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An Experimental Investigation on the Optimized Mechanical Properties of Glass Fiber Epoxy Composites with Fillers

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ABSTRACT;

Now a days Glass Fibre Reinforced Plastics find their application into various industries due to their better and distinctive properties. However, these properties can be improved further by incorporating different filler materials in the glass/epoxy polymer composite. The optimization technique has a crucial role in developing advanced composites with enhanced properties. Response Surface Methodology (RSM) has been incorporated for optimizing fabrication parameters using Box-Behnken Design (BBD). The Polymer composite fabrication process parameters are optimized with various percentages of Hardener (5%, 10%, and 15%), various percentages of Curing Temperatures (400C, 500C, and 600C) and Aluminium Oxide as a filler having particle size of 5 microns will be added to the resin with varying percentage (5%, 10%, and 15%) to find the optimum value. The process is optimized and the optimize conditions are validated by Genetic Algorithm. The main goal of this project is to enhance the strength and reinforcement of fiber glass epoxy composites by comparing the results of composites with different fillers in the optimize condition.

Keywords: Fibers, Glass Reinforcements, Mechanical Properties, RSM Methods

1.INTRODUCTION;

Composites in general are very strong, stiff, light weight, possess high strength-to- weight ratio in comparison to pure matrix alternatives, and are widely used in many industrial applications. Glass fiber epoxy composites have been subjected many researches to increase the strength and reinforcement. Adding fillers to various weight percentages has been many more effects to increase the mechanical properties of glass fibers. Ceramic fillers with different percentages by weight (5 wt%, 10 wt%, 15 wt%) are introduced into epoxy-based fiber composites, since ceramic materials are rigid in nature and affect property Flexibility in bending. Alumina (Al_2O_3), Silicon Carbide (SiC) and Titanium Dioxide (TiO_2) Particulate Fillers used in producing Composites by Hand Layup technique and tested in accordance with ASTM D 790. Results show that it has a significant effect of loading on the Flexural Strength of the GFRP composite; It varies greatly depending on the filler material and its percentage. In this study, the objective was to develop, investigate and evaluate the mechanical properties of glass fiber epoxy composite

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materials using Alumina (Al2O3) as filler with various percentages by weight for enhancing the strength properties.

The GA obtains the optimal operational conditions through using the NNs. From this, it can be clearly seen that a good agreement is observed between the predicted values and the experimental measurements [9].

I. METHODOLOGY

Design of experiments (DOE Sheet) had been prepared based on 15 different fabrication composition of GFRP composites.

Design of Experiments calculated for the sample preparation is listed below:

Sl. No	Hardner (%)	Curing Temp (^{0}C)	Filler (%)
S1	15	50	15
S2	15	40	10
S3	10	50	10
S4	5	50	5
S5	10	60	15
S6	15	60	10
S7	10	50	10
S8	10	40	15
S9	15	50	5
S10	10	50	10
S11	5	50	15
S12	5	40	10
S13	10	60	5
S14	10	40	5
S15	5	60	10

Table1: DOE Table for Samples Fabrication

Fabricated 15 samples plates incorporating different percentage of Hardener, different percentage of temperature, different percentage of filler. Specimens were prepared from the 15 sample plates as per ASTM standards and tensile, hardness, impact and immersion tests were carried out.

Optimization of the fabrication parameters were carried out by using RSM (Response Surface Methodology) method. Test results used to optimize the parameter values by RSM. GA (Genetic Algorithm) optimization were carried out to compare and validate the results derived from RSM.

II. FABRICATION OF SAMPLES

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel (PVA) is spread on the mold surface to avoid the sticking of polymer to the surface. Thin OHP sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of

woven glass fiber mats is cut as per the mold size (100X160X3mm).

