International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Vol. 48, Special Issue, (TAME-2019, April 4-5, 2019)
(An Indexed, Referred and Impact Factor Journal approved by UGC- Journal No. 42581)
ISSN (Online): 2319-6564
www.ijesonline.com

VIRTUAL ANALYSIS AND MANUFACTURING OF FLAT SPECIMEN OF CARBON FIBER COMPOSITE FOR COMPUTING TENSILE STRENGTH

Joginder Singh[1], M.R.Tyagi[2] , Abhinav Chawla[3], Vinay Prabhakar[4], Dinesh Kashyap[5], Abdul Ahad[6]

[1,2,3,4,5,6] Department of ME, Manav Rachna University,
Sector-43, Delhi-Surajkund Road, Faridabad

[1]joginder@mru.edu.in,[2]mrtyagi1953@gmail.com,[3] abhinav.97.16v@gmail.com,[4] vinaymru99@gmail.com
[5] kashyap.dinesh23@gmail.com,[6] samarahad007@gmail.com

Abstract

Tensile strength is one of the important mechanical properties. To check the tensile strength, flat specimen is designed as per the ASTM E8M standard. Two materials were selected to compare the tensile strength i.e. Steel and Carbon Fibre Composite material. The overall dimensions of the specimen were 200 x 70 x 4 mm. The Specimen of Steel was manufactured with the help of Wire Cut Machine. The Specimen of composite was developed from the scratch i.e. Carbon Fibres and Epoxy. The developed specimen was machined by Water Jet Machine. 2D and 3D of the specimen was developed in the CATIA software. Both machines were computer operated therefore good accuracy achieved in the 2D profiles. Few problems were faced during machining of Carbon Fibre Composite material with Water Jet Machining like delamination, fibre pull out and abrasive embedment in the specimen. There was huge difference in the weight of specimen of said materials. Weight was reduced by 83.2% when Carbon Fibre Composite material used. Virtual analysis of Steel and Carbon Fibre Composite material was performed in ANSYS software. For the same boundary and loading conditions, Carbon Fibre Composite material showed the better results in context of stresses. Future belongs to the Carbon Fibre Composite material because of its various advantages.

Keywords**:** Carbon Fiber Composite, Water Jet Machining, CATIA, ANSYS.

1. Introduction

Steel is one of the most widely used materials in the mechanical and civil engineering. No doubt it has various good mechanical and electrical properties. But its weight is one of the main constraints and it is creating adverse effect on the environment. That's why various researches are working on different materials to reduce the weight without compromising the other properties. Composites are one of the good alternatives. It has various advantages like light weight, corrosion resistant, heat resistant, high stiffness, electrical properties, etc. The strongest carbon fibre is 10 times stronger and 5 times lighter than steel. Similarly, the strongest carbon fibre is 8 times stronger and 1.5 times lighter than Aluminium [1]. One of the biggest disadvantages is that it is very costly compare to Steel and Aluminium. Even then it is used in various applications where cost is hardly matter. The performance of both machines and human beings increases by using these composites. That's why it is being used in various industries like automobile, railway, aerospace, sporting goods, shipping, wind turbine blades, cycling, etc.

Similarly, industries are moving from conventional manufacturing to computer integrated manufacturing. Water Jet Machining, Electric Discharge Machining, 3D Printing and CNC are becoming more famous because of computer integration. Higher accuracies are achieved without intervention of human errors. In the same way, specimens were manufactured with the help of Wire Cut Machine and Water Jet Machine [2].

Product validation can be done by Physical Testing and Virtual Testing. But now Physical Testing of the products is reducing day by day because of its high cost and time consuming. Customers don't have time and becomes more demanding. If demand is not fulfil, customer will go somewhere else. To meet the continuous requirements, industries prefer Virtual Testing. Because it also gives up to 95% accurate results and it is less costly and less time consuming. In this experiment, 2D and 3D model is created in CATIA Software and Virtual Testing performed on ANSYS Software. Therefore, CAD/CAM/CAE is the necessity of any industry to survive in the market.

2. Design of the Flat Specimen

Flat Specimen developed strictly as per the standard of ASTM E8M. CATIA Software is used for 3D Modelling and Drafting. There is linkage between the 3D Model and 2D Drafting of the part. Various commands were used in Sketcher, Part Design and Drafting Module of the CATIA. Steel material was applied through the CATIA Software and the following parameters were observed which is shown below [3].

