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Modeling and Analysis of Process Parameters of Momordica Angustisepala Fibres and Ant hill Particles/Polyester Hybrid Composites

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Abstract

The modeling and analysis of process parameters of Momordica angustisepala fibres (MAf) and Ant hill particles/polyester hybrid composites was done using response surface method. Impact energy was used for modeling and analysis. The morphology of the composites was done using scanning electron microscope. Optimum conditions were obtained at 5wt% Ant hill particles, 6wt% MAf, curing temperature (87°C) and curing time (5 hours) with impact energy of 7.82 Jmm^2.The composition of 5wt% ant hill particles, 6wt% MAf, curing temperature (87°C) and curing time(5 hours) is recommended for structural application(car bumper) with impact energy of 7.72 Jmm^2.

Keywords: *Ant hill particles, curing time, microstructure, momordica angustisepala fibres*

INTRODUCTION

Polymer composites are potentials candidate been used in the automotive industry, construction, outdoor and indoor applications due to their high strength to weight ratio [1, 2]. Research and development today use experimental design in the modeling of the properties of these composites for structural applications. The used of experimental design not only save time but reduced drastically the cost of the materials. Pulakesh et al., reported on the optimization tensile strength using Taguchi orthogonal array of L_9 [3]. It was observed that feed rate and cutting speed have great effect on the polymer composite.

Mohana Krishnudu et al., used response surface method (RSM) and Taguchi method to optimize the mechanical properties of polyester/coir and Luffa hybrid composites [4]. They observed that weight percentage coir have effect on the tensile strength of the composites. Amit Binda et al., reported on hybridization synthetic (glass) and natural fibers (chemically treated jute) polyester composites [5].

Madu et al., reported on effect of process parameter to determine the optimum values of toughness, hardness, and tensile, compressive and flexural strengths of polyester/saw dust-rice composites for board application [6]. They obtained optimum values of 3.75, 182, 19.6MPa, 8.8MPa and 5.8MPa toughness, hardness, tensile, compressive and flexural strengths respectively. Bharathiraja et al., reported on the composites developed from polyester reinforced with coir, red mud and termite soil [7]. Design of experiment was used to determine the effect of processing parameters; it was observed that weight percentage fillers have great effect on the mechanical properties. Based on the forgoing that motivate interest in the study of experimental and numerical

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Analysis of Momordica angustisepala fibres and Ant hill particles/polyester hybrid composites. Since it has been reported by Atuanya et al., [8] that Momordica angustisepala fibres and Neife et al., that Ant hill particles are both promising reinforcing polymer materials for engineering applications [9].

MATERIALS AND METHOD

Materials

The polyester used in this study was the unsaturated isophthalic resin having a density 1.35gm/cc and elastic modulus 3.25. The Momordica Angustisepala (MA) fibre was purchase from Enugu Nigeria (Fig. 1) and the Ant hill used for the study was obtained in Awka Nigeria. In order to prevent the composites from sticking to the mould petroleum jelly was used as releasing agent. Cobalt nephthalate and Methyl-ethy-ketone (MEK) peroxide was used as catalyst and accelerator. They were purchased from Tony Chemical Enterprise, Lagos. Other materials used are: Sodium hydroxide solution, Acetic acid solution, distilled water, Stirrer.



Figure 1: *Pictorial view of momordica angustisepala (M.A) fiber.*

Method

The MA-fibres was extracted, cleaned with water and dried. The alkali treatment of MA-fibres was done by soaking in 5wt% NaOH aqueous solutions, and was further treated with 2wt% acetic acid for neutralization based on standard treatment. In order to remove impurities from the ant hill, the ant hill was soaked in water for two weeks and was then washed and sun dried and ground to powder with pulverizing machine. The ground ant hill particle was sieved to 250 µm mesh size. Response surface method was used for the experiment and modeling of the impact strength because the property is very important for indoor and outdoor engineering applications such as in car bumper. The aim of our experiment is to optimize the production of hybrid bio-composites using polyester resin as matrix, MA fibres and ant hill particles (AHp) as reinforcement. Table 1 displayed the process parameters used in the work.

Table 1: *The process parameters and levels.*

Process Parameters	Very Low (-2)	Low (-1)	Medium (0)	High(+1)	Very High (2)
Wt% ant hill powder	0	5	10	15	20
Wt% MAf	0	2	4	6	8
Post Curing Temperature (°C)	60	70	80	90	100
Curing Time (Hours)	2	3	4	5	6

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Based on the response surface method, the orthogonal array was constructed. The production of the composites was done using process parameters shows in Table 1. 2% each of methyl-ethyl-ketone and cobalt nephthalate was added to the composites mixture.

