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Detection and Classification of Defects in Composite Materials Using SEM Analysis

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ABSTRACT: The specific aim for our project is to Detection And Classification Of Defects In Composite Material. We tested and analyzed a product which is made using polymer matrix composite material. Here we are using carbon fibre as reinforcement and epoxy as a matrix Initially wefabricates a product by hand layup method with a specific ratio as we observe from the several literature. The fabricated product is planned to evaluate its mechanical properties such as tensile strength impact strength, compression strength and finally the Morphological characteristics analysis before and after tensile tests were studied using scanning electron microscopy (SEM) technique to follow the failure evolution on carbon fiber reinforced polymer (CFRP) and epoxy resins.

KEYWORDS: Vacuum Bagging, Carbon/Epoxy composites, SEM

I.INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly .Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

Composite materials have continuously replaced conventional materials due to their excellent properties like high strength to weight ratio, wear resistance. In the present investigation, a mechanical and machining characteristic of the CFRP aluminum sandwich composite material is studied. This chapter at first introduces the importance of composite materials and its different kind of availability and it also mainly discusses the importance of CFRP composite materials, its fabrication process and their applications. Then it discusses about the sandwich laminates, its properties and their applications.

II. RELATED WORK

Conventionally, Carbon/Epoxy composites are fabricated by compression moulding, Hand layup, Autoclave moulding, Resin Transfer moulding and etc. components produced by these manufacturing processes are not good in surface finish and having lots of defects. Fibre to resin ratio important while manufacturing carbon/epoxy composites. The perfect fibre to resin ratio is obtained in vacuum bagging. But in other processes, the resin content is high in nature and the resin properties are higher in the composites. Aerospace and marine industries are concentrated on the weight reduction. Strength to weight ratio is also important while making composites. The light weight components with high strength to weight ratio is obtained through this vacuum bag setup. Compare to this method, the installation cost is higher and not portable. Vacuum bag size is varied with the size of the mould. Vacuum pump is the heart of this manufacturing process. Pump selection plays a major role in this method. Perfect vacuum cannot be obtained by the vacuum pump.



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Composite materials are the combination of two or more materials obtained by embedded continuous carbon fibre in one or more orientation in a polymer matrix. The fibre describes the strength, while polymer serves as a binder

III. FABRICATION DETAILS

Sample 1 is fabricated using vacuum bagging method. The 90×90 mm square plate is selected as a mould. Mould wax is applied on the surface of the mould4 to 5 times. The vacuum bag is selected for the required mouldsize. First the full vacuum bag setup is assembled. Then the epoxy resin and hardener istaken 10:1 ratio. After applied the layers the mould is set into the bag. Now the bag is sealed and check for the leak. Before applying the vacuum, the pressure inside and outside the envelope remains same as atmospheric pressure. After applying the vacuum, the pressure inside the envelope decreases. The pressure difference between inside and outside of the envelope creates the clamping force. The curing time of the process is about 3 to 4 hours. Throughout the process, the pressure inside the envelope remains same.Finally the sample 1 is taken out from the bag. The sample is cut for the required dimensions for the testing purpose. The sample preparation refers to ASTM standards.



Fig 2 (a) Vacuum bag

Sample 2 is fabricated using hand layup method. The same size mouldtaken for this method also. mould wax is applied 4 to 5 times. The layers and resins are taken for the same amount similar to the vacuum bagging. After applying the layer and resins the mouldisplaced on the open room. It is cured in the presence of air. Then the sample is removed from the die and the excess of the piece is removed by the wire cut machine. The required dimensions for the testing are marked and to be cut using the wire cut machine as per ASTMstandard.



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Fig 3 (a) Carbon fiber helmet finished component

IV. EXPERIMENTAL DETAILS

The physical and mechanical properties are to be tested. The physical properties such as mass, thickness, volume and density of the two samples are to be tested. Physical properties can be observed and measured without changing or breaking the sample. Weighing scale is used to measure the weight of the sample. Digital weighing scale is more accurate than the analog scale.So we are using digital weighingscale to measure the sample piece. Thickness of the specimen is measured by various measurement tools. But we use Vernier caliper to measure the thickness of the sample. Vernier caliper is used to measure the outer dimensions of object using main jaw and to measure the inside dimensions using smaller jaw on the top.

