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Fabrication & Wear Analysis of GFRP Composite Using DOE

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Abstract- *Composites meet diverse design requirements with significant weight savings and exhibit high strength-to-weight ratio compared to conventional materials. They have proved to be a worthy alternative to other traditional materials even in the high pressure and aggressive environmental situations. Composite materials exhibit excellent fatigue performance, good resistance to temperature extremes and wear, especially in industrial sectors. The strength of any composite depends upon volume/weight fraction of reinforcement, length to diameter (L/D) ratio of fibers and other factors. In the dissertation work an attempt is made to study the Fabrication and Wear Resistance of the material of Glass Fibre Reinforced Epoxy Composite using Design of Experiments (DOE) approach. The composite is fabricated using Epoxy Resin and woven Glass Fibre mats of different Grams/Square Meter (GSM) values. Hand lay-up technique is used for fabrication of the composite. The composite is tested as per ASTM standards for Wear Resistance by varying the process parameters during the test such as load applied, loading time and speed. As per the Design of Experiments approach, the three parameters are varied in two levels and single replicates i.e. L8 array. The specified number of experiments is conducted to obtain the optimum condition for Wear Resistance by the composite. Taguchi method was employed in DOE & Minitab software was used for the analysis of the results obtained.*

Key Words: GFRP, Wear Resistance, DOE, Taguchi method, Minitab.

1. INTRODUCTION

The unique and diverse characteristics of composite materials have increased in their utilisation worldwide. From featherweight fly fishing rods to high performance airplane parts, the use of fiber reinforced composite materials is becoming more popular due to their high strength to weight ratio combined with easy manufacturing methods. Fiber reinforced polymer matrix consists of reinforcing fibers and polymer resin. The fibers are considered as principal load carrying constituent of the composite, while the role of polymer matrix is to transfer the load between fibers as well as provide corrosion resistance damage tolerance and thermal environmental stability.

Fillers are used along with various commodity as well as engineering polymers to improve the properties and reduce the cost. Incorporating inorganic mineral fillers into plastic resin improves various physical properties of the materials such as mechanical strength, modulus etc. In general the mechanical properties of particulate filled polymer composites depend strongly on size, shape and distribution of filler particles in the polymer matrix and extend of interfacial adhesion between filler and matrix.

At present, epoxy resins are widely used in various engineering and structural applications such as electrical industries, and commercial and military aircrafts industries. In order to improve their processing and product performances, and to reduce cost, various fillers are introduced into the resins during processing. However polymeric composites are susceptible to mechanical damage, when subjected to tension, wear and flexural loads resulting in interlayer delamination. Over the past several decades enormous efforts have been made to study the mechanical characteristics of composites.

Design of Experiment is the process of planning a study to meet specified objectives. Planning an experiment properly is very important in order to ensure that the right type of data and a sufficient sample size and parameters are available to answer the research questions of interest as clearly and efficiently as possible. Taguchi method is used in DOE to conduct the Wear analysis of the GFRP.

Taguchi method is a powerful tool for the design of high-quality systems. It provides a simple, efficient and systematic approach to optimize the designs for performance, quality, and cost. Taguchi parameter design can optimize the performance characteristics through the settings of the design parameters and reduce the sensitivity of the system performance to sources of variation. In recent years, the rapid growth of interest in the Taguchi method has led to numerous applications of the method in a world-wide range of industries and countries.

1.1 Overview

The dissertation work deals with analysing the fabrication process & determining the wear resistance of glass fibre reinforced epoxy composite. The composite is manufactured by hand-layup process. Specimens were cut and tested according to ASTM standards. The Wear resistance of the composite was checked using the Design of Experiment (DOE) approach by varying the Load, Speed and Loading time on the specimen.

The experimental procedure carried out during the course of the dissertation work mainly deals with two aspects i.e. Fabrication of the composite specimen and Wear Testing of the fabricated specimen for various parameters.