The particulate AHp was mixed in the polyester resin and the matted MA fibers was added in the composites mixture inside the mould. Curing of the composites was done for 24 hours under light pressure. Then the samples were post cured at temperatures and times as shown in Table 1 and in line with that done by Gay [10]. Furthermore post curing treatment was carried out in other to enhance better fiber-matrix interaction by conditioning; the process. After the completion of this process the samples of suitable dimension were cut for impact testing.

Charpy impact test was performed on pendulum impact tester accordance to ASTMD256 standard. Samples with 10mm×5mm×55mm dimensions and V-notch of 2mm deep were used. A velocity of 3.46 m/s was used for the analysis. The test results were calculated and the impact energy absorbed by the samples displayed. Morphology of the composites was analyzed using scanning electron microscope model: JEOLJSM-6480LV.

RESULTS AND DISCUSSION

Mean Effects of the Response Surface

Mean responses associates were determined with the help of mintab software 16. The various results obtained for the impact energy are shows in Table 2 and the plots are shows in Fig. 2.

From Fig. 2, main effects of mean to mean of the parameters affecting the impact energy of the composites. From Fig. 2, it was observed that as the weight percentage of MAf increases lead to increment in impact energy. Also the impact energy decreased with increase with wt% Ant hill from -2 to +2levels. The composite optimized result obtained at 5wt%Ant hill particles and 6wt% MAf composition was able to support impact load of the developed composite.

It was observed in Fig. 2 that as the curning temperature increaesd the impact energy also increaed. The thermal curing of the composites serves to increase the setting and thermal stability to the composites. From the work, it is quite clear that increase in temperature increased the impact energy. Curing temperature at level 2 (100°C) had great influence on the impact energy. It is clear that the higher the curing time the higher the impact energy.

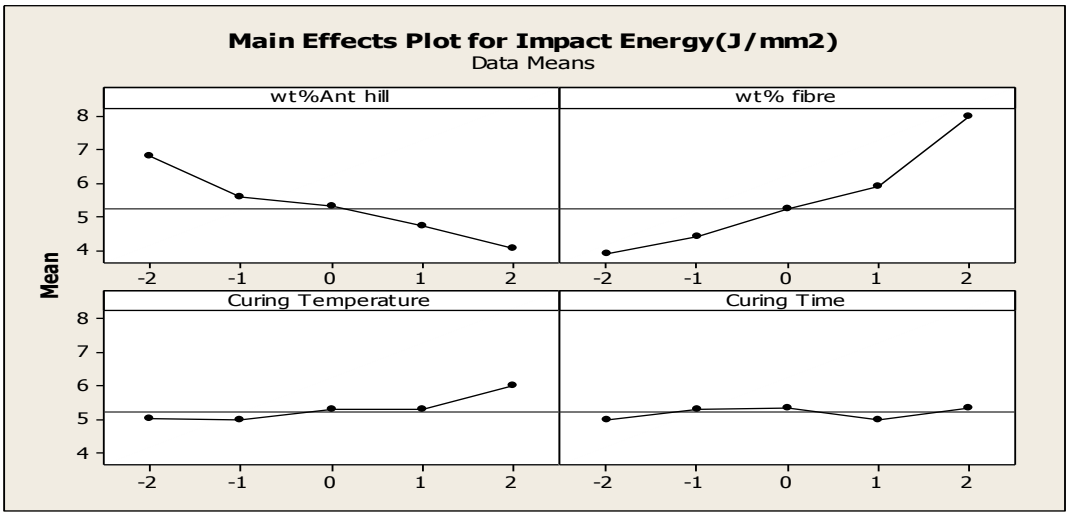


Figure 2: *Main effects plot for the means.*

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Table 2: *Orthogonal array RSM experimental design layout.*

Sr. No	Wt%Ant Hill	Wt% fibre	Temp	Time	wt% Ant hill	MAf	Temp	Time	Impact Energy(J/ mm^2)
1	0	0	0	0	10	4	80	4	5.08
2	-1	-1	1	1	5	2	90	5	4.01
3	1	-1	-1	-1	15	2	70	3	4.30
4	1	1	-1	-1	15	6	70	3	5.00
5	-1	1	1	-1	5	6	90	5	7.31
6	1	-1	1	-1	15	2	90	3	5.50
7	-1	1	-1	-1	5	6	70	3	5.60
8	1	-1	1	1	15	2	90	5	3.20
9	0	0	0	0	10	4	80	4	5.05
10	-1	-1	1	-1	5	2	90	3	4.20
11	1	1	1	1	15	6	90	5	6.78
12	-1	-1	-1	1	5	2	70	5	3.40
13	0	0	0	0	10	4	80	4	5.03
14	1	1	1	-1	15	6	90	3	4.30
15	1	1	-1	1	15	6	70	5	3.20
16	-1	-1	-1	-1	5	2	70	3	6.05
17	-1	1	1	1	5	6	90	5	7.05
18	0	0	0	0	10	4	80	4	5.03
19	1	-1	-1	1	15	2	70	5	4.56
20	-1	1	-1	1	5	6	70	5	7.01
21	0	0	0	2	5	6	80	6	5.34
22	2	0	0	0	10	4	80	4	4.05
23	0	2	0	0	10	8	80	4	7.98
24	0	0	0	0	10	4	80	4	5.08
25	0	0	0	0	10	4	80	4	5.07
26	0	0	-2	0	10	4	60	4	5.03
27	-2	0	0	0	0	4	80	4	6.78
28	0	0	2	0	10	4	100	4	5.99
29	0	0	0	-2	10	4	80	2	5.00
30	0	-2	0	0	10	0	80	4	3.89

