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Fabrication, Evaluation and Optimization of Tensile Characteristics of Waste Plastic Reinforced Polymer Composite

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***Abstract*- The objective of this work is to investigate the Tensile properties of Non recyclable waste plastics particulate reinforced unsaturated polyester composite. Waste plastic particulates of particle sizes 1, 2, 3 mm were embedded into the unsaturated polyester resin to produce a composite. The specimens were made at 20, 30 and 40% weight percentages of the particulate filler in polyester matrix. Tensile tests were conducted on prepared samples of the composite material as per ASTM standards. Hand layup process was used for composite making. In this work the process parameters such as percentage composition of filler, percentage of catalyst addition (Methyl Ethyl Ketone Peroxide) and particulate size were defined by Taguchi method. The influence of the process parameters on tensile properties of the composite was optimized and regression equation was also formed using ANOVA. For the optimization process, MINITAB 17 software is utilized. The results showed that the tensile strength of the composite with 30% waste plastic reinforcement, 1.2% catalyst addition and 1mm particulate size was maximum. The composite could be considered for applications in areas were a better tensile and light weight material is required. Also this can be a good solution for converting waste plastics into useful products without any toxic emissions which are the main sources of air pollution [1] [6].**

Keywords: Unsaturated polyester resin; Hand layup method; Methyl ethyl ketone peroxide (MEKP); Taguchi method; Non recyclable waste plastics.

I. INTRODUCTION

Plastic is a material consisting of wide range of synthetic or semi- synthetic organics that are malleable and can be molded into diverse shapes. Plastics can be divided into thermoplastics and thermosetting plastics as shown in figure 1. Thermoplastics do not undergo any chemical change in their composition when heated and can be molded many times. Thermosetting plastics can be shaped once; after that its shape cannot be changed. In the thermosetting process, a chemical reaction occurs that is irreversible. Mostly the thermoplastics are recyclable, while thermosetting plastics cannot be recycled. The properties of plastics which affect the environment are as follows:

It has very slow rate of degradation, it take 500 to 600 years to decompose based on the type of plastic. Since its degradation rate is much slower, the plastic waste thrown to the land will block the water passages, drainage and it will not allow the rain water to penetrate inside the ground. If we burn the plastics, it will release enormous amount of toxic gases like nitrogen oxides, sulphur dioxide, volatile organic chemicals (VOCs), dioxin, carbon monoxide, carbon di oxide, etc. To inhale dioxin or to be exposed to its fumes can cause cancer, impotence, asthma, allergies and even death [2] [5].

It also affects the water bodies like, rivers, lakes, ponds, seas and oceans and affects the species living in that. During recycling the plastics should be sorted out very carefully, since mixing of plastics make them non recyclable next time and the plastics after separation, gets melted and then extruded and pelletized to make another new product which also needs energy [3] [4]. So the eco friendly way is to reuse the plastics. Mostly the non recyclable plastics such as BPA (Bisphenol A), polycarbonate, polystyrene, polyvinyl chloride (more toxic), polylactide, nylon, butadiene, styrene which are used to make water pipes, insulation, clothing, furniture, toys, packaging foams, drinking cups, DVDs, frames, water bottle caps, water cans, etc are taken for reinforcement at required percentage and the composites are fabricated using hand layup process.

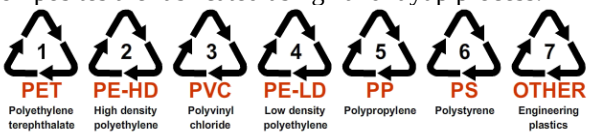

Fig. 1. Types of plastics

II. MATERIALS AND METHODS

A. Matrix material:

Mostly polymer-based composite materials, such as fiberglass, carbon fiber, and Kevlar, include at least two parts, the substrate and the resin. The matrix material is a resin. The catalyst used is MEKP (methyl ethyl ketone peroxide). If peroxide is added with the resin, it decomposes to generate free radicals, which initiate the curing reaction. The curing agent used was a cobalt octoate which act as a hardener. In this work the polyester resin is taken in three different compositions such

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as 20, 30 and 40%. The catalyst MEKP is also taken in three different ratios such as 1.2, 1.6 and 2% by weight.

B. Reinforcement material:

Reinforcement adds strength and greatly decreases crack propagation. Fiber-reinforced composite materials can be categorized into short fiber-reinforced materials and continuous fiber-reinforced materials. The short fibers come in the form of flakes, chips, and random mate. In this work the polycarbonate which is a non bio- degradable plastic used to make cds and dvds is used as a reinforcement in crushed short particulate form. The waste and scratched cds and dvds are collected and made into small particles by chopping. It is then segregated into three different particles sizes such as 1, 2 and 3mm by means of sieves. The waste plastics (polycarbonate) in the form of DVDs and CDs are added to the matrix in the following ratios: 20:80, 30:70 and 40:60.

