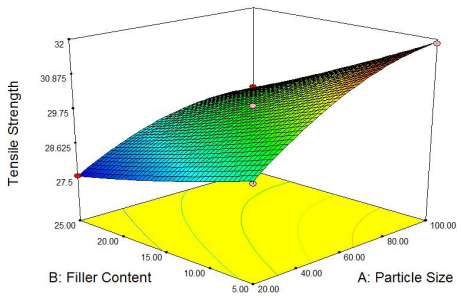

Fig 17

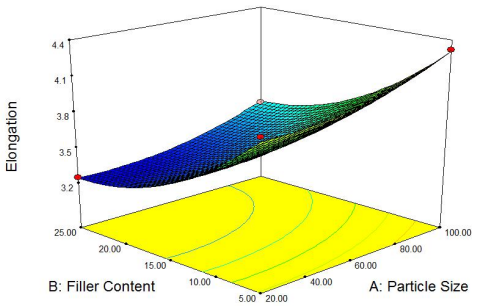

Fig 18

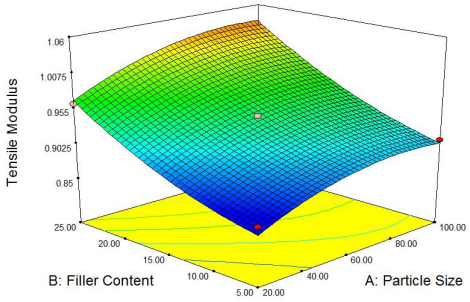

Fig 19

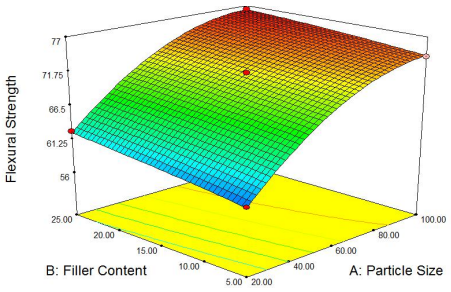

Fig 20

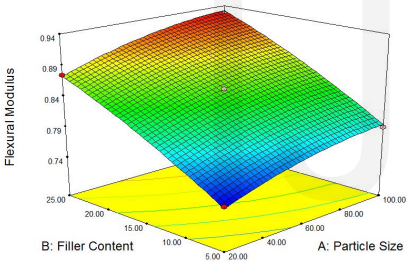

Fig 21

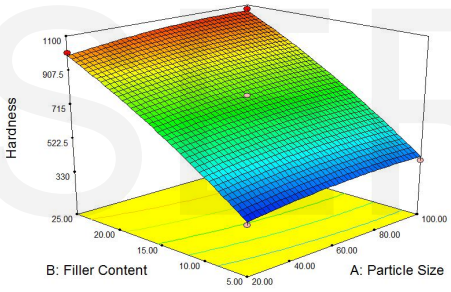

Fig 22

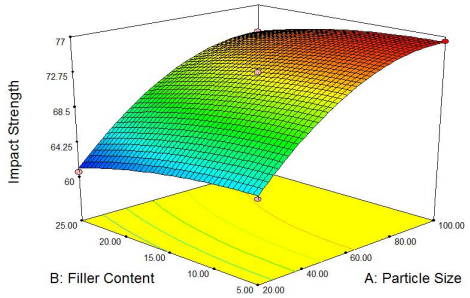

Fig 23

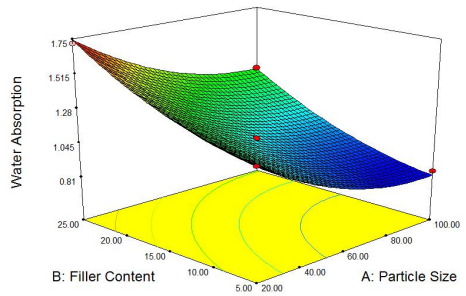

Fig 24

Fig(17-24): 3 D surface plots for Y_{TS}, Y_E, Y_{TM}, Y_{FS}, Y_{FM}, Y_{BH}, Y_{IM} and Y_W of HDPE/AWF composite.

The normal probability plots of residual for HDPE/AWF composite are shown in Fig (1-8). These plots are also used to determine the adequacy of the final model. These indicate whether the residuals followed a normal distribution, in which case the points will follow a straight line. Therefore, the points on the plots lie reasonably close to a straight line, confirming that the errors were normally dispersed.
The plot of predicted versus actual showed that there were proper correlations between actual and predicted mechanical and water absorption properties. These were indicated in Fig (9-16)
The Fig (17-24) described the 3D-surface plots of the models, showing the interactions between the independent variable (particle size and filler content) and the actual dependent variables (responses). The factors in these plots are the interaction between the particle size and filler content, and the output factors. The output factors are tensile strength, elongation, tensile modulus, flexural strength, flexural modulus, hardness, impact strength and water absorption, respectively as was observed.