Model Selection and Verification of Impact Energy

Design Expert 9 software used to analyze the analysis of variance (ANOVA). Table 3 displayed the results of the ANOVA. It was observed in Table 3, F-values of 4.19 means that the work is significant. Factors such as: A(Ant hill powder), B(MAf), AB(interaction between Ant hill and MAf), BD(interaction between MAf and curing time)are significant since the F-values less than 0.05 (Table 3).

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Table 3: *Dislayed ANOVA results of the work.*

Source	Sum of squares	DF	Sum of men	F	P	
Model	33.3	14	2.38	4.19	0.0046	Significant
A	6.46	1	6.46	11.37	0.0042	
B	16.68	1	16.68	29.37	0.0001	
C	0.79	1	0.79	1.39	0.257	
D	0.10	1	0.10	0.18	0.677	
A^2	0.019	1	0.019	0.03	0.858	
B^2	0.67	1	0.67	1.18	0.295	
C^2	0.068	1	0.068	0.12	0.734	
D^2	0.034	1	0.084	0.06	0.811	
A X B	2.88	1	2.88	5.07	0.040	
A X C	0.12	1	0.12	0.22	0.647	
A X D	0.08	1	0.08	0.14	0.713	
B X C	1.71	1	1.71	3.01	0.103	
B X D	3.53	1	3.53	6.21	0.025	
C X D	0.18	1	0.18	0.32	0.579	
Residual Error	8.52	15	0.57			
Lack-of-fit	8.52	10	0.85	1681.09	0.0001	Significant
Pure Error	0.00253	5	0.0005.06			
Total	41.85	29				

Mathematical Modeling

The second order polynomial equation obtained in the work for the impact energy is shown in equation 1. From equation 1 it is observed that the coefficient associated with wt% MAf and curing temperature is positive while coefficient associated with wt% Ant hill and curing time is negative. This means increasing the wt% MAf lead to increase in the impact energy. In this work, it has been seen clearly that wt% MAf have the higher effect on the impact energy.

Impact Energy (J/mm^2) =+5.07-0.52* A+0.83 * B+0.18 * C-0.065* D+0.02* A^2+0.16* B^2+0.050* C-0.035 * D^2-0.42* A * B+0.088 * A * C+0.071 * A * D+0.33 * B * C+0.47* B * D +0.11* C * D (1)

The residual plots of the experiment are shown in Fig. 2. Fig. 2 and 3 show that the adequacy of the research is good since the differences between the predicted and experimental values are closed since that absolute errors obtained in the work is 1.95%, hence the accuracy obtained in the regression model was good.