Table 1. Specification of the Flat Specimen

S.No.	Characteristics	Values
1	Length	0.2 m
2	Width	0.070 m
3	Thickness	0.004 m
4	Volume	$3.00x10^{-5}$ m^3
5	Area	0.018 m^2
6	Mass	0.236 kg
7	Density of Steel	7860 kg/m^3

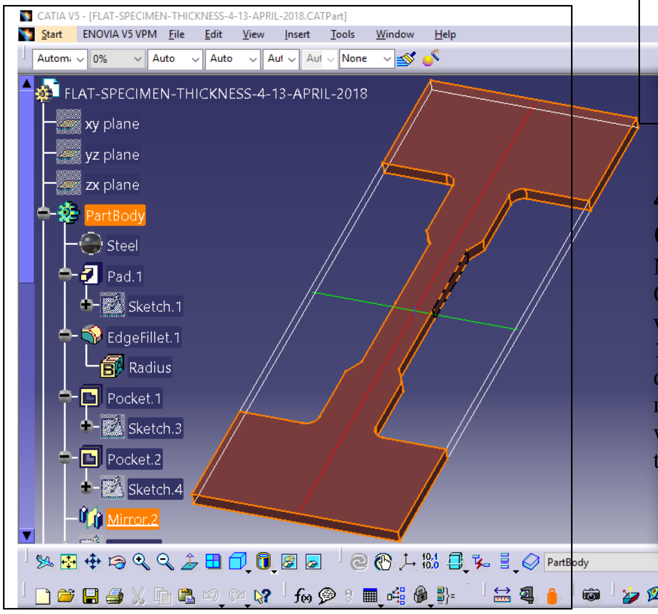


Figure 1. Design of the Flat Specimen using CATIA Software

3. Manufacturing of the Flat Specimen from Steel Material

The specimen was developed in the Steel material with the help of Wire Cut Machining. The standard of the steel was IS:1079 with HR1 Grade [4]. In the machine, wire moves as per the 2D Drawing and it is computer operated. Therefore, the accuracy of the profile is very good. Total 4 Specimen were developed. **The weight of a Single Specimen was 0.226 kg as shown below**. As the Steel material was Isotropic material so there was no variation in the weight of the specimens.

Table 2. Material Properties of Steel

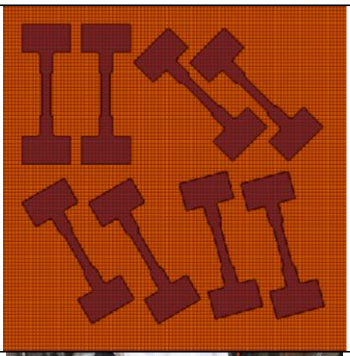
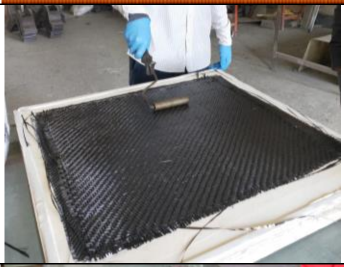
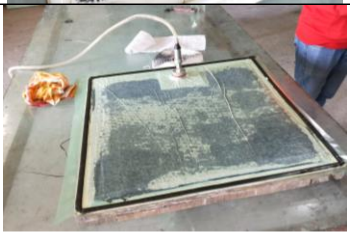
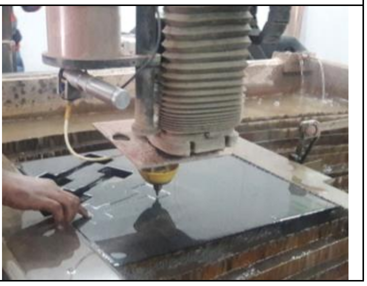
Material Properties	Standard Values
Ultimate Tensile Sterngth	440 Mpa
Young's Modulus	2 x 10^5 MPa
Poisson's Ratio	0.3
Yield Strength	250 MPa
Tangent Modulus	1450 MPa

Figure 2. Weight of the Flat Specimen of Steel Material

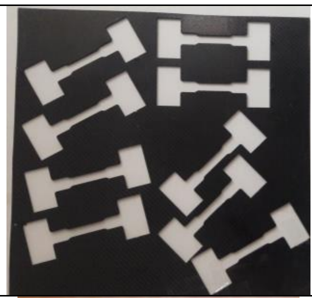
4. Fabrication of the Flat Specimen of Carbon Fibre Composite

Main aim was to manufacture the specimen in the Carbon Fiber Composite material and to compare their weight. Fibres were oriented at different angles like 0°, 15°, 30° and 45°. Two specimens with every angle were developed by Hand Layup method [5]. So the total number of specimens required was 8. Numbers of steps were followed to develop the specimen shown in the table given below.