2. FABRICATION

The composite was fabricated using the conventional Hand layup method. The materials used and their specification is as follows:

☐ Epoxy Resin (Araldite LY556):

Aspect (visual)	: clear, pale yellow liquid
Epoxy content	: 5.30 – 5.45 eq/kg
Viscosity at 250 C	: 10,000 – 12,000 mPa s
Specific Density (ρ) at 250 C	: 1.15 – 1.2 gms/cm^3
Flash Point	: ≥ 200
Storage temperature	: 2 – 400^0 C

☐ E-glass Fiber (woven mat):

Glass fibre per square meter (GSM)	: 600 and 415 GSM
Specific Density (ρ) at 250 C	: 1.2 – 1.3 gms/cm^3
Modulus	: 86.8 (GPa)
Elongation	: 5.4 %
Coefficient of Thermal Expansion	: 23-27.0 (10^7/^{0}c)

☐ Hardener (HY951):

10% hardener liquid of the quantity of resin is used for appropriate curing action to take place.

The quantity was decided based on the calculations of fibre volume fraction.

To find the weight of the fibre, the following equation was used:

$V_f = (\rho_m * W_f) / (\rho_f * W_m + \rho_m * W_f)$

V_f = Volume of Fibre
ρ_m = Specific Density of Matrix
ρ_f = Specific Density of Fibre
W_f = Weight of Fibre
W_m = Weight of Matrix

2.1 Procedure

A layered structure i.e. laminate was fabricated using the conventional hand layup technique.

Sample fabrication was done and the Hand Lay Up method involved these following steps:

1) A flat table was made ready for the laying of the material by cleaning and polishing it.
2) A release gel coat was then applied to the surface of the table to aid easy removal of the composite laminate.
3) A thin coat of resin was applied on the table.
4) A glass fiber woven mat was laid out over the resin coating on the table.
5) A coating of epoxy resin was applied uniformly on top of the fibre. The resin was prepared in the following manner:
The required weight of the resin was taken (such that the weight of the fibres to the weight of resin was 40:60). To this measured weight of the resin, hardener was added, such that the weight of the hardener was 10% of the total weight of the resin. The resulting mixture was properly stirred to ensure proper mixing. Addition of hardener is done to facilitate easy hardening of the composite laminate during curing.
6) The mixture was stirred properly before applying to the glass fibre.
7) Rolling was done under uniform pressure, so that the resin properly penetrates the fibre mat. A roller was used for this purpose.
8) Then the second fibre mat was laid over the first one, and again uniform coating of resin was applied, followed by proper rolling.
9) The process was repeated till 3 woven fibre mats were laid, one over the other (with resin in between).
10) Finally a coat of resin was applied above the top mat.
11) It was then left for curing for 24 hours and later post cured in an oven at 1200^0 C for 4-5 hours.

Figure - 1: Fabrication of composite

After the composite laminate is fabricated, it is then cut into samples of desired dimensions.

A hacksaw mounted with a hexa blade cutter, file etc was used to cut each laminate into smaller pieces, each having dimensions as per the requirements of the wear tests to be carried out and thickness same as that of the laminate. This was done in accordance with ASTM standards.

3. WEAR TEST

Abrasion testing is used to test the abrasive resistance of solid materials. Materials such as composites can be tested with this method. The intent of this test method is to produce data that will rank materials in their resistance to sliding abrasion under a specified set of conditions and can help to predict the life time of a material. Abrasive wear tests were conducted on the composite specimen

according to ASTM standards i.e. ASTM G 65. The wear tests were conducted on a pin-on-drum abrasive wear tester, designed for standard wear tests described in ASTM standards. In this method, the test specimen translates over the surface of an abrasive paper, which is mounted on a revolving drum, with the resulting wear of the material expressed as volume loss.
The test setup is schematically illustrated in figure below:

Figure - 2: Pin-on-Disc Wear Apparatus

An alumina (Al_2O_3) abrasive which is substantially harder than either the matrix or the reinforcement was used. The specimen is continuously in contact with new abrasive surface. A static normal load, *L*, was applied directly on the specimen to press it against the center of the drum that caused wear. Design of Experiments approach (DOE) was used to conduct this test. By Taguchi method, L8 array was used containing 3 parameters and 2 levels. Load, Loading time and Speed are the three parameters that were varied. All tests were carried out in dry ambient air laboratory conditions.