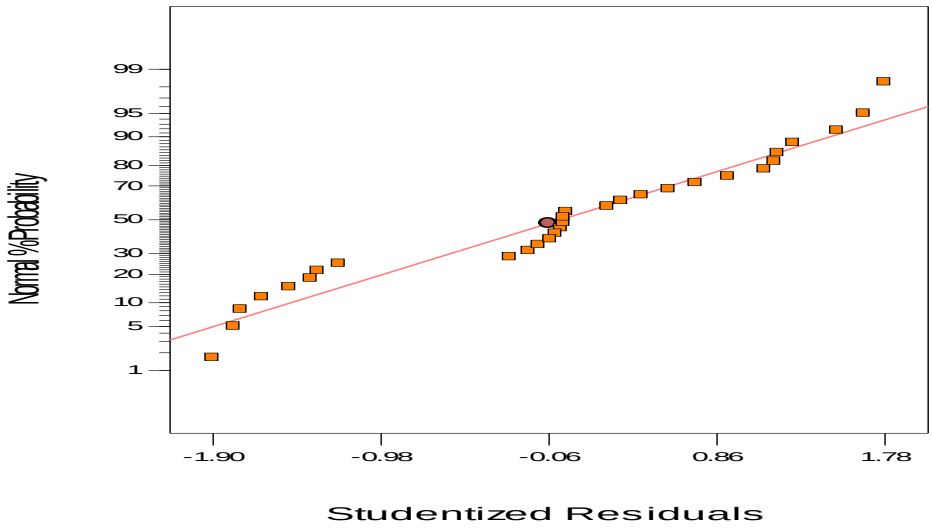


Figure 2: *Residual plots for impact energy.*

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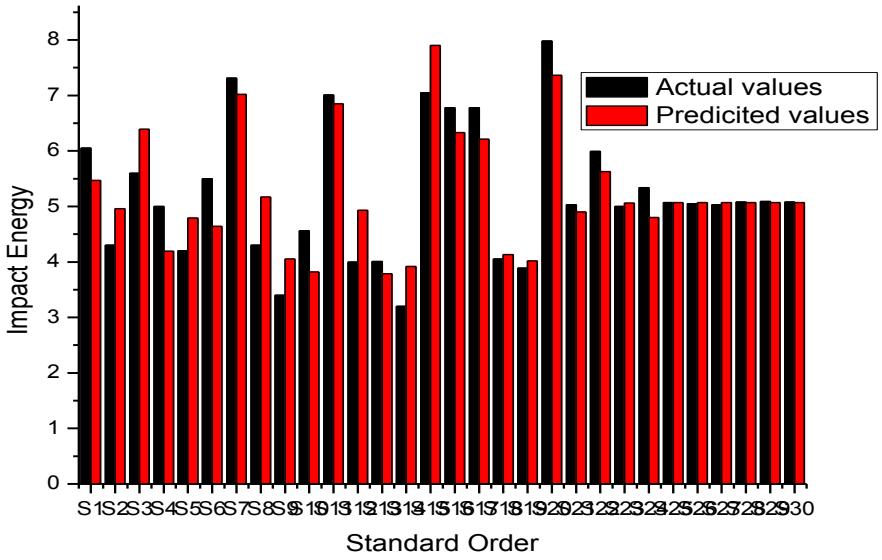


Figure 3: *Validation of mathematical model.*

Analysis of Response Surfaces

Fig. 4 to 8 displayed the results of the 3D response surface plots and contour plots of the factors: Ant hill, MAf, curing temperature, and curing time on impact energy. From Fig. 4, it was observed that the MAf had the greatest effect on the impact energy, followed by curing temperature and curing time. From Fig. 4, it can be seen that increasing the wt% MAf and decreasing the wt% Ant hill particles improves the impact energy. This could be attributed to the tough nature of the MAf. This is in par with the work of Muthuraman et al. [11].

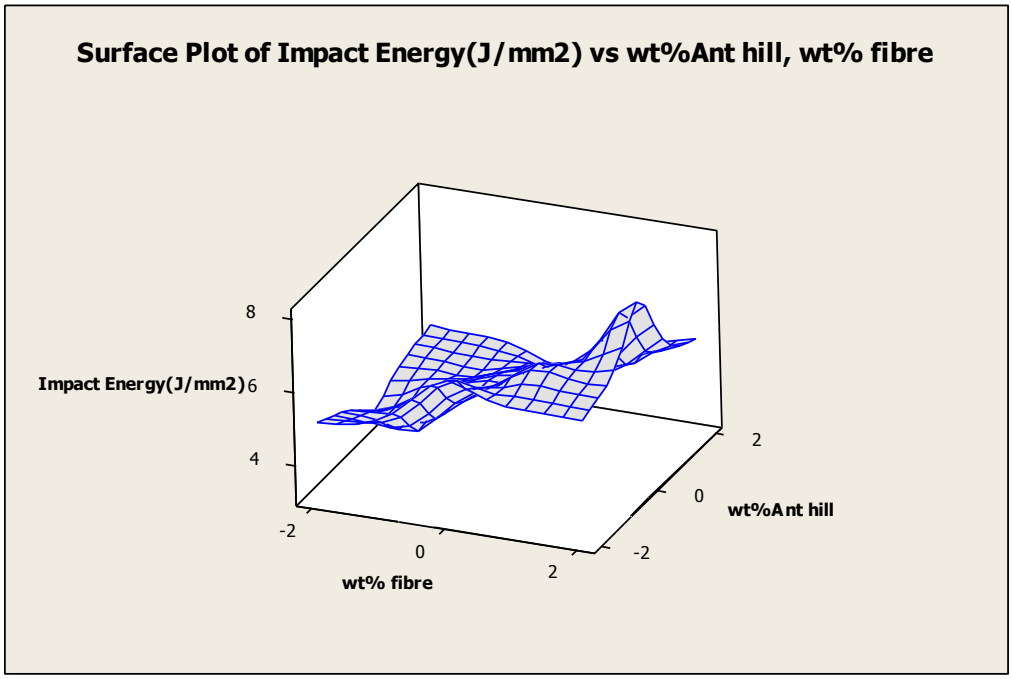


Figure 4: *3D plot of impact energy with wt% MAf and Ant hill.*

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From Fig. 5, it was observed that increasing the wt% MAf and increasing the curing temperature improved impact energy. This could be attributed to the tough nature of the MAf which help to strengthening the composites and the thermal curing of the composites that helped to improve the impact energy.

