

# Morphological Analysis of Fibre Reinforced Laminate Made By Hand Lay-Up Process

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**Abstract:** The usage of composite in industries or in aerospace sectors is in increasing demand which is been taken care in this noble work. This experimental study comprises of fabrication of composite by hand lay-up process and their characterization. Specifically laminated composites have been fabricated aiming different orientations of fibre. It is well known that orientation of fibre along the load direction will surely tailor the strength and different mechanical properties of the composite material. Two different kind of laminated composites have been fabricated of which one is randomly oriented and other is structured woven-glass / epoxy laminate. The aim of the research work is to monitor the hand lay-up of the fibres which directly influences the strength of each lamina in a complete laminate. To check the distribution of the fibres different test has been performed like X-Ray Diffractometer (XRD) and Transmission Electron Microscope (TEM). The result procured from the above test justifies the proper distribution and orientation of fibres and their effect on different mechanical properties. The outcome of the work will be helpful in tailoring the strength of the laminate by more specific skilled hand lay-up process.

**Keywords:** Composite, Hand Lay-up process, XRD, TEM.

## I. INTRODUCTION

The fibre reinforced polymer composite have both industrial and commercial applications. The areas of concern in which composites are used are space, aircraft, marine and automotive sectors. Thus, tailoring material according to our need forms the critical step in mechanical design process. A designer has to undergo morphological analysis of the new composite form. Thus, a fibre reinforced composite must undergo different structural analysis like Scanning Electron Microscope (SEM), X-Ray Diffractometer (XRD) and Transmission Electron Microscope (TEM). Based on the literature review, requirement of characterization for laminated composite is perceived. The work contains the accurate composition of laminated composite plate with high precision, to obtain the desired characteristic of the material.

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## II. EXPERIMENTAL PROCEDURE

The experimental procedure contains the step by step procedure carried out to make the woven composite laminate material.

### A. Work station preparation

Before carrying the layup process it is required to manage and arrange the work station for carrying out all the process. All the materials like fibre, resin, hardener, and all supporting materials was taken out from store and kept on a table in the lab room.

### B. Mold preparation

Mold preparation is the second most important of our experimental work. Firstly, the cleaning of mold and thereafter release agent applied on the surface of mold to avoid the resin to stick to the mold also a thin plastic sheet was wrapped tightly all around the mold as a one more protective layer to avoid sticking and damage of mold.

### C. Composition preparation

Before starting the lay-up process it is necessary to get mixed all the resin and hardener in desired ratio as per suitability to temperature and environmental condition. The resin and hardener was mixed in proper ratio of 10:1. After mixing both resin and hardener the mixture is stirred for approximate 25 minutes in order to form a homogenous solution. After the mixture preparation sheet of glass fibre is cut into square pieces of dimension 250mm each for stacking during the layup process.

### D. Lay-up process

Once the workstation is ready, mold preparation done, all the materials are prepared and mixture was ready the lay-up process can be started. Spread the mixture of resin and hardener all over the plastic film wrapped on mold. After that place the woven glass fibre square cut piece on the mixture and again pour the mixture over fibre and spread it all around until the whole fibre gets wetted using brush and roller so that there will be equal distribution of the mixture and also no air bubble gets trapped inside the lamina. Again place another woven glass fibre square piece and repeats the steps until the desired thickness is not attained. Figure No:- 2.1, 2.2 and 2.3 shows the preparation of epoxy mixture which is stirred and the random and symmetric woven-glass fibre opted for making the composite.