Table 3. Steps to achieve the specimen of Carbon Fibre Composite Material

Process	Description	Photo
Layout of the Specimen	Minimum area of sheet calculated with the help of CATIA Software. Specimens were oriented at various angles as mentioned above. The size of the sheet calculated was 500 x 500 x 4 mm to get the specimen as per orientation of fibres.	
Hand Layup Procedure to fabricate the Carbon Fibre Composite Material	Composites can be fabricated in different ways like Hand Layup, Spray Layup, etc. Hand Layup method was implemented because it involves less cost. 400 gsm Carbon Fibre was used and it gives thickness of 0.4 mm in single layer. So 10 layers as mentioned angles were arranged to achieve the required thickness i.e. 4 mm. Matrix material used was Epoxy i.e. Araldite LY 1564. Roller was applied after every layer to remove the air pockets. So it was a stack up lamina of 10 layers.	
Vacuum Bagging System	Vacuum Bagging System is implemented after Hand Layup to remove the air pockets and to absorb the extra Epoxy from the layers. Then it was cured at the room temperature for 24 hours.	
Finished Product after Fabrication of the Carbon Fiber Composite	A sheet of Carbon Fibre Composite Material was achieved after performing the fabrication operations. The size of the sheet was 500 x 500 x 4 mm.	
Water Jet Machining of the Carbon Fiber Composite	Water Jet Machining is a computer guided machine which works as per the 2D profile of the workpiece. So 2D profile of the layout provided in the format of dwg extension. The various parameters on which machine works were Stand-off Distance (mm), Jet Pressure (MPa), Traverse Rate (mm/min) and Abrasive Mass Flow Rate (g/min).	

International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Vol. 48, Special Issue, (TAME-2019, April 4-5, 2019)
(An Indexed, Referred and Impact Factor Journal approved by UGC- Journal No. 42581)
ISSN (Online): 2319-6564
www.ijesonline.com

Skeleton of the carbon fibre sheet after machining	It is the scrap which was left after the machining. But there were total 9 pieces which cut down because starting piece fall into the tank of the machine. It is very difficult to get the part from the tank of the machine. So this is the disadvantage of this machine.	
Finished Flat Specimen after Water Jet Machining	8 pieces were obtained after the fabrication and machining at various angles. There are few limitation of using Water Jet Machining for Carbon Fibre Composite material like Delamination of the layers, Fibre pull out from the Specimen and Abrasive embedment in the Specimen [6]. Delamination in one specimen was observed. Fibre pull out was observed almost in every sample. For Abrasive embedment, samples to be checked from Scanning Electron Microscope.	

5. Comparison of weight of the Flat Specimen

Carbon Fibres Composite has many advantages and one of the biggest advantages is light weight. Specimens so achieved have very less weight compared to steel as shown in the table given below.

Table 4. Weight of Carbon Fibre Composite Material

Sample Number	Orientation of Fibers	Weight of the Sample	Photo
1	0°	0.036 kg	
2	0°	0.036 kg	
3	15°	0.038 kg	
4	15°	0.038 kg	
5	30°	0.038 kg	
6	30°	0.038 kg	
7	45°	0.038 kg	
8	45°	0.038 kg	

Weight of one specimen of Steel material was 0.226 kg and that of Carbon Fibre Composite material was only 0.038 kg. So the weight of Carbon Fibre Composite material was reduced by 83.2%. Comparison of weight is shown below in the table.

Table 5. Comparison of Weight of Steel and Carbon Fibre Composite Materials

Parameter	Steel (CAD Model)	Steel (Actual)	Carbon Fibre Composite (CAD Model)	Carbon Fibre Composite (Actual)
Weight (Kg)	0.236	0.226	0.045	0.038

6. Virtual Analysis of the Flat Specimen of Carbon Fibre Composite Material

There is no doubt that with the Carbon Fibres Composite, weight is reduced drastically. But whether it can take load or not, it should be verified by Virtual and Physical Testing of the Flat Specimen. That's why specimen is developed but physical testing is not covered in this paper. Only Virtual analysis of Carbon Fiber Composite material is covered in this paper [7]. The properties of Epoxy Carbon Woven Wet were entered in the software as shown in the Table 7.