C. Fabrication method

Selection of a method for a particular part will depend on the property materials, the part design and end-use or application. A mold tool is required to give the unformed resin /fiber combination a required shape.

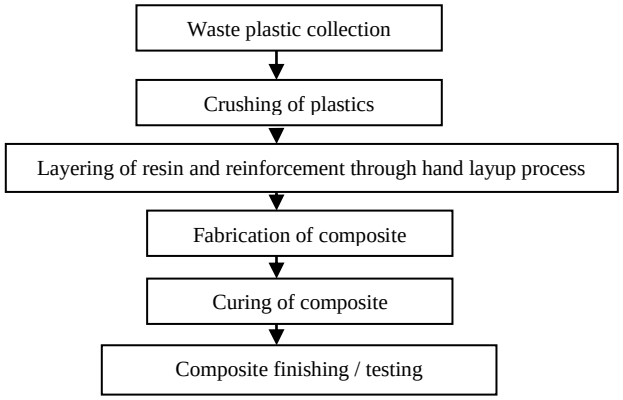

Fig. 2. Fabrication process flow chart

The mostly preferred fabrication technique for thermoset composites is hand layup technique, which is a simple technique for polymer composite processing. First of all, a release gel is sprayed on the mold surface to avoid the sticking of resin to the surface. Reinforcement is dispersed in the form of crushed particles as per the mold size .Then thermosetting polymer in liquid form is mixed with hardener and catalyst is poured onto the surface of the mold. The polymer is uniformly coated over the surface with the help of brush. Second layer of reinforcement is then dispersed on the polymer surface and a roller is moved with a mild pressure to remove any air trapped as well as the excess resin present. The process is repeated for each layer of composite, till the required layers are attained. After that, release gel is sprayed on the inner surface of the top mold plate and the pressure is applied. After curing at room temperature, mold is opened and the finished composite part is taken out and further processed. The schematic layout of hand lay-up is shown in figure 3 and the whole process is described in a flow chart in figure 2. The time of curing depends on the amount of catalyst used for composite processing. Then the fabricated composites are taken out and filed out to the required dimension and the unwanted projections are removed. Hand lay-up method is used in many areas like aircraft components, automotive parts, boat hulls, dash board, deck etc.

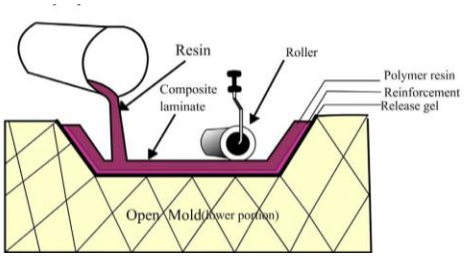

Fig. 3. Hand layup process

III. EXPERIMENTS

A. Tensile test

The most commonly used specimen geometries for tensile test are of dog bone type. The specimen used for this experiment is shown in figure 5. The tensile tests were conducted according to the ASTM D 3039-76 standard on universal testing machine (UTM, H10KS, Tinius Olsen, UK) at 23°c as shown in figure 4. The cross head speed of 5mm/min and a constant strain rate of 5 mm/min are given [7] [8] [9].

Fig. 4. UTM, H10KS, Tinius Olsen, UK

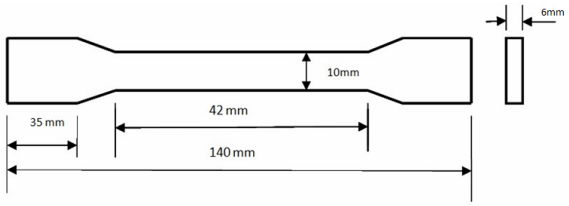

Fig. 5. Specimen for tensile test

B. Taguchi method

Traditional experimental design methods are very complicated and difficult to use. Also, those methods require a

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large number of experiments when the number of process parameters increases. To minimize the number of tests required and to make the task easier, Taguchi experimental design method is a powerful tool for designing high-quality system[10].

C. *Design of Experiments*

The objective of this research was to evaluate and optimize the tensile properties of the banana pistil composite. Variables such as percentage of fiber loading, different chemical treatments and suitable resin type were identified as the most influencing process parameters. All these parameters were varied at three levels. The process parameters and their levels in this study are given in Table 1. The three level orthogonal array L_9 with nine experimental runs was selected for the present work. The tests values for nine trial condition were tabulated and given in Table 2.