Figure 2.1 Epoxy preparation

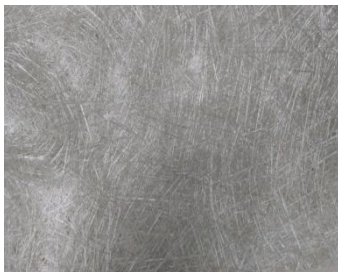


Figure 2.2 Random Woven-glass Fibre

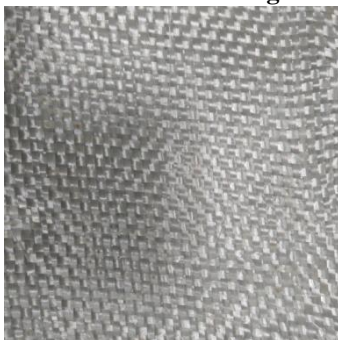


Figure 2.3 Symmetric woven-glass fibre

## E. Curing

The part can be cured at maintained temperatures using any kind oven or normally at room temperature. The correct curing time of resin-hardener, as well as the working time is instructed by the supplier. For epoxy resin to be cured the room temperature is sufficient. In this study, the part was left for one day in an open environment maintained at room temperature.

## F. Cleaning

After placing the part to be cured at room temperature now, it comes to the cleaning of all the instruments used in this process. All the cleaning work is done using acetone because of its property to work against stickiness. All the beaker and stirring rod cleaned using acetone and tissue paper. After using the acetone it is must to wash the hand very carefully.

Figure no:- 2.4 shows the final composite material prepared by the hand layup process.

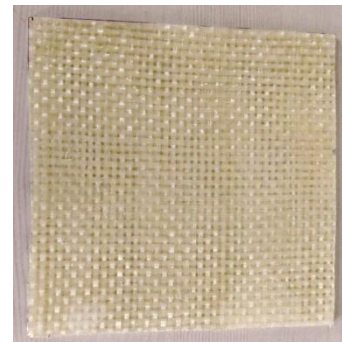


Figure 2.4 Woven – glass/epoxy composite

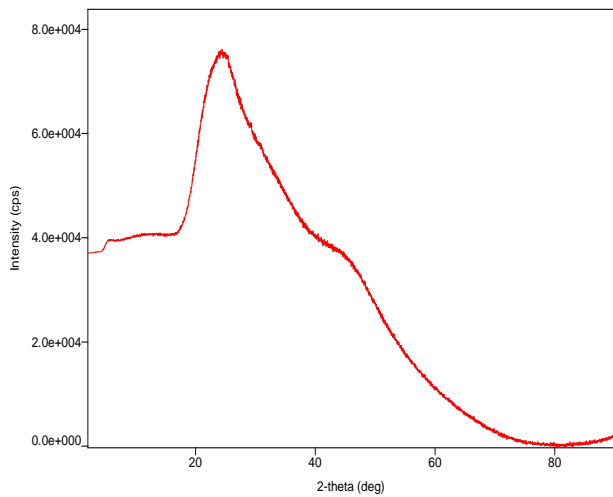
## III. RESULTS AND DISCUSSIONS

The morphological characters of composite material are determined by careful polishing of sample surface. The specimens with different phase composition are identified by X-Ray Diffraction (XRD- RigakuMiniflex 600) as shown in Figure no:- 3.1 and microstructure analysis has been carried out by transmission electron microscope (TEM-TEOL) to study the internal distribution of the specimen as shown in Figure no:- 3.1 (a-e).

Fig. 3.1 shows the evaluation of different phases in the composite procured through X-ray diffraction analysis. From the figure, higher strength of the composite material is achieved at the angle of  $18^\circ$ . It also confirms the rigid property of the material at different intensities and inclination of rays. The highest intensity procured is  $7.6 \times 10^4$  cps (cycle per second). This also indicates the stable reaction occurred between the resin matrix and woven glass fibre. In addition, the high intensity indicates the required volume fraction in the composite.