3. RESULTS & DISCUSSION

The results achieved from the mechanical testing of the various wear tests on the fabricated GFRP composite specimen is discussed below.

The Design of Experiments (DOE) approach is used to conduct the wear test. L8 array under Taguchi method is used which varies two levels and three parameters i.e. Load, Loading Time and Speed. The results obtained after conducting the wear test as per Design of Experiments approach was used to calculate the Wear Volume & Wear coefficient. The readings of the tests conducted are shown below:

Table - 1: Wear Test Results for 415 GSM specimen

Speed (rpm)	Load (kgs)	Time (min.)	Δ Weight (mg)	Wear Coefficient
300	1.5	2	1.6	$6.55 * 10^{-14}$
300	1.5	4	4.2	$7.25 * 10^{-14}$
300	3	2	4.5	$7.76 * 10^{-14}$
300	3	4	5.5	$4.74 * 10^{-14}$
600	1.5	2	3.0	$5.16 * 10^{-14}$
600	1.5	4	4.0	$3.44 * 10^{-14}$
600	3	2	4.1	$3.53 * 10^{-14}$
600	3	4	5.7	$2.45 * 10^{-14}$

Table - 2: Wear Test Results for 600 GSM specimen

Speed (rpm)	Load (kgs)	Time (min.)	Δ Weight (mg)	Wear Coefficient
300	1.5	2	3.5	$1.21 * 10^{-14}$
300	1.5	4	5.9	$2.04 * 10^{-14}$
300	3	2	3.7	$6.38 * 10^{-14}$
300	3	4	6.8	$5.86 * 10^{-14}$
600	1.5	2	3.9	$6.71 * 10^{-14}$
600	1.5	4	5.0	$4.30 * 10^{-14}$
600	3	2	4.2	$3.61* 10^{-14}$
600	3	4	5.4	$2.32 * 10^{-14}$

The results were then analysed using the Minitab software. The Response Tables for Signal to Noise Ratio (S/N) & Means by Taguchi Analysis for both the composites was obtained as shown below.

Table - 3: Response Table for S/N Ratios for 415 GSM

Level	Speed	Load	Time
1	-11.478	-9.906	-10.109
2	-12.239	-13.811	-13.608
Delta	0.761	3.905	3.498
Rank	3	1	2

Table - 4: Response Table for Means for 415 GSM

Level	Speed	Load	Time
1	4.025	3.275	3.375
2	4.200	4.950	4.850
Delta	0.175	1.675	1.475
Rank	3	1	2

Table - 5: Response Table for S/N Ratios for 600 GSM

Level	Speed	Load	Time
1	-13.58	-13.02	-11.63
2	-13.23	-13.78	-15.17
Delta	0.35	0.76	3.54
Rank	3	2	1

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Table - 6: Response Table for Means for 600 GSM

Level	Speed	Load	Time
1	4.975	4.575	3.825
2	4.625	5.025	5.775
Delta	0.350	0.450	1.950
Rank	3	1	2

Main Effects Plot for Means & S/N ratios for both the GFRP specimens was obtained as shown below.

