Performance on tensile properties of GFRP stacking sequence using Taguchi Method

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ABSTRACT – The performance of glass fibre direction on tensile strength (σ_{TS}) and modulus (E_{TS}) was studied. The GFRP sequence directions of -45^o, 0^o, 45^o and 90^o were lay-up in five levels and symmetrical laminated. The specimens follow ASTM D638 type II. Orthogonal arrays design of Taguchi method was applied and the data was analyzed using analysis of variance (ANOVA). It is found that the most GFRP sequence direction affected the tensile properties is fibre layup at direction of 0^o while at -45^o, 45^o and 90^o show less significant. Result after validation of optimum parameter for σ_{TS} reduces to 1.59% however E_{TS} value was unchanged after validation process.

1. INTRODUCTION

Composite materials have excellent mechanical property and offer light weight characteristic with high end performance that required in many manufacturing sectors like body boats, aerospace industry, railway coach and automotive application. Various types of reinforcement have been used in polymer composites such as reinforcement made from PTFE fibre [1], fine fibre [2], and natural fibre [3]. Glass fiber reinforced polymer (GFRP) one of the composite materials have been used for many years due to their low cost as compared to other composite materials, chemical or galvanic corrosion resistance, non electrical conductor and offers various types of weaves such as plains, basket, satin, twill, etc. Various investigation on composite materials have been done such as studied the effect of fibre volume fraction [4], different orientation of fibre [5], and fiber aspect ratio [6]. Sharma et al. revealed that fiber orientation significantly influence both mechanical and tribological property. It was found that fiber oriented beyond 45^o deteriorated the performance [7]. Tian studied the effects of fiber orientation on the tensile strength of Csf/Mg. They found that the tensile strength of Csf/Mg composites gradually decreased with the fiber orientation angle increasing from 0° to 60° and slightly increased with the fiber orientation angle increasing from 60° to 90° [8]. Recently, design of experimental becomes essential to optimize the responses [9]. Therefore, in this study the effect of GFRP sequence directions is implemented using Taguchi method.

2. METHODOLOGY

Glass fibre reinforce polymer (GFRP) was used as a workpiece material for this study. Temperature 48.8^{o}C and full vacuum at 20”Hg is applied in autoclave machine to prepare the workpiece samples. Then, the specimens were cut using diamond sliding saw which parallel to the warp fiber direction within ± 3^o after the curing process. Finally, the specimens were machined according to ASTM D638 type II [10].

Table 1 shows the selected parameters performed for this study with two working levels. The range of experimental parameters value between low and high was decided with sequence directions of -45^o, 0^o, 45^o and 90^o at axis direction of tensile test. Five factors with two levels were performed in this experiment and direction of glass fibre was indicated by direction A, B, C, D and E.

Table 1 Stacking sequence of GFRP

Parameters	Low	High
Direction A	0 (|)	45 (⁄)
Direction B	0 (|)	90 (—)
Direction C	45 (⁄)	-45 (\ )
Direction D	-45 (\ )	0 (|)
Direction E	-45 (\ )	90 (—)

3. RESULTS AND DISCUSSON

3.1 *Analysis result of ultimate tensile strength*

Explanation of the result analysis is described by the graph and percentage of contribution value. It is determined that each of selected parameter influenced all the responses based on the percentage of contribution value. S/N ratio for σ_{TS} after analyzed using Minitab software is shown in Figure 1. It is found that parameters A and D are dominant factor affecting σ_{TS}. This result of dominant can be observed from the higher slope created from the graph. Result after validation on combination optimization using Taguchi method of these parameters decreases the σ_{TS} for 1.59%. Some researchers had agreed that the tensile strength decreased when the orientation of fibre increases more than 30^o and become more significantly when fibre oriented to 45^o [8].

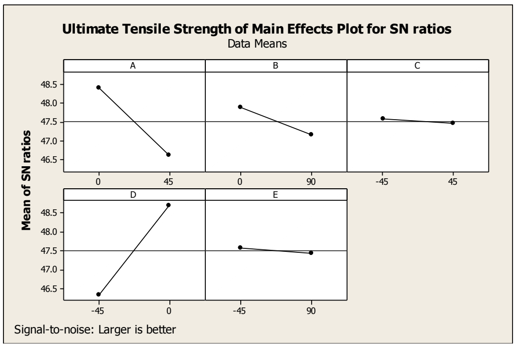

Figure 1 S/N graph for ultimate tensile strength

In order to study the percentage significance of the parameters affected the quality characteristic of interest, ANOVA analysis was performed. The summary of the result percentage is indicated using R-Sq as shown in Table 2. Considering the value of percentage that shows the significant factors influenced σ_{TS}, it can be determined that direction of parameters D is the highest percentage with 59.68%.

Table 2 One way ANOVA for ultimate tensile strength

Level	A	B	C	D	E
Rank	2	3	5	1	4
R-Sq (%)	33.85	5.55	0.13	59.68	0.24

3.2 Analysis result of tensile young's modulus

The S/N response graph of tensile young's modulus (E_{TM}) is shown in Figure 2 with initial setting the larger the better. It shows that the optimum parametric combinations of A, B, C, D & E are 0^o, $90^{o,}$ 45^o, 0^o and 90^o respectively. After validation of optimum parameters, the result of validation shows similar with the higher result in the actual experiment.

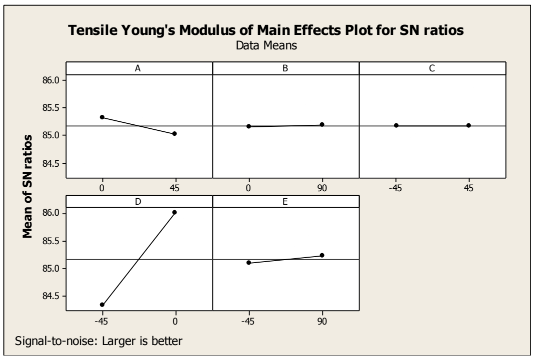

Figure 2 S/N graph for tensile young' modulus

Table 3 shows that direction D is the highest percentage with 80.76% followed by parameter A, E, B and C. Result of this experiment shows that when direction at -45^o and 0^o the higher of E_{TM} can be achieved.

4. CONCLUSIONS

It can be concluded that stacking sequence at 0^o contributes the most significant factor for tensile properties of GFRP. The direction fibre that perpendicular to the acting force developed higher resistant energy to the tensile properties of GFRP.

Table 3 One way ANOVA for tensile young' modulus

Level	A	B	C	D	E
Rank	2	4	5	1	3
R-Sq (%)	2.5	0.04	0.00	80.76	0.51

5. ACKNOWLEDGEMENT

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