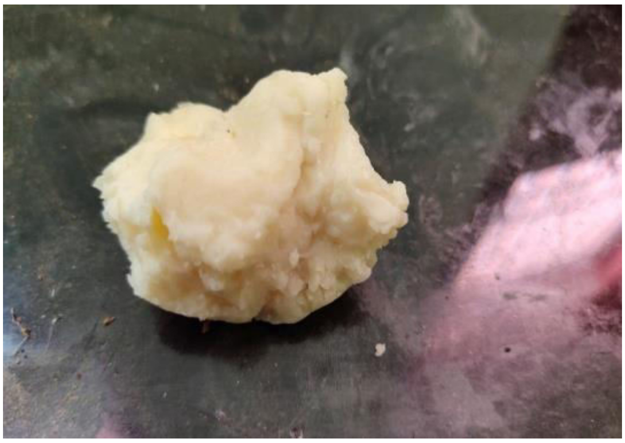

Fig 1: Die for glass fiber reinforced composite fabrication

Fig 2: Mold Release Wax

Then with a prescribed hardener HY 991 (curing agent), with Fillers (Ceramic powder Al_2O_3) then mixed more than 10 minutes for perfect mixture of resin and hardener and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush.

Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the sheet, PVA gel is spread on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied.

After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. For example, for epoxy-based system, normal curing time at room temperature is 18-24 hours. Under a pressure of 280 psi in UTM machine. This method is mainly suitable for thermosetting polymer-based composites. Capital and infrastructural requirement is less as compared to

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other methods. Production rate is less and high-volume fraction of reinforcement is difficult to achieve in the processed composites.

Fig 3: Epoxy Resin and Hardner

The following are the procedure for manufacturing composites, using hand lay-up method:

The DOE method used to fabricate 15 different compositions of samples. Glass fibre reinforced composites with filler specimens fabricated in different % of Hardener (5%, 10% and 15%), Different weight % of Filler (5%, 10% and 15%) and Different Curing Temperature (40oC, 50oC and 60 oC) composition.

The fibers should be ready as per the dimension beforehand and to make easy to accessible. The die base horizontal and should be straight to prevent polymer uneven spread. Apply the PVA (releasing agent) on the Die base. Put one Non-Stick sheet on the Die base for good surface finish in the composites. Then the mold (PVA applied) placed on the die base. The polymer mix poured in the mold as light layer; Brush used to spread the resin in even the surface of mold. Then first layer carbon fiber mat positioned manually in the mold. Entrapped air is removed manually with squeegees or rollers to complete the laminate structure. Apply the second layer, impregnating it by using the resin from the previous layer.

When there is no more resin in underneath layer, new resin is applied. The rest of the layers are applied as described above. This process is continued till the final layer of glass fiber mat is coated with resin. The top plate of mold place on the middle of complete assembly and then the mold is compressed by weight. The compression ensures that entrapped air bubbles are completely removed and the excess resin flows out. This mold is left for 18 hours to 24 hours at a room temperature to complete the curing process. Under a pressure of 280 psi in UTM machine. The same technique was used to fabricate the remaining laminates.

In order to convert epoxy resin into hard, infusible, and rigid material, it is necessary to cure the resin with hardener, Curing initiated by the catalyst in the resin system. The speed of curing is controlled by the amount of hardener in an epoxy resin. Epoxy resin cure quickly and easily at practically any temperature from 5-150 0C on choice of curing agent.

III. RESULTS AND DISCUSSION

A. Mechanical Test Results of samples

1)*Charpy Impact Test Result*

Composite Samples	Charpy Impact (J/mm^2)
S1	0.21
S2	0.164
S3	0.19
S4	0.175
S5	0.29
S6	0.27
S7	0.195
S8	0.169
S9	0.178
S10	0.186
S11	0.199
S12	0.17
S13	0.24
S14	0.181
S15	0.235

Table 2: Impact Test Results of Samples

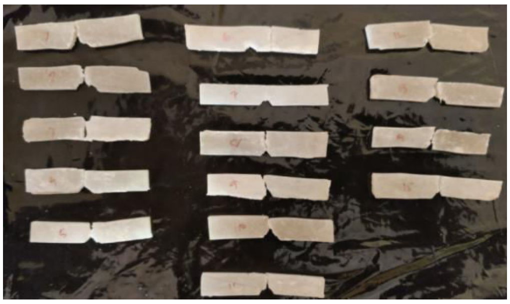

Fig 5: Samples After Impact Test

2) *Hardness Result*

Composite Samples	Hardness (BHN)
S1	88
S2	80
S3	79

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S4	72
S5	86
S6	84
S7	80
S8	76
S9	73
S10	72
S11	76
S12	71
S13	83
S14	71.52
S15	85