Figure - 3: Main Effects Plot for S/N ratios for 415 GSM

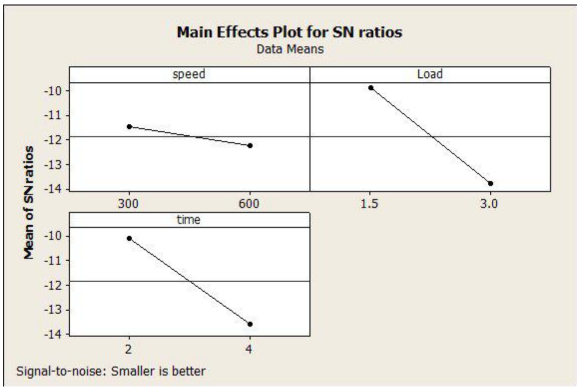


Figure - 4: Main Effects Plot for Means for 415 GSM

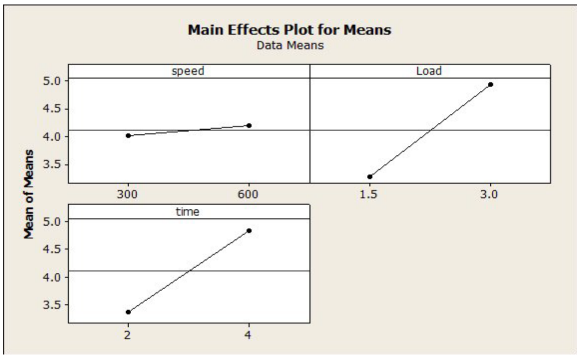


Figure - 5: Main Effects Plot for S/N ratios for 600 GSM

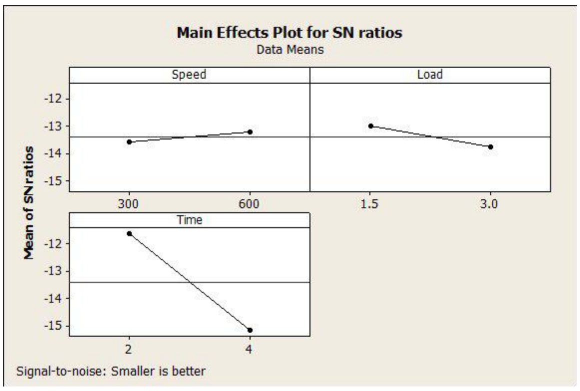
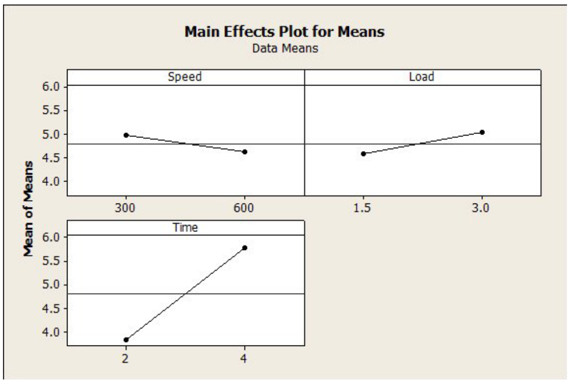


Figure - 6: Main Effects Plot for Means for 600 GSM



3. CONCLUSIONS

The results obtained from Wear tests were used to analyse and interpret the results using Design of Experiments (DOE) approach and Minitab software. The results show the Mean values, Signal to Noise (SN) ratio values and the rank of the different parameters that varied. It is observed that as the GSM values of the GFRP specimens and the load increase, the wear observed on the specimen increases i.e. the wear resistance of the specimen decreases.

REFERENCES

[1] Hull D & Clyne T W, An Introduction to Composite Materials, (Cambridge University Press, Cambridge), 1996.

[2] Aggarwal B D, Broutman L J. Analysis and performance of Fiber Composites. Canada: Wiley-Interscience, 1990.

[3] Knops m., Bogle c. gradual failure in fibre/polymer laminates composites science and technology (2005).

[4] A.M.A. El-Habak Mechanical behaviour of woven glass fibre-reinforced composites under impact compression load Composites, Volume 22, Issue 2, March 1991.

[5] Manoj Singla and Vikas Chawla, "Mechanical Properties of Epoxy Resin Composite", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No. 3, 2010, 199-210.

[6] S. Sethi, P.K.Panda, R.Nayak and B.C.Ray - 'Experimental studies on mechanical behavior and microstructural assessment of glass/epoxy composites'.

BIOGRAPHY

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