Table 4: Optimum parameters for the mechanical and water absorption properties of HDPE/AWF composite

Properties	Particle Size (mesh)	Filler Content (%)	Prediction	Experiment	Percentage Error (%)
HDPE/AWF Composite					
Y_{TS} (MPa)	100	23.27	29.34671	29.318	0.097935
Y_{E} (%)	100	23.27	3.542058	3.533	0.256376
Y_{TM} (GPa)	100	23.27	1.018416	1.015	0.336573
Y_{FS} (MPa)	100	23.27	76.2366	76.123	0.149232
Y_{FM} (GPa)	100	23.27	0.922318	0.917	0.579954
Y_{BH} (Pa)	100	23.27	1022.276	1001.892	2.034562
Y_{IM} (KJ/m^2)	100	23.27	74.01456	73.856	0.214686
Y_{W} (%)	100	23.27	1.230679	1.271	3.17241

3.1.2 Validation of the models

It was observed in Table 4, that the optimum condition for HDPE/AWF composite in terms of the particle size and filler content is 100 mesh and 23.27%, respectively. The mechanical and water absorption properties at these conditions were 29.347MPa for tensile strength, 3.542058% for percentage elongation, 1.018416GPa for tensile modulus, 76.2366MPa for flexural strength, 0.922318GPa for flexural modulus, 1022.276Pa for Brinell hardness, 74.01456KJ/m^2 for impact strength and 1.230679% for water absorption respectively. These optimized values were in very close agreement with experimental values which include 29.318MPa tensile strength, 3.533% percentage elongation, 1.018418GPa tensile modulus, 76.123MPa for flexural strength, 0.917GPa flexural modulus, 1001.892Pa Brinell hardness, 73.856KJ/m^2 impact strength and 1.271% water absorption respectively. The percentage errors between the predicted and experiment values were less than 3.2%.

Conclusion

The statistical variables showed that the models for the optimization of mechanical and absorption properties of HDPE/AWF composites were significant. From the results, the optimization values using response surface methodology were in agreement with one obtained in the experimental data.

References

[1] A.K. Bledzki and J. Gassan, composites reinforced with cellulose based fibres'. Journal of Progress in Polymer Science, 24: 221-274, 1999.

[2] V. Haristov and S. Vasileva, "Dynamic mechanical and thermal properties of modified polypropylene composites wood fiber composites". Macromolecular Materials and Engineering, 288,798-806, 2003.

[3]A.J.Nunez ,J.M.Kenny,M.M. Reboredo,M.I.Aranguren and N.E.Marcovich, "Thermal and dynamic mechanical characterization of polypropylene wood-wood flour composites".Polymer Engineering and science,42,733-742,2002.

[4]S.E.Selke and I. Wichman,"Wood fiber/polyolefin composites.Composites":Part A:Applied Science and Manufacturing,35,321-326,2004.

[5] M. Kaci,S. Cimmino,C.silvestre,D. Duraccio, A. Benhamida and L.Zaidi,"Ethylene butyl acrylate glycidylmethacrylate terpolymer as an interfacial agent for isotactic polypropylene/wood flour composites".Macromolecular Materials and engineering,291,869-876,2006.

[6]S.N. Walford, "Sugarcane bagasse: How easy is it to measure its constituents" ? Proceedings South Africa Sugar Technology Association , 81: 266 – 273,2008.

[7] S.Y. Ding and M.E. Himmel, The maize primary cell wall microfibril: a new model derived from direct visualisation Journal Agric Food Chemistry, 54: 597-606, 2006.

[8] S.E. Jacobsen and C.E Wyman, Cellulose and hemicelluloses hydrolysis models for application to current and novel pretreatment proceeees''. Applied Biochemistry Biotechnology, 84-86: 81-96,2000.

[9] A.K. Mohanty, M. Misra and L.T. Drzal, Evaluation of interphase properties in fiber reinforced polymer composite using contact resonance force microscopy''. Composite Interfaces, 8: 313, 2001.

[10] B. Netral, T. Sabu, K.D. Chapal and A. Rameshwa, "Analysis of morphology and mechanical behaviors of bamboo flour reinforced polypropylene composites". Nepal Journal of Science and Technology 13(1): 95-100, 2012.

[11] M.Tajvidi and G. Ebrahimi, "Water uptake and mechanical characteristics of natural-polypropylene composites". Journal of Applied Polymer Science, 88:941-946, 2003.

[12] M. E. Malainine, M. Mahrouz, A.Dufresne, "lignocellulosic flour from cladodes of opuntia ficus–indica reinforced polypropylene composites", Macromolecular Materials and Engineering, 289: 855-863, 2004.

[13] Q. Li and L. M. Matuana, Surface of cellulosic materials modified with functionalized polyethylene coupling agent.Journal of Applied Polymer Science, 88: 278-286, 2003.

[14] A.G. Supri and .B.Y Lim, "Effect of treated and untreated filler loading on the mechanical, morphological, and water absorption properties of water hyacinth fibers low density polyethylene composites". Journal of Physical Science, 20(2): 85-96, 2009.

[15] A.I. Khuri and J.A. Cornell, Dekker M. Response surfaces: design and analysis. New York: Dekker; 1987.

[16] K.Kuchi, "Hopped delay for multiply process power control and handover procedure and optimization", Irving USA, Wiley, 2000.