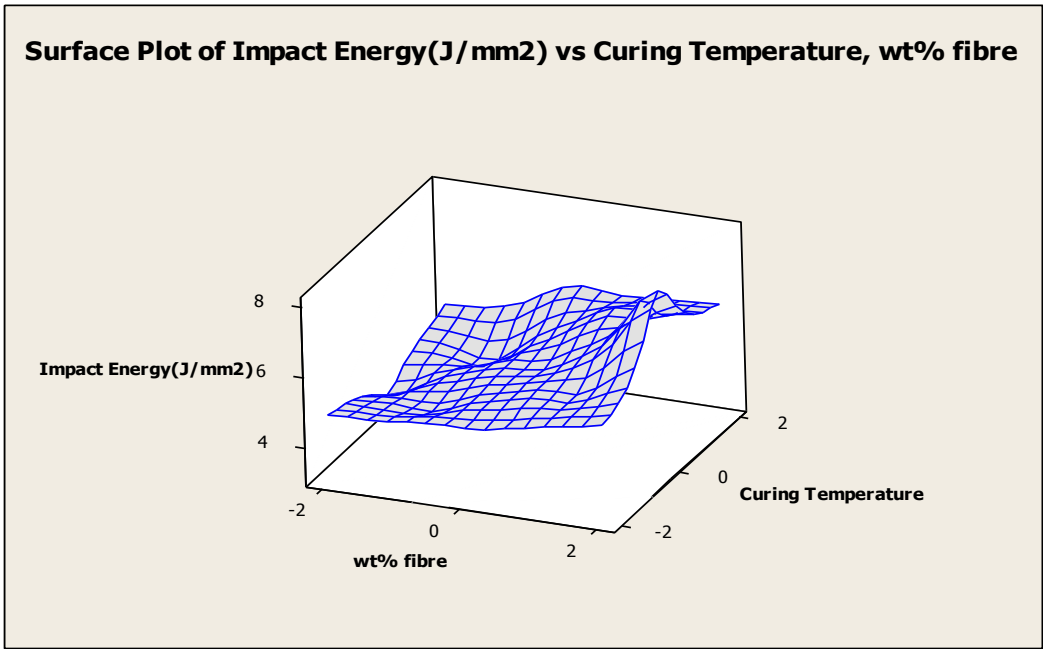


Figure 5: *3D plot of impact energy with wt% MAf and curing temperature.*

From Fig. 6, it is observed that by increasing the wt% MAf and decreasing the curing time impact energy improved. This could be attributed to the tough nature of the MAf and reduced time of the composites to set which help to strengthening the composites.