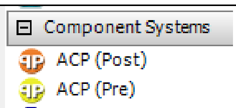
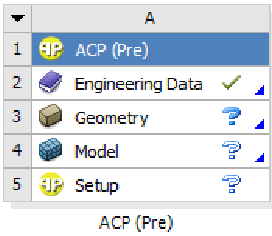
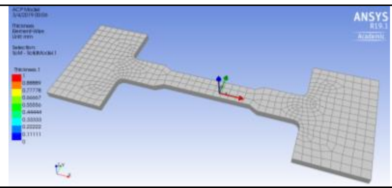
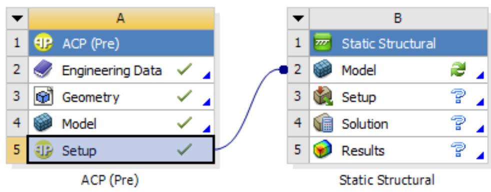
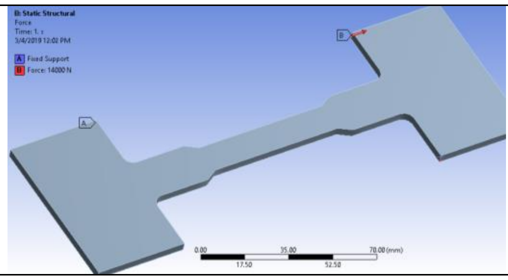
Table 6. Properties of Epoxy Carbon Woven Wet

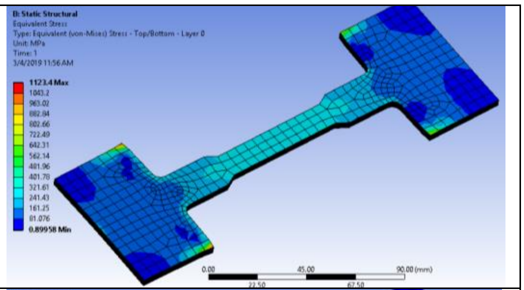
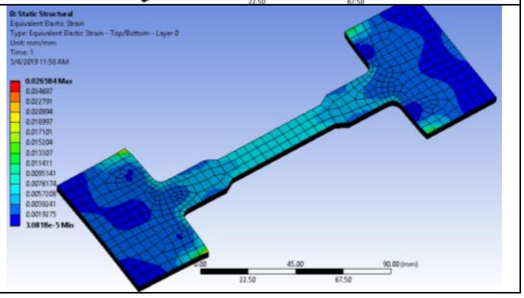
S.No.	Property	Value	Unit
1	**Density**	1.451×10^{-9}	t/mm^3
2	**Orthotropic Elasticity**		

	Young's Modulus X Direction	59160	MPa
	Young's Modulus Y Direction	59160	MPa
	Young's Modulus Z Direction	7500	MPa
	Poisson's Ratio XY	0.04	
	Poisson's Ratio YZ	0.3	
	Poisson's Ratio XZ	0.3	
	Shear Modulus XY	17500	MPa
	Shear Modulus YZ	2700	MPa
	Shear Modulus XZ	2700	MPa
3	**Orthotropic Stress Limits**		
	Tension X Direction	513	MPa
	Tension Y Direction	513	MPa
	Tension Z Direction	50	MPa
	Shear XY	120	MPa
	Shear YZ	55	MPa
	Shear XZ	55	MPa
4	**Orthotropic Strain Limits**		
	Tension X Direction	0.0092	
	Tension Y Direction	0.0092	
	Tension Z Direction	0.0078	
	Shear XY	0.02	
	Shear YZ	0.015	
	Shear XZ	0.015	
5	**Tsai-Wu Constants**		
	Coupling Coefficient XY	-1	
	Coupling Coefficient YZ	-1	
	Coupling Coefficient XZ	-1	
6	**Ply Type**		
	Type	Woven	

Virtual Testing can be performed in many types of Software like ANSYS, Nastran, Hyperworks, Abaqus, etc. Every software has their own speciality. Here ANSYS is selected because composite materials can be analysed. ACP Pre is used to solve the problems of composite materials. How the ANSYS is used to solve the Carbon Fibre Composite materials is shown in the table given below.