Table 1 Process parameters and their levels

Sl. No	Parameters	Unit	Levels		
			1	2	3
1	Filler loading(A)	%	20	30	40
2	Catalyst addition (B)	%	1.2	1.6	2
3	Particle size (C)	mm	1	2	3

Table 2 Nine trial conditions for Taguchi method

Trial No	Designation	Filler loading (%)(A)	Catalyst addition(%) (B)	Particle size (mm) (C)
1	A1B1C1	20	1.2	1
2	A1B2C2	20	1.6	2
3	A1B3C3	20	2	3
4	A2B1C2	30	1.2	2
5	A2B2C3	30	1.6	3
6	A2B3C1	30	2	1
7	A3B1C3	40	1.2	3
8	A3B2C1	40	1.6	1
9	A3B3C2	40	2	2

IV. RESULTS AND DISCUSSION

A. *Tensile test*

After testing, the test results are tabulated in table 3 and the corresponding graphs are drawn taking different ratio of specimens on x-axis and tensile strength on y-axis as shown in figure 6.

Table 3. Tensile Strength Results

Sl.No	Specimen	Tensile strength(Mpa)
1.	A1B1C1	86.20
2.	A1B2C2	81.26
3.	A1B3C3	75.43
4.	A2B1C2	79.31
5.	A2B2C3	75.20
6.	A2B3C1	71.80
7.	A3B1C3	75.60
8.	A3B2C1	72.30
9.	A3B3C2	68.00

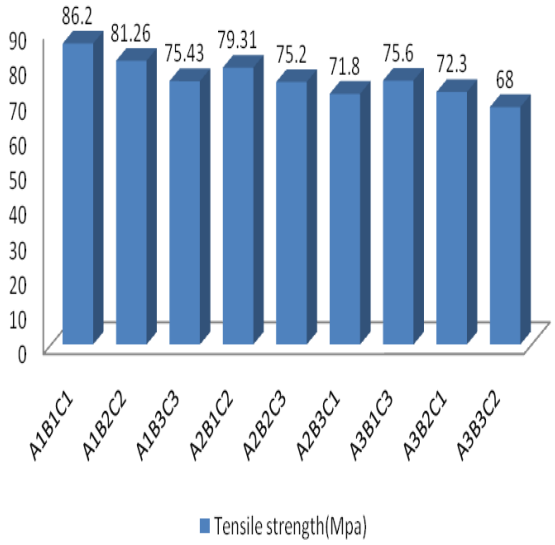

Fig. 6. Tensile test results on bar chart

B. *Regression analysis*

To predict the tensile strength within the specific level values of parameters, using regression analysis, a first order polynomial regression equation for tensile strength with significant parameters is derived with R-Sq value of 98.67% and given as Equation.

Tensile strength = 108.23 - 0.4498 × percentage of filler
-10.783 × percentage of catalyst addition
– 0.678 × particle size (1)

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C. *ANOVA*

A statistical technique used to identify and screen the significant parameters that influence the tensile strength. From the analysis of variance for S/N ratios of the tensile strength shown in Table 4 with computed R-Sq value of **98.67**%, percentage of filler was identified as the influencing parameter with maximum contribution and next to that the consequence of catalyst addition was identified as the significant parameter and particle size was found to be insignificant on the tensile strength with very low percentage contributions.

Table 4 ANOVA for S/N ratio of Tensile strength

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	235.8	78.6	123.42	0
Composition	1	121.41	121.41	190.64	0
Catalyst Addition	1	111.629	111.629	175.28	0
Particle Size	1	2.761	2.761	4.34	0.092
Error	5	3.184	0.637		

S	R-sq	R-sq(adj)	R-sq(pred)
0.798030	98.67%	97.87%	95.94%

The contribution chart (Fig. 7.) is plotted from the ANOVA and shows the contribution of the individual factors on the tensile strength of the composite. The Percentage of filler addition shows the maximum contribution followed by the percentage of catalyst addition and the particle size is found to have a negligible contribution on the tensile strength.