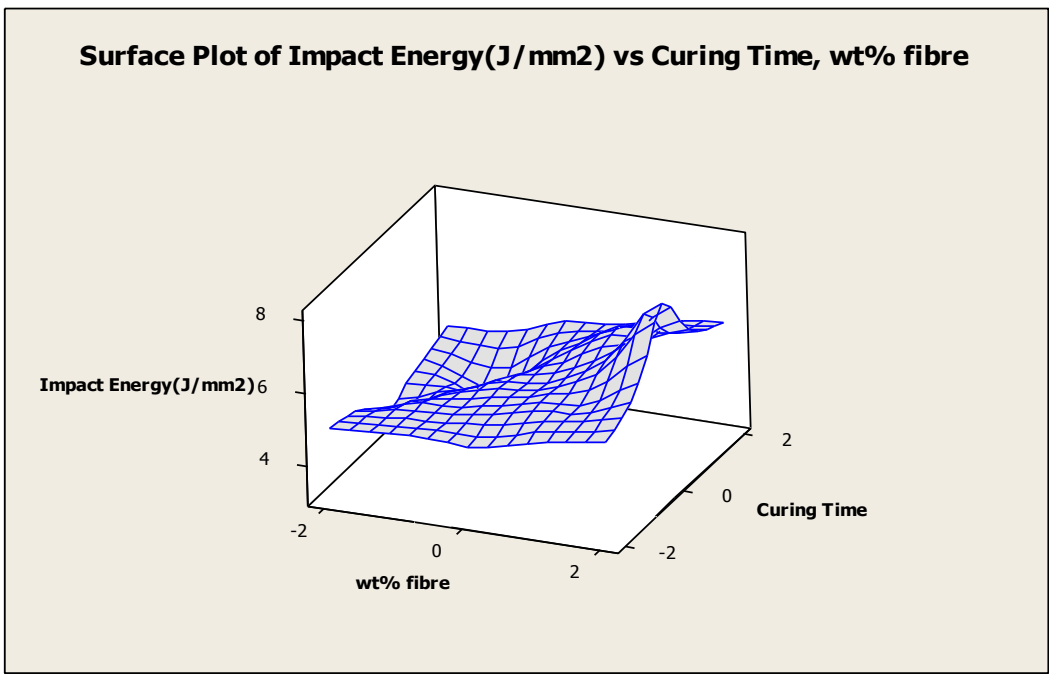


Figure 6: *3D plot of impact energy with wt% MAf and curing time.*

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From Fig. 7, it was observed that decreasing the wt% Ant hill and decreasing the curing time improved impact energy. This can be attributed to Ant hill particle contributing little in increasing the toughness of the composites.

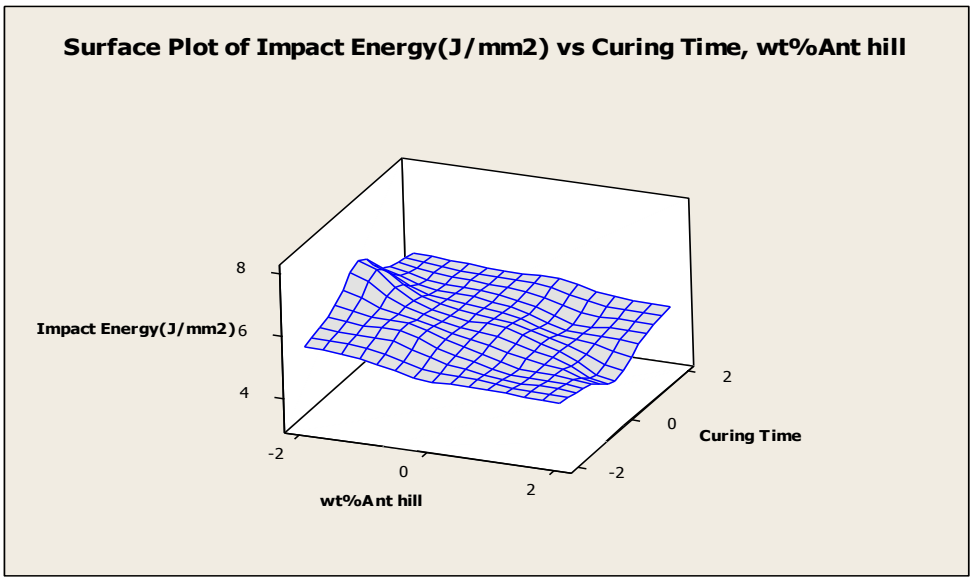


Figure 7: *3D plot of impact energy with wt% Ant hill and curing time.*

From Fig. 8, it was found that increasing the curing temperature and decreasing the curing time improved impact energy. This can be attributed to the fact that thermal curing of the composites reduced the curing time hence improves the toughness of the composites. Similar observation was observed by Ragupathi et al. [12].

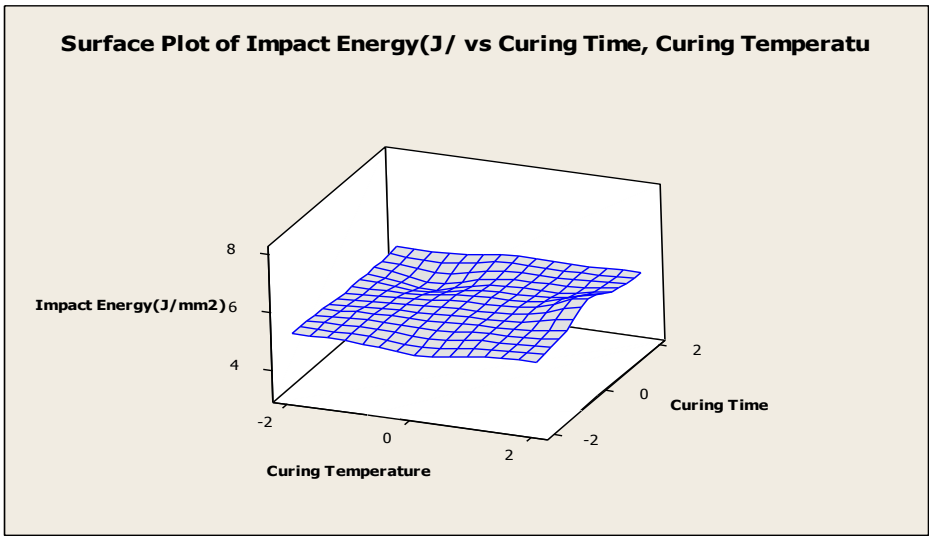


Figure 8: *3D plot of impact energy with temperature and curing time.*

Optimization of the Experiment

Fig. 9 displayed the optimization values of the impact energy. It was seen clearly in Fig. 9 that the impact energy of the composite with 5wt% Ant hill powder loading (-1), 6wt% MAf (+1), 87°C curing temperature and 5 hours curing time with 94.5% desirability with the greatest impact energy of 7.72J/mm^2 is the optimum condition since that values of 94.5% of z desirability is close to the acceptable values of 100%.