ASTM D3039 is the standard for testing the tensile properties of the composite materials. The test is conducted on the universal testing machine. By this tensile test we determine the in-plane tensile properties of polymer matrix composite materials strengthened by high-modulus fibers can be obtained. Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance.

ASTM D7264 is the standard for flexural properties of the composite materials. The test is conducted in the universal testing machine. The test is carried out by the three-point testing method. Standard specimen thickness is 3mm and width is 13mm and it is 125mm long. From the experiment compressive strength (MPa), maximum displacement (mm) and ultimate load can be calculated. The flexural strength of a material is defined as its ability to resist deformation under load. For materials that deform significantly but do not break, the load at yield, typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yieldstrength.

Charpy impact strength test is an ASTM standard method of finding the impact resistance of materials. The test is conducted in the impact testing machine. ASTM D256 is the standard for the composite materials. The dimensions are $63.5 \times 12.8 \times 3.2$ mm. And a 22.5° V notch is cut in the center of the samples. From the above mechanical properties, the efficiency of the fabrication methods isevaluated.

Rockwell is a method of hardness testing that simply relies on the metal's resistance to indentation using a specific load application and a specific indenter. It has two load systems for measurement, which is light load and major load. The Rockwell hardness test is defined in ASTM E 18 and several other standards.



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Fig 4 (a) Drop weight impact testing machine

Drop Weight Impact Test method was to drop a weight in a vertical direction, with a tube or rails to guide it during the "free fall." Once again, with the height and weight known, impact energy can be calculated. In the early days, there was no way to measure impact velocity, so engineers had to assume no friction in the guide mechanism.

They also give information about mode of failure and specific response of composite to particular type of loading.. The correlation between the environmental degradation on FRP composite and failure is a vast field for the investigation. By observing carefully the fracture surface of the composite the factors affecting their respective failure and the type of environment they were subjected to coulde determined.



Fig 5 (a) Translaminar A (b) Translaminar B

SEM micrograph of cryogenically conditioned (77K) carbon /epoxy composite sample showing crack propagation along the interface at crosshead speed of 100mm/min.

The matrix contraction at cryogenic temperature is resisted by stiff fibers through fiber/matrix interfacial bonding that originates residual stresses. The matrix response to an applied load is temperature dependent and change in temperature can cause internal stresses to be set up as a result of differential thermal contraction and expansion of the two constituents. Increased thermal stresses are the underlying cause of micro cracking in composites at cryogenic temperatures.



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(a)



Fig 5 (a) Intralaminar A (b) Intralaminar B

Fracture surface of carbon/epoxy composite specimen failed in 3 Point Bend testing.

The above micrographs fig shows crack propagation the interlaminar plies moving from left side of the fracture surface to the right hand side of the surface which can be inferred form the markings produced by cavity nucleation and growth ahead of the advancing crack front. The crack front changed its path orientation when a ductile matrix inferred in its path

Physical and mechanical properties of the samples are evaluated. We take two samples, sample 1 is made by vacuum bagging technology and sample 2 is made by hand layup method. All the tests are conducted on composite materials made by hand layup method and vacuum bagging method.

Standard specimen thickness is 3mm and width is 13mm and it is 125mm long. From the experiment compressive strength (MPa), maximum displacement (mm) and ultimate load can be calculated. The flexural strength of a material is defined as its ability to resist deformation under load. For materials that deform significantly but do not break, the load at yield, typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength.



Fig 5 (a) Interlaminar A (b) Interlaminar B

V. RESULTS AND DISCUSSION

Physical and mechanical properties of the samples are evaluated. We take two samples, sample 1 is made by vacuum bagging technology and sample 2 is made by hand layup method. All the tests are conducted on composite materials made by hand layup method and vacuum bagging method. The physical properties of the composite materials such as weight, area, volume, density and thickness for both samples are taken. the size of the sample mould 90 \times 90 mm^2. The following table shows the physical properties of the samples. Both samples are made by 3layers of carbon fibre reinforcement polymer.