Figure 3.1(b) shows TEM micro graphs of the layered composite laminate. The group of figures (a) (b) (c) (d) (e) shows the micrograph at different magnification and inclination. Fig. 3.1 (a) and (b) is observed at  $0.2 \mu\text{m}$  magnification, the congested black region interprets that electron beams are not able to cross the specimen i.e. signifying the intactness of the polymer reinforced composite. Fig. 3.1 (c), (d) and (e) predicts the regular stacking sequence made by parallel layers of the laminate. It also emphasis that on increasing magnification from  $0.2$  to  $0.5 \mu\text{m}$  the distribution of layers can easily be observed and bonding can be defined clearly. The figures show the clear grain boundary, which ensures the proper grain distribution. The observation is based on specimen tilted angle, which confirms the better interaction between the beams and the sample at different orientations. The voltage maintained for the complete high resolution transmission electron microscope at an accelerating voltage of  $180 \text{ kV}$  while the revelation time are varied from  $0$  to  $100$  seconds.

The symmetric laminate is made of four layers of woven roving glass fibres and remaining as matrix. The TEM figures also justify the equal inter layer distance between the four different laminas.



FigureNo.:- 3.1 XRD analysis

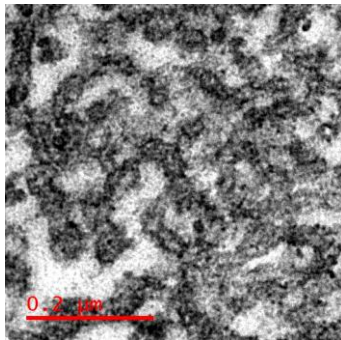


Fig 3.1 (a) Microstructure of woven glass epoxy composite

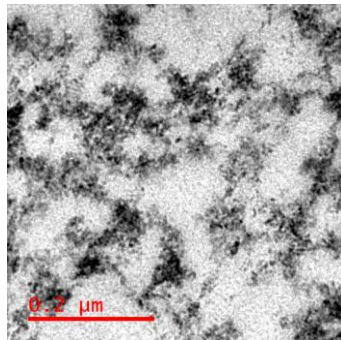


Figure3.1(b) Microstructure of random woven-fibre glass / epoxy

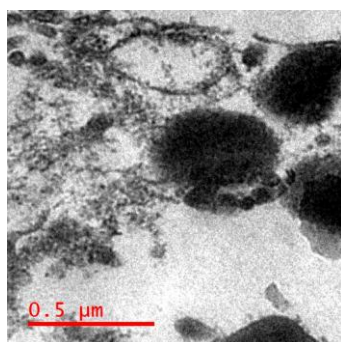


Figure 3.1 (c) Microstructure of structured woven-fibre glass / epoxy

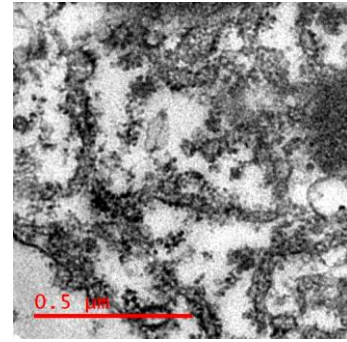


Figure 3.1 (d) Microstructure of structured woven-fibre glass / epoxy at 0.5 μm

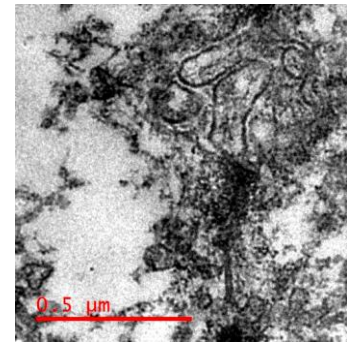


Figure 3.1 (e) Microstructure of random woven-fibre glass / epoxy at 0.5 μm.

#### IV. CONCLUSION

The above study represents different aspects of handmade woven glass fibre composite. Different test performed like XRD and TEM signifies the proper distribution of matrix and fibre and the strength of the material. The research also reveals the microstructure analysis, which gives the complete picture about the equidistant inter-layers of laminate. The XRD results showing peak values signifies the aggregation of fibres representing strength in that direction. The results procured also ensures about the ratio maintained while the making of matrix. The present study may be further extended for different types of fibres.

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