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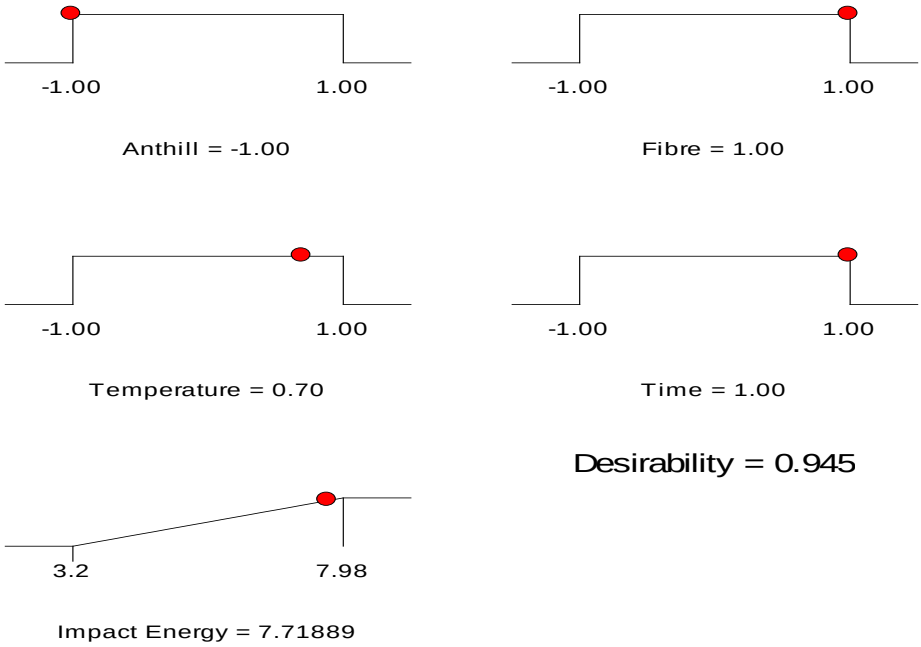


Figure 9: *Optimum condition of the composites.*

Microstructure

The fracture morphologies of the polyester and it composites produced with MAf and Ant hill particles are displayed in Fig. 10 and 11. In Fig. 10, it was observed there is chain of lamellae and interlamellar amorphous structure with sharp edge. Fig. 11 revealed the composites produced with Ant hill particles and MAf. It was observed that there was no agglomerates of Ant hill particles in the matrix, this shows that the composite reduce obstacles to chains movement and decreased failure under stress.