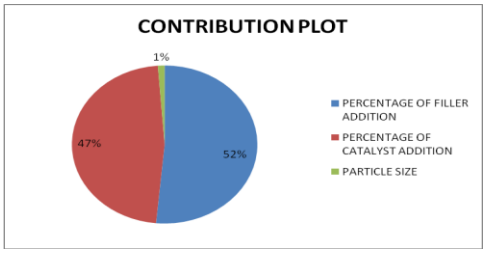

Fig. 7 Contribution plot for parameter on Tensile strength

The contour plot bands indicate the ranges of tensile strength against the percentage of filler and percentage of catalyst addition are shown in Fig. 8. From the contour plot it was observed that the maximum tensile strength can be obtained in the addition of filler percentage ranging from 20% to 22% and percentage of catalyst addition ranging from 1.2% to 1.3%**.** The tensile strength found to reduce with the addition of fillers and by adding more catalyst.

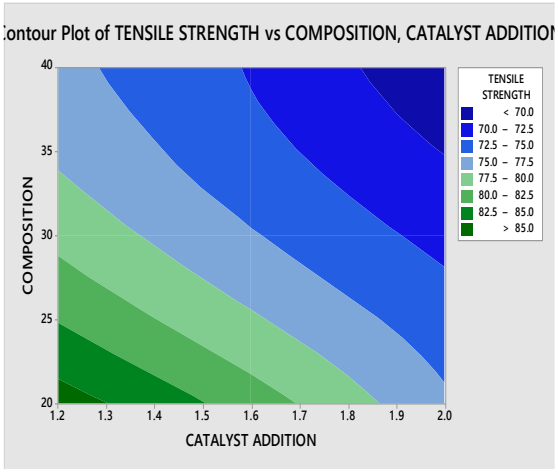

Fig. 8 Contour Plot for tensile strength

The main effect plot as shown in fig.9. gives the optimal process parameters to obtain a maximum tensile strength, with a filler percentage of 20% and catalyst addition of 1.2% and 1 mm particulate size. Also further it was observed that percentage of filler has major influence on tensile strength. The percentage of filler as increased is found to have a negative effect on the tensile strength which decreases from 81Mpa to 72Mpa.

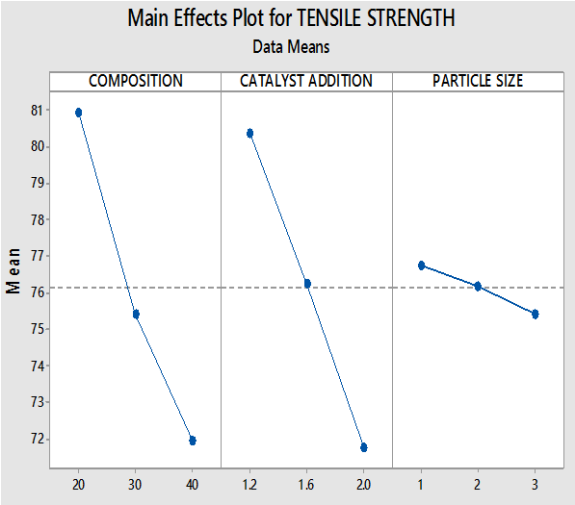

Fig. 9 Main Effect Plot for tensile strength

The interaction plot for tensile strength between percentage of filler, percentage of catalyst and particle size was shown in Fig. 10. In Interaction graph, the parallel lines specify the absence and non-parallel lines point out the presence of interaction effect of the factors on a response. The interaction plot suggests that catalyst addition and particle size and percentage of filler and particle size interacts each other. The percentage of filler and catalyst addition, is found to have no interaction effect in-between.

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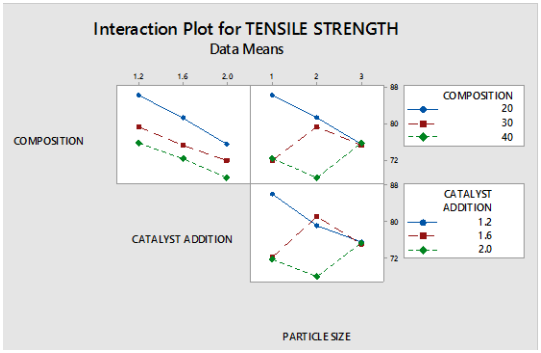

Fig. 10 Interaction Plot for tensile strength

V. CONCLUSION

Taguchi method has been used to perform analysis of the tensile strength with respect to various combinations of process parameters. The best level of the parameters on the tensile strength is determined using ANOVA. The results of ANOVA reveal that percentage of filler addition and percentage of catalyst addition is the influential parameters, which has greater effect on tensile strength. The optimal levels for the controllable factors are 30% of filler addition, 1.2 % of catalyst addition and particulate size of 1 mm. Through these factors a maximum of 86.2 Mpa of tensile strength was obtained which is slightly a higher value than the tensile strength of the neat resin.

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