Table 3: Hardness Test Results of Samples

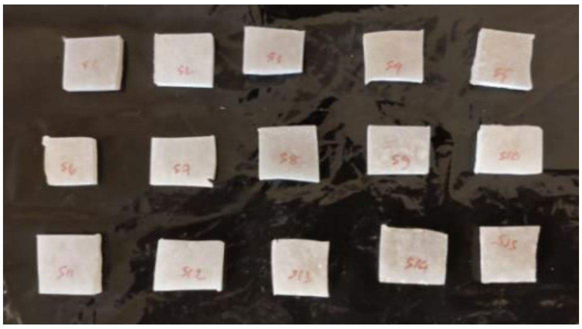

Fig 6: Samples After Hardness Test

3) *Ultimate Tensile Strength Results*

Composite Samples	Ultimate Tensile Strength (MPa)
S1	385
S2	311
S3	275
S4	298
S5	364
S6	370
S7	365
S8	256
S9	344
S10	290
S11	301
S12	241
S13	380

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S14	243
S15	381

Table 4: Tensile Strength Test Results of Samples

Fig 7: Samples After Tensile Test

B. Response Surface Methodology

1) Input Parameters

Sl.No	Parameters	Low	Mid	High
1	Hardner	5	10	15
2	Curing Temp	40	50	60
3	Filler	5	10	15

Table 5: RSM Input Parameters

2) RSM OPTIMIZATION RESULTS;

a) Regression Equation:

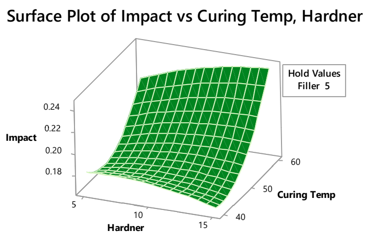
Hardness=83.14 + 1.291 Hardner - 1.283 Curing Temp + 0.102 Filler + 0.01826 Hardner* Hardner + 0.02126 Curing Temp* Curing Temp - 0.00893 Filler * Filler- 0.04442 Hardner * Curing Temp + 0.11048 Hardner * Filler - 0.00729 Curing Temp * Filler

Tensile=-245.72 + 6.481 Hardner + 13.818 Curing Temp + 2.094 Filler + 0.74403 Hardner * Hardner - 0.02777 Curing Temp * Curing Temp+ 0.13732 Filler *Filler - 0.40540 Hardner *Curing Temp+ 0.36775 Hardner*Filler - 0.14976 Curing Temp * Filler

Impact=0.8143- 0.00594 Hardner- 0.02522 Curing Temp- 0.01812 Filler- 0.000202 Hardner*Hardner+ 0.000245 Curing Temp * Curing Temp + 0.000208 Filler * Filler + 0.000205 Hardner * Curing Temp + 0.000080 Hardner * Filler + 0.000310 Curing Temp * Filler

b) Surface Plots

i)Surface Plot of Impact Vs Curing Temperature, Hardener



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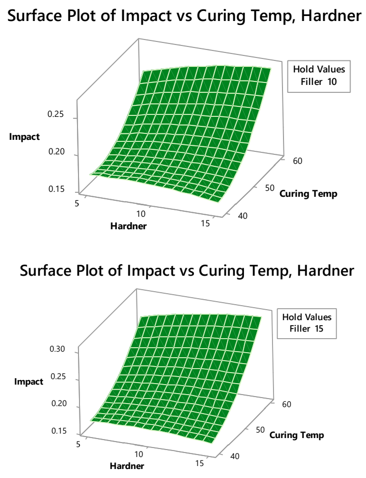