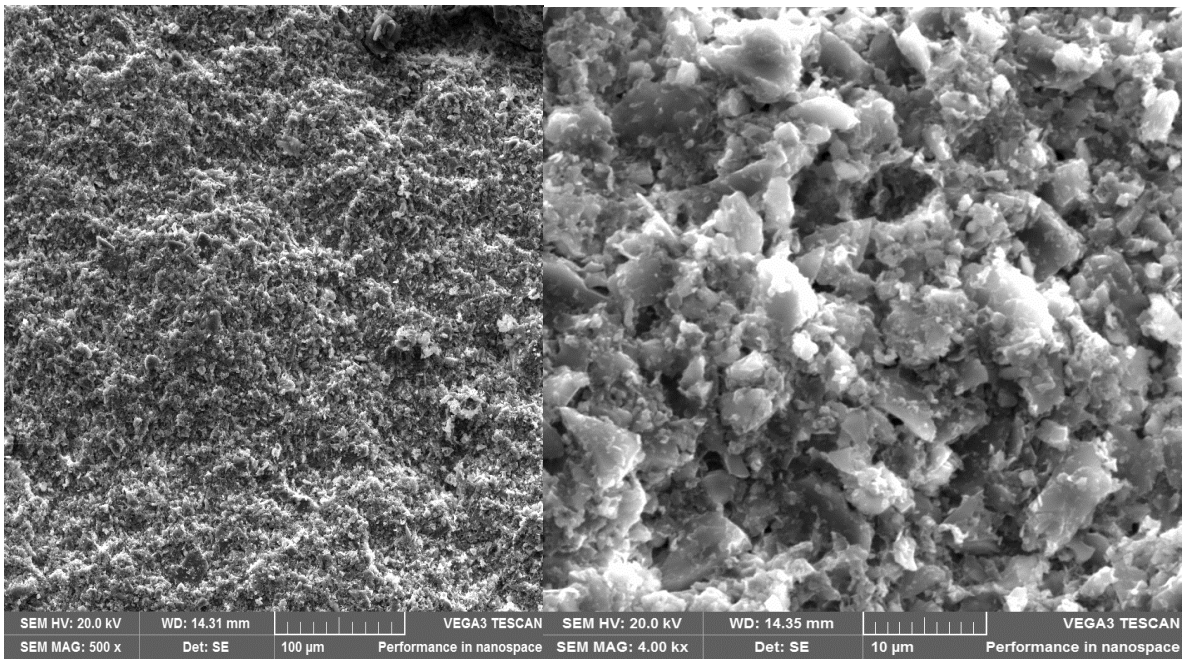


Figure 10: *SEM image of the polyester matrix.*

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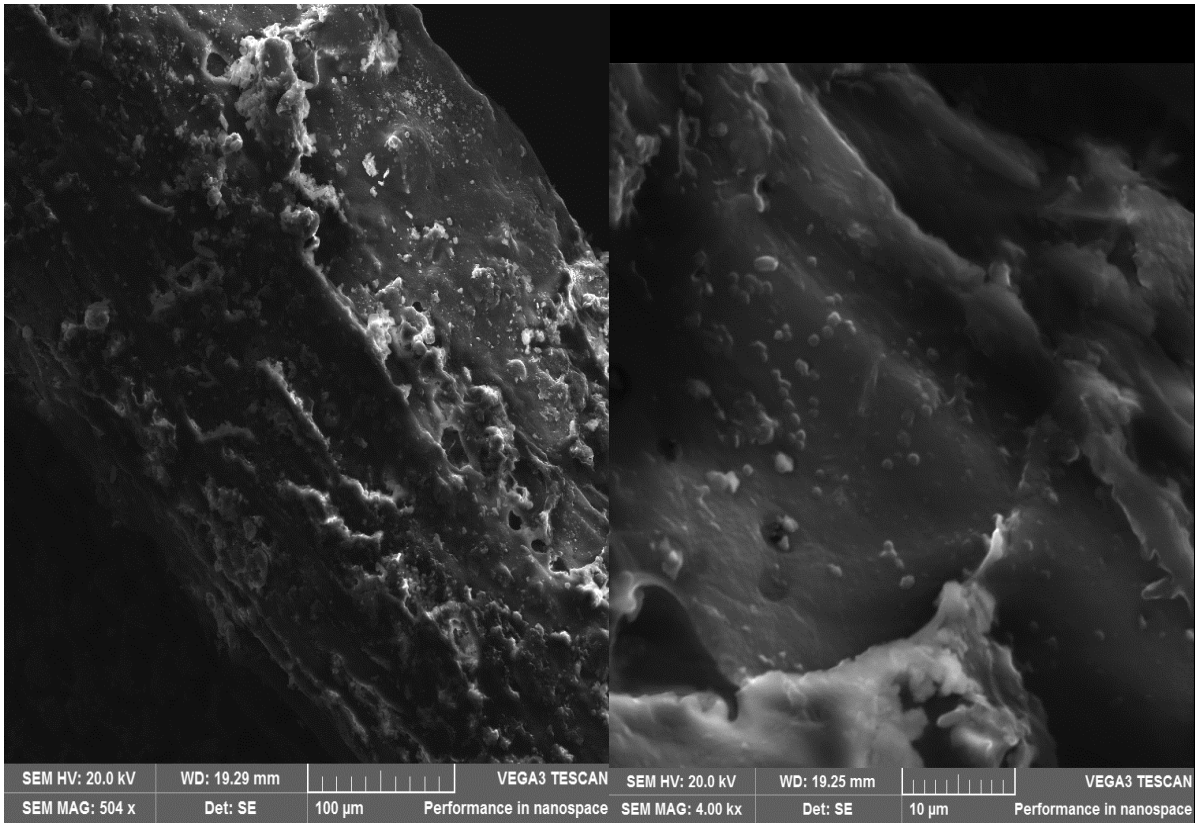


Figure 11: *SEM image of the composite.*

CONCLUSIONS

This present research is based on the development of car bumper from polyester resin reinforced MAf and Ant hill particles hybrid composites. The following conclusions are made:

- Response surface method was successful used for the optimization of the impact energy of the developed composites.
- Increase in curing temperature and MAf increased the impact energy.
- The composition of 5wt% Ant hill particles, 6wt% MAf, curing temperature (87°C) and curing time (5 hours) is recommended for structural application(car bumper) with impact energy of 7.82Jmm^2.

DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST

There are no potential conflicts of interest in this work.

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