LAY–UP OPTIMIZATION OF COMPOSITE LAMINATED PLATE SUBJECTED TO BENDING LOAD INTHE PRESENCE OF DELAMINATION

Venkate Gowda C[1], Rajanna[2], N. G. S. Udupa[3]

[1]Research Scholar, Department of Mechanical Engineering, NCET, Bengaluru
[2]Associate Professor, Departmentof Mechanical Engineering, GEC, Kushalnagara
[3]HOD-PG, Departmentof Mechanical Engineering, NCET, Bengaluru

Abstract

Composite materials find applications in various fields sinceits properties can be tailor made for the particular applications. In this work,the number of symmetric layers of carbon glass laminate is optimized such that it can with stand more load without deformation or failure. The specimens are subjected to 3-point bending load under computerized universal testing machine. The specimens are prepared using VARTM method so that defects can be reduced. The optimized stacking sequence is obtained by doing finite element analysis using ANSYS. Later specimens are prepared for those optimized layer orientations. Experiments are conducted and results are analyzed and concluded. In this case, for the optimized layer sequence obtained, the specimens are prepared for with and without delamination defect. The delamination is introduced in the specimen centre. The load carrying capacity is analyzed when defect such as delamination are present in specimens.

Keywords: *Composites; Delamination; 3-Point Bending, VARTM Process*

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1. INTRODUCTION

The thought of composites materials is not another or late one. Nature is overflowing with examples of composite materials. The coconut palm leaf is a cantilever utilizing the idea of filaments support. Wood is a stringy composite with cellulose fiber in a lignin grid. Bone is another illustration of a natural composite that supports the heaviness of different individuals from the body. It is a combination of short and sensitive collagen filaments in a mineral framework known as apatite. Not with these naturally happening composites, there are plenty of other designing materials which are composites in most part way and that have been being used for quite a while. The improvisation on materials for general execution are so incredible and differing that no material can fulfill them. This actually prompted an old idea of consolidating diverse materials in an indispensable composite material to fulfill the necessities. Such composite material frameworks result in an execution unattainable by the individual constituents and they offer the immense favorable position of an adaptable outline: that is, one can, on a fundamental level, tailor-make the material according to determinations of an ideal configuration.

2. SPECIMEN PREPARATION

Composite specimens can be manufactured or prepared using different techniques. Fabrication of composite components is mainly concerned with the placing and orientation of fibres in the direction and required form obtaining desired properties that performs requires function. It mainly depends on the need of specimen, desired properties required, applications, type of composite fibers used, component geometry, reinforcement and matrix type, marketing economics. The two tasks are involved in manufacturing of composite laminate:

1. Fabrication/manufacturing technique andProcessing.
2. Fabrication phase consists of fiber reinforcement along with matrix material are placed or shaped into a structural form.

The fiber and matrix material are combined to obtained desired structural form. In processing phase, heat and pressure are required to densify and consolidate the structure.

3.VAPOUR ASSISTED RESIN TRANSFER MOULDING

VARTM is closed mold composite manufacturing method. This process uses a low viscosity resin which is capable of producing fiber volume fraction between 40-50%. The ratio of resin to fiber helps in determining the overall strength and performance of specimen. The carbon and glass fibers was cut into length of 250 x 250 mm. the plates were prepared using symmetric laminates of 8 layers out of which 4 carbon and 4 glass layers. The carbon fiber was placed in 0^0orientation and glass at 90^0. VARTM method for specimen preparation was used. The specimens were prepared at Aeronautical Department, Indian Institute of Science, Bangalore.

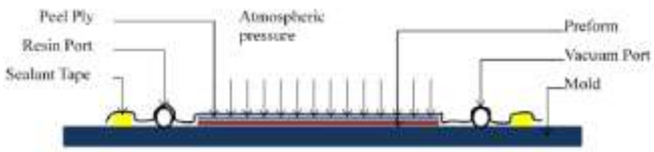

Figure 1: Typical VARTM setup

Figure 1 shows a schematic sketch of the VARTM processs. The VARTM is a composite manufacturing technique by infusing resin into base materials formed with woven fabric or fiber using vacuum pressure. The details of On comparing withconventional composite fabrication methods in the aeronautical field, VARTM process is preferable technique for using low cost composite materials without prepregs and autoclaves.VARTM is a similar to that of RTM where the top mold is replaced with a flexible vacuum bag, which decreases manufacturing cost considerably. Here, vacuum applied stimulates required pressure gradient for the resin flow and compaction of perform.