Table 7. Steps of Virtual Analysis of Carbon Fibres Composite Material in ANSYS

S.No.	Process	Photo
1	ANSYS opened, **ACP Pre** from the Component Systems selected. ACP Pre is used to analysis of Composite Materials. ACP stands for ANSYS Composite.	
2	**Engineering Data** edited and Engineering Data Sources selected. **Composite Materials** selected and from new window **Epoxy Carbon Woven Wet** selected.	
3	Geometry imported	
4	**Model** edited, units and material selected, meshing generated, thickness of 4 mm provided and the model updated.	
5	**Setup** edited, **fabric** created and **material** selected and thickness of each layer i.e. 0.4 mm provided, **rosette** created, oriented selection set created, 10 modelling ply with various angles i.e. 0°, 15°, 30° and 45° created and Setup updated.	
6	**Static Structural** created, Setup connected to the Model and **transfer solid composite data** selected.	
7	**Model** edited**, BCs** applied, Loading Condition applied and solver activated. Load of 14 KN applied on the required faces as shown in the figure.	

8	The maximum stress in the gauge length was 241.43 MPa.	
9	The maximum strain in the gauge length was 0.0057.	

7. Comparison of Virtual Analysis of the Flat Specimen

Flat Specimen virtually analysed in the software with materials i.e. Steel and Carbon Fibres Composite.

Table 8. Comparison of Virtual Analysis of the Flat Specimen

S.No.	Characteristics	Flat Specimen of Steel	Flat Specimen of Carbon Fibre
1	Tensile Stress	279.3 MPa	241.43 MPa
2	Strain	0.0014	0.0057

8. Conclusion

From this paper, following conclusion can be made:

- By Virtual Analysis, Tensile Stress of steel was 279.3 MPa and of Carbon Fiber Composite was 241.3 MPa.
  Tensile Stresses reduced by 13.6% if material changed from Steel to Carbon Fibre Composite Material.
- By Virtual Analysis, Tensile Strain of steel was 0.0014 and of Carbon Fiber Composite was 0.0057. Strain increased by 407.1% if material changed from Steel to Carbon Fibre Composite Material.
- Weight of the Flat Specimen is reduced by 83.2 % if material changed from Steel to Carbon Fibre Composite Material.
- Water Jet Machining can be used for the cutting of Carbon Fibre Composite but with few limitations.
- Stresses in Carbon Fibre Composite are less compared to stresses in Steel specimen. It means Carbon Fibre Composite can take more load compared to Steel.
- Deformations in the Carbon Fibre Composite are more compared to deformation in Steel Specimen.

References

[1] Comparison of Strength and Weight of Steel, Aluminium and Carbon Fibre, http://www.trudesign.net

[2] Korat, M.M., Acharya, G.D.: Review on Current Research and Development in Abrasive Waterjet Machining, Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 1 (Version 2), January 2014, pp.423-432.

[3] Standard Test Methods for Tension Testing of Metallic Materials (ASTM E8/E8M), https://www.astm.org/Standards/E8.htm.

[4] Bogomolov, A.V., Zhakupov, A.N., Kanayev, A.T., Sikach, I.A., Tugumov, K.K.: Comparative Structural Strength Research of Hardened Carbon Steel and Hot-Rolled Alloy Steel, VII International Scientific Practical Conference "Innovative Technologies in Engineering", IOP Publishing, IOP Conference, Series: Materials Science and Engineering 142 (2016) 012076, doi:10.1088/1757-899X/142/1/012076.

[5] Abdurohman, K., Satrio, T., Muzayadah, N.L., Teten: A comparison process between hand lay-up, vacuum infusion and vacuum bagging method toward e-glass EW 185/lycal composites, 6th International Seminar of Aerospace Science and Technology, IOP Publishing, IOP Conference Series: Journal of Physics: Conf. Series 1130 (2018) 012018, doi:10.1088/1742-6596/1130/1/012018.

[6] Dhanawade, A., Kumar, S., Kalmekar, R.V.: Abrasive Water Jet Machining of Carbon Epoxy Composite, Defence Science Journal, Vol. 66, No. 5, September 2016, pp. 522-528, DOI : 10.14429/dsj.66.9501, 2016, DESIDOC.

[7] Li, J., Xiao, M., Liang, Y., Tang, X., Li, C.: Three-dimensional Simulation and Prediction of Solenoid Valve Failure Mechanism Based

on Finite Element Model, ESMA 2017, IOP Publishing, IOP Conference, Series: Earth and Environmental Science 108 (2018) 022035, doi :10.1088/1755-1315/108/2/022035.