Fig 8: Suface Plot for Impact Vs Curing Temperature, Hardner

ii)Surface Plot of Hardness Vs Curing Temperature, Hardener

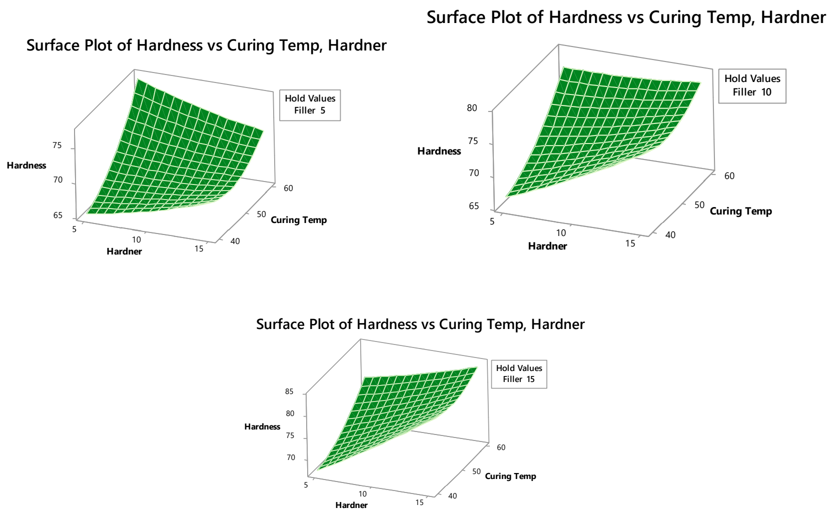

Fig 9: Suface Plot For Hardness Vs Curing Temperature, Hardner

iii)Surface Plot of Tensile Vs Filler, Hardener

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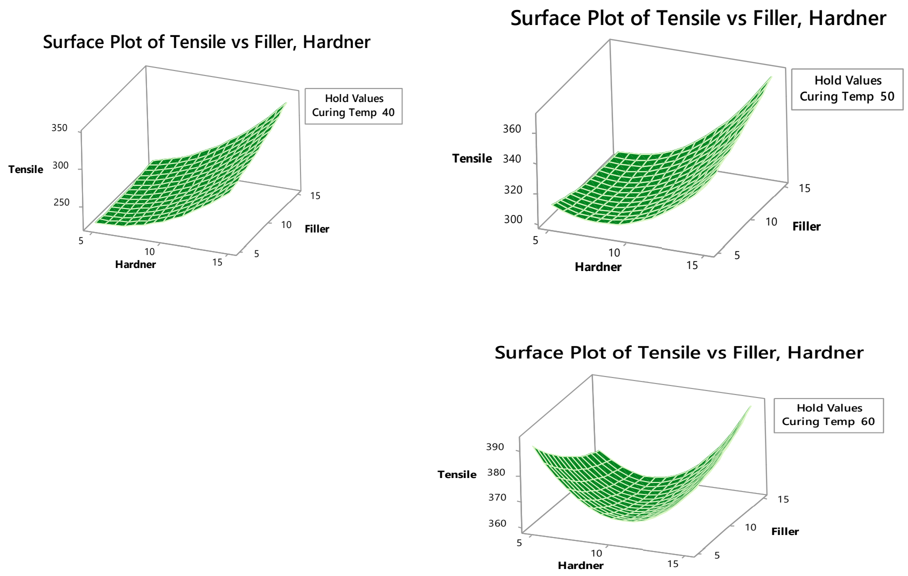

Fig 10: Suface Plot For Tensile Vs Filler, Hardner

c) RSM Optimized Parameters Plot

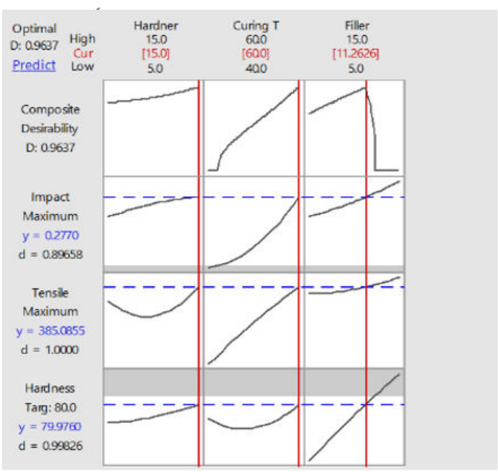

Fig 11: RSM Optimized Parameters Plot

RSM Optimized parameters are Hardener: 15%, Curing Temperature: 60 ^{0}C, Filler: 11.262 %.

d) RSM Optimized Condition Test Results

Hardness Test Results for RSM Optimized Condition are tabulated below:

Samples	Hardness Optimum	Hardness Exp	% or Error
OS-1	80	80.102	-0.127337645
OS-2	80	80.081	-0.101147588

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OS-3	80	79.878	0.152732918

Table 6: Hardness Test Results for RSM Optimized condition

Tensile Test Results for RSM Optimized Condition are tabulated below:

Samples	Tensile Optimum	Tensile Exp	% or Error
OS-1	385.085	385.485	-0.103765386
OS-2	385.085	385.547	-0.119829748
OS-3	385.085	385.878	-0.205505367