Initially, layers of preform are arranged on a solid mold in the required shape of the component, as per the required orientation. Peel ply and release film are then placed on the preform, where peel ply is used for surface finish and release film for easy release of the process consumables from the preform. Lastly, high permeability medium is placed for increasing the overall permeability and thereby decreasing the infusion time. Then the whole setup is enclosed with a flexible vacuum bag with the vacuum port kept on one end and the resin port on the other

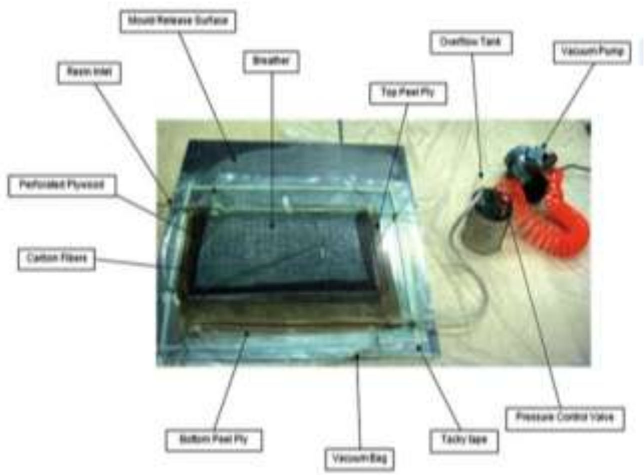

Figure 2: Specimen preparation Set-up

Initially, the workbench is cleaned with water droplets to remove the dust particles and keep place clean for specimen preparation. Glass and carbon fibers are cut to the required dimension and orientation. On the other hand resin and hardner mixture calculations are done and mixed, kept ready. Figure 2 shows the specimen preparation set-up.The layers are placed gently one above the other without any folds of layers in between. The layers are compacted tightly. An extra layer is placed on top layer to absorb extra mixture. The entire set up is covered with vacuum bag and closed with help sealants so that no extra air is entered from outside and vacuum is maintained.Two openings at two opposite corners are provided where two pipes are made to pass in them and tightly closed. In 1 pipe the resin hardener mixture is allowed to enter and in another the pressure is controlled with the help of vacuum pump. The resin flow to inside is controlled with help of pressure control valve.The resin flows within 30min to 1 hr into layers. The flow of resin can be seen through the eyes and flow rate can be controlled. Precaution must be taken that no air bubbles are formed.Later the set up is kept for 12 to 14 hrs for curing without disturbing the setup. By that time the layers get compactly packed. Thus the specimens are prepared.For the plates with delamination was prepared using teflon paper at the centre. The delamination of 10 mm and 20 mm was introduced in the plate in both 0/90 and ±45 orientation plates at centre in between glass-glass layer. The delamination was introduced along the width of specimen

Figure 3: Specimens

4. SCANNING ACOUSTIC MICROSCOPE

The scanning acoustic microscope (SAM) uses sound to measure or image an object. It is used in non destructive evaluation. SAM is the superior tool to detect delaminations at sub-micron thickness. SAM is a high-performance tool enabling nondestructive acoustic investigations for dedicated high throughout analysis, quality control and research applications. It features a new high speed maintenance free stage and new RF and transducer technologies of upto 400MHz, controlled through user friendly graphical interface.SAM uses sound energy to image by the use of transducers. Samples are immersed in a fluid medium making sure that ultrasound waves propagate through samples. The ultrasonic transducers send pulses into liquid. The transducers also receive reflected pulses from non continuous and disturbances from sample. Transducer transforms the reflected sound pulses into electromagnetic pulses which are displayed as pixels with defined gray values there by creating an image.