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Table 1Physical Properties

	Area	Volume	Density	Mass	Thickness
	(mm^2)	(mm^3)	(Kg / m^3)	(grams)	(mm)
Sample 1					
(VBS)	8100	9720	1337.45	13	1.2
Sample 2					
(hand layup)	8100	18630	966.18	18	2.3

Result – from the table 2, the thickness of sample 1 is less than the sample 2. Compare to sample 2, there is a weight reduction in sample 1 that is made by vacuum bag setup. Vacuum bag setup (sample 1) shows the better physical property than hand layup (sample 2). Also we test the thickness of the samples made by vacuum bag setup, by increasing the layers. For this we take three samples. Sample 1 (3 layer), sample 2 (5 layer), sample 3 (10 layer). Table 2 shows the thickness and density variation

Table 2Layers Variation

	Layers	Thickness	Density
Sample 1	3	1.2	1337.45
Sample 2	5	2.4	1388.89
Sample 3	10	5.3	1461.31

Result - The increase in layer increases the thickness of the sample. Also increase in layer causes increase in density.

Table 3 Mechanical Properties

	Tensile strength(MPa)	Flexural strength (MPa)	Impact strength(KJ/m^2)	Hardness (RHN)
Sample1 (VBS)	271.4	226.8	0.733	87
Sample2 (hand layup)	234.1	198.4	0.708	82



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Result - The mechanical properties of the samples are evaluated and shown in the table The tensile strength of the Sample 1 (Vacuum bagging) is comparatively high with Sample 2 (Hand Layup), this is because of the heat treatment and the sample is kept in the above the room temperature, whereas the Sample 2 (Hand Layup) is kept in the room temperature while fabrication. It is noted that the tensile strength of the samples is satisfied. So, the stability of the Sample 1 (Vacuum bagging) is enough.

The flexural strength of the Sample 1 (Vacuum bagging) is higher than the Sample 2 (Hand Layup) this is due to the weight ratio of the reinforcement and matrix is low when compared to the Sample 2 (Hand Layup). This show that the carbon fibre has the better flexural strength than the epoxy resin.

The flexural strength of the Sample 1 (Vacuum bagging) is higher than the Sample 2 (Hand Layup) this is due to the weight ratio of the reinforcement and matrix is low when compared to the Sample 2 (Hand Layup). This show that the carbon fibre has the better flexural strength than the epoxy resin.

The graphical representation of the hardness is shown in the figure 6 (b). By comparing these values, the Sample 1 (Vacuum bagging) is having better hardness than the Sample 2 (Hand Layup). This shows that the excess resin content in the top layer of the hand layup method. This cause the hardness of the Sample 2 (Hand Layup) is comparatively lesser than the Sample 1 (Vacuum bagging).



Fig 6 (a)Tensile And Flexural Strength Of The Samples (b)Hardness number of the samples

IV. CONCLUSION

Durability and long life of FRP have been major area of concern. Several models have been developed to explain service failures of composites .However heterogeneous nature of FRP makes the process quite cumbersome. In the present work it's been tried to explain the failure mechanism actually occurring in the tested samples on the basis of established theories through SEM factor graphs. Fracture behavior depends on factors, such as, resin relaxation, state of interfaces, post-curing phenomena, stresses relaxation and development, crazing and cracking in the matrix resin and also micro-void formation because of differential contraction/expansion among constituent phases.

Also the micrographs of the multiple failure mechanisms using SEM are developed to determine structural composition and observe defects at the micro-level. By observing the orientation and structure of various primary and secondary features like river patterns, shear cups and hackles, the point of initiation and propagation of insidious crack can be predicted. They also give information about mode of failure and specific response of composite to particular type of loading.. The correlation between the environmental degradation on FRP composite and failure is a vast field for the investigation. By observing carefully the fracture surface of the composite the factors affecting their respective failure and the type of environment they were subjected to could be determined.



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