Table 7: Tensile Test Results for RSM Optimized condition

Impact Test Results for RSM Optimized Condition tabulated below:

Samples	Impact Optimum	Impact Exp	% or Error
OS-1	0.277	0.271	2.21402214
OS-2	0.277	0.276	0.362318841
OS-3	0.277	0.278	-0.35971223

Table 8: Impact Test Results for RSM Optimized condition

C. Genetic Algorithm Optimization

a) Optimized Parameter For GA

Genetic algorithm optimized parameters are shown in the below table:

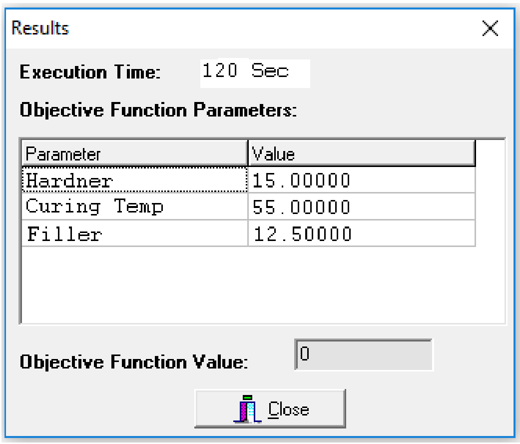

Fig 12: GA Optimized Parameter

Design of Experiments calculated for the sample preparation is listed below:

b) GA Optimized Condition Test Results

Hardness Test Results for GA Optimized Condition are tabulated as given below:

Samples	Hardness Opt	Hardness Exp	% or Error
OS-1	81.2	81.205	-0.006157256

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OS-2	81.2	81.202	-0.002462994
OS-3	81.2	81.199	0.001231542

Table 9: Hardness Test Results for GA Optimized condition

Tensile Test Results for GA Optimized Condition are tabulated as given below:

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Samples	Tensile Opt	Tensile Exp	% or Error
OS-1	387.085	387.0859	-0.000232507
OS-2	387.085	387.079	0.001550071
OS-3	387.085	387.0878	-0.00072335

Table 10: Tensile Test Results for GA Optimized condition

Impact Test Results for GA Optimized Condition are tabulated as given below:

Samples	Impact Opt	Impact Exp	% or Error
OS-1	0.289	0.2891	-0.034590107
OS-2	0.289	0.2889	0.034614053
OS-3	0.289	0.2891	-0.034590107

Table 11: Impact Test Results for GA Optimized condition

IV. CONCLUSION;

Engineers, researchers, non-abrasives, environmentally friendly and adequate mechanical properties around the world are a substitute for fiber reinforced polymer compounds, due to the high-quality properties of fiber specific strength, low weight, and low cost, very good mechanical properties. From this point of view, there is a brief analysis of the use of a large number of fibers.This paper presents an analysis of the mechanical properties and frictional Epoxy + glass fiber + ceramic composite (70:25:5), Epoxy + glass fiber + ceramic (65:25:10), Epoxy + glass fiber + ceramic composite (60:25:15), properties of polymer blend glass fiber with ceramic (Al2O3) filler. The integration of intermittent bonds between fiber and polymer matrix is an important aspect of the optimal mechanical performance of fiber-reinforced compounds with general and elegance. The proportions are 70:30 and 80:20. The quality of the fiber-matrix interface is important to strengthen the plastics to use glass fibers and different ceramic fillers (10, 15 wt %). Since fibers and modules are chemically different, strong adhesion in their interfaces requires an effective transition to stress and bond distribution through an interface. The Test results are optimized by response surface methodology.

The RSM parameters are optimized and those parameters are Hardener: 15%, Curing Temperature: 60 0C, Filler: 11.262 %. The RSM Responses are optimized, that are Impact Strength is 0.277 N, Tensile Strength is 385.0855 MPa and Hardness is 79.9760. The Genetic Algorithm parameters are optimized and the GA Optimized parameters are Hardener: 15%, Curing Temperature: 55 0C, Filler: 12.500 %. The GA Responses are optimized, that are Impact Strength is 0.289 N, Tensile Strength is 387.085 MPa, Hardness is 81.2.

After the experimental trial for optimized parameters condition, the error percentages are higher than GA validation. The validation results of GA are very less comparing to the RSM. So, the GA is having a higher accurate optimization.

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