The specimen is immersed in liquid.. The specimen is scanned along its length. Since the exact thickness of each layer is not known, the specimen was divided into seven subparts and scanned. The presence of delamination and voids was indicated in red color

Figure 4: Scanning electron microscope

5. UNIVERSAL TESTING MACHINE

The specimens once after doing scanning for checking of delamination, it was subjected to a 3 point bending test in computerized universal testing machine. The experiment was conducted at, Material characteristics lab Nano- Science department at IISc, Bangalore.According to ASTM D-790standards, the specimens were cut into dimensions of 130 x 25.4 mm.The total length was 130 mm while the span length was 110mm .The load was applied at the centre of specimen exactly. The load was applied at the rate of 2mm/min. The load was applied till the fracture (crack) was formed.

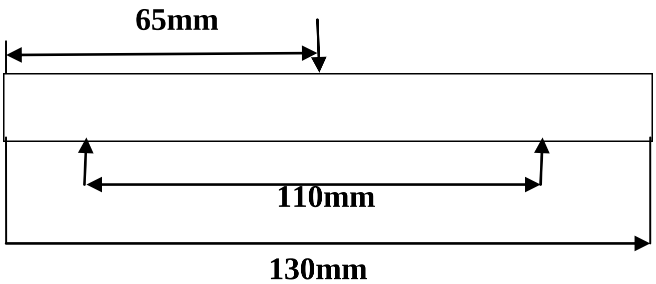

Figure 5: Test dimensions

6. RESULTS AND DISCUSSIONS

The experiments were conducted at Mechanical characteristics lab, Centre for nano Sciences, IIsc Bangalore. The results obtained for various sets are discussed there was two sets of specimens and further among them I had three subsets. The main classification was based on fibre orientation. The first set was of $(0/90)^0$orientations and other was $\pm 45^0$ orientation of fiberes. These two sets further considered three sub levels: without delamination, 10mm delamination and 20mm delamination. Delamination was introduced at centre of specimen.

Figure 6: Experimental Set up with specimen after load applied

Case 1:
Load and Displacement of 3-point bending $(0/90)^0$

In first set, the specimens without delamination were considered. Experiments were conducted on three specimens. The average result was taken and compared with other two sets.

Table 1: Load displacement without delamination

Specimen	Load(N)	Displacement(mm)
1	274	11.44
2	287	11.01
3	263	10.57
Average	274.66	11.00

Table 2: Load displacement with 10mmdelaminations

Specimen	Load(N)	Displacement(mm)
1	236	9.96
2	209	10.65
3	245	10.86
Average	230	10.49

Table 3: Load displacement with 20mmdelamination

Specimen	Load(N)	Displacement(mm)
1	145	23.24
2	145	23.54
3	154	24.45
Average	148	23.74

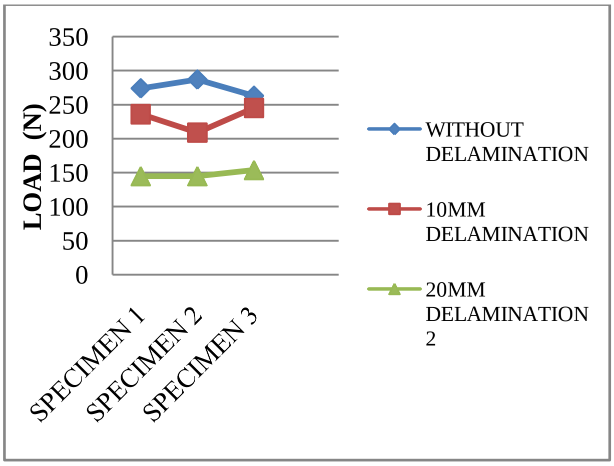

Figure 7: Comparison of load of (0/90)^0 orientation subjected to 3-point bending

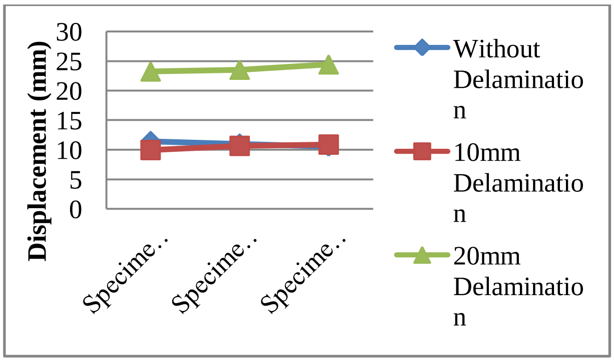

Figure 8: Comparison of displacement of (0/90)^0 orientation subjected to 3-point bending

The figure 7 and 8shows load and displacement variations of all three categories of (0/90)^{0}specimens. It is evident from graphs that specimens without delamination have more load carrying capacity while their displacement is very low. The specimen with more delamination has high displacement but less load carrying capacity.

Case 2:

Load and Displacement of 3-point bending (±45)^0

Table 4: Load displacement without delamination

Specimen	Load(N)	Displacement(mm)
1	172	19.03
2	175	20.03
3	164	19.14
Average	170.3	19.4

Table 5: Load displacement with 10mm delamination

Specimen	Load(N)	Displacement(mm)
1	164	20.21
2	149	19.25
3	160	20.67
Average	170.3	20.04

Table 6: Load displacement with 20mm delamination

Specimen	Load(N)	Displacement(mm)
1	76	19.12
2	73	18.18
3	73	16.64
Average	74	18.22

Table 4, 5 and 6 shows results of (±45)^0 oriented specimens of load and displacement. Based on above data, load and displacements graphs are plotted as shown below

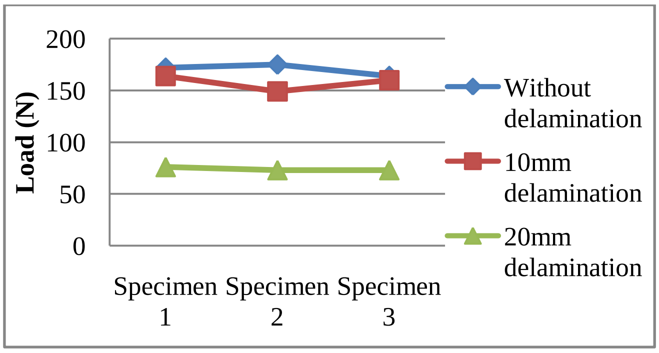

Figure 9: Load carrying capacity of specimens of (±45)^{0}specimens

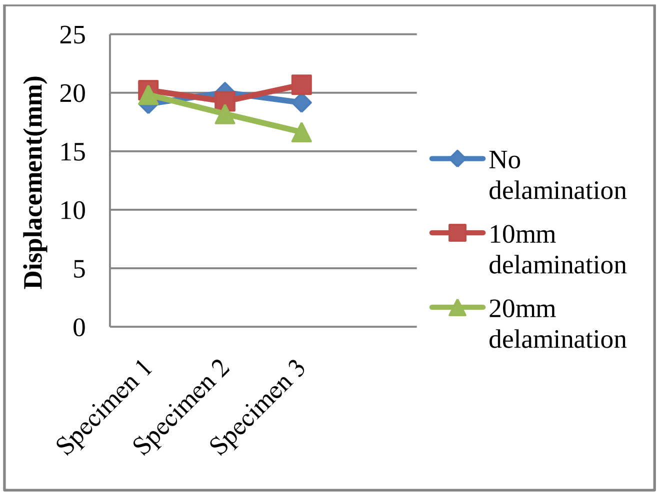

Figure 10: Comparison of displacement of (±45)^{0}Orientation subjected to 3-point bending

The figures 9 and 10 shows load and displacement of (±45)^0 specimen. In this category though the load was varied for all categories, displacement remained almost same in all. This shows that components with (±45)^{0}orientations can withstand for longer period though component cracks without sudden failing

7. CONCLUSIONS

The specimens was prepared without delamination and scanned for voids or any dislocations and then subjected for loading. The specimen without delamination of (0/90)^0 carried more load (avg-275 N) compared with ±45^0 with load capacity (avg - 170 N).The specimen of $(0/90)^0$ had less displacement carrying more load compared with other orientation used in project. The specimens with $(0/90)^0$ can be used for more load carrying conditions with lesser displacement or bending. The specimens with $(\pm45)^0$ can be used for lesser load carrying capacity conditions and more bending takes place.

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