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Experimental Investigation of Glass Fibre Oriented Reinforced Polymer Laminates

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Abstract:* To know the mechanical properties of GFRP laminates. Using hand lay-up and press moulding fabrication techniques, the testing samples are prepared as perASTM-D882,ASTM-D790,ASTM-D785standardby varying orientation. These specimens are tested under tensile test, flexural test (three-point bend test) and hardness test. The results are compared within three different aligned orientations (0°, 135°, 90°) for fabricated composite. GFRP laminates have wide spread application because of their several advantages like high wear resistance, high strength-to-weight ratio. The results of tensile strength, percentage felongation, flexural strength, flexural modulus and hardness of the composite were compared. However, the highest values respectively suggesting fibre orientation for effective and maximum stress transfer in laminated composites. The unknown properties obtained by these laminates are used in ABAQUS and HYPERMESH for analysis. The results are compared to obtain the better of the orientations suitable for the composite to manufacture anycomponents.
Keywords: Glass fibre reinforced polymer (GFRP), Hand lay-up Technique, Mechanical properties, ABAQUS, Hypermesh.

I. INTRODUCTION

Reinforcement materials like fibres, fillers, particles and flakes that surrounded in a matrix (resin) for example polyester, epoxy, and vinyl ester to fabricate composites. The resin holds the fibres together to create products with any shape and transfer the applied load to the fibres. Most oftheappliedloadsaretakenbythefibres.Themechanical properties are different in different directions while the mechanicalpropertiesaresameinanydirectioninisotropic materials. However, fibre reinforced polymers are directional materials or in other words, the optimum mechanicalpropertiesareinthedirectionofreinforcement. Therefore, the fibres are placed in the composite materials according to the applied load. Also, the type and direction ofreinforcementsareselectedaccordingtotheapplication.

II. METHODOLOGY ANDEXPERIMENTATION

Laminates are prepared by using hand lay-up technique varying orientation ($0^0/0^0$, $0^0/135^0$, $0^0/90^0$) of the fibre and numberofglasslayersareconstant.Thetestingsamplesare prepared as per the ASTM Standards. During the experimentation tests of tensile (ASTM-D 882), flexural (ASTM-D 790) and Hardness (ASTM-D 785) are done on the GFRP laminates of different orientations. The Analysis was carried out in framework of ABAQUS and HyperMesh FEA packages, the objective of this FEA analysis of Polymer laminates is to predict the mechanical propertiesandtheirresponseofthepolymerlaminatessuch as tensile and flexural then the results will be compared with experimental results. The geometry of the test specimen for HyperMesh Analysis is the same as ABAQUS in dimensions and design. The material constantsusedintheanalysisofthecompositelaminateare Young'sModulusE_1=71660.0MPa,Young'sModulusE_2= 20700.0 MPa, Poisson's Ratio for the given material is NU_{12} = 0.244, Shear Modulus of the given material areG_{12}= 10690.0 MPa, G_{1Z} = 10690.0 MPa, G_{2Z} = 11000 MPa anddensity 2.6e -24 kg-m^3. The following Fig.1 shows the model of the experimental in ABAQUS.

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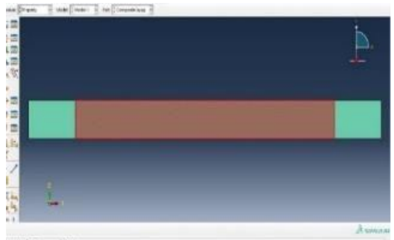

Fig 1: Composite laminate model

The composite layups of the tested specimens during the experimentationaredefinedinthecompositelayupmodule in ABAQUS. The following Fig.2 show the composite layup inABAQUS.

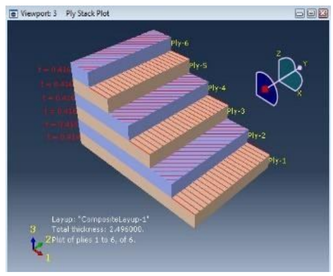

Fig 2: Composite layup of orientation $0^0/135^0$

Theboundarycondition(BC)andloadmustbedefinedand willbeactivatedduringtheAnalysis.TheAnalysiswasset to run with three different orientations and calibration was done to get close results to the experimental results. The JOB module in the ABAQUS is used to carry out the rest of the analysis to satisfy the experimental analysis. The following procedure for analyzing the composite material in HyperMesh are to create the composite material and property. Applying the BC's to the model. Performing the job in OPTISTRUCT. Post-process the results to view in Hyper View module. The following figure 3 shows the assigning of the ply properties like thickness and angle of orientation.

Number_of_Plies =

	MID	T	THETA
1	eglass (1)	0.421	0.0
2	eglass (1)	0.421	90.0
3	eglass (1)	0.421	0.0
4	eglass (1)	0.421	90.0
5	eglass (1)	0.421	0.0
6	eglass (1)	0.421	90.0

Number_of_Plies =

	MID	T	THETA
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4	eglass (1)	0.421	0.0
5	eglass (1)	0.421	0.0
6	eglass (1)	0.421	0.0

Number_of_Plies =

	MID	T	THETA
1	eglass (1)	0.421	0.0
2	eglass (1)	0.421	45.0
3	eglass (1)	0.421	0.0
4	eglass (1)	0.421	45.0
5	eglass (1)	0.421	0.0
6	eglass (1)	0.421	45.0

Fig 3: Assigning Ply Properties in HyperMesh

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III. RESULTS

A. Comparison Of Experimental And Fea Results

1) FlexuralResults

Table 1**:** Comparison of stresses for Experimentation and FEA.

S. N	Orient	Load	Maximum Stresses (MPa)		
			Experimental	ABAQUS	HYPERMESH
1	$0^0/0^0$	121.5	46.66	49.00	45.79
2	$0^0/135$	342.6	131.58	133.12	136.33
3	$0^0/90$	165.3	63.49	64.77	60.85

By performing flexural test method, the following results are obtained 46.66 MPa,131.58 MPa, 63.49MPa. The flexural strength for $0^0/135^0$ orientationis131.58MPabecausethefibreisthemainload carrying element, so it is more than $0^0/0^0$ & $0^0/90^0$ orientationcompositespecimens.Theflexuraltest(3-point bend test) give a better understanding of the mechanical behavior of the laminated composites. The experimental valuesarenowcomparedwithFEAvalues.FEAvaluesfor the orientations are slightly varied from the experimental values.InFEA,$0^0/135^0$ishavingthehighflexuralstrength of133.52MPa(ABAQUS)and136.32MPa(HyperMesh). So this orientation is having the high flexural strengththan the other two orientations i.e. ($0^0/0^0$ & $0^0/90^0$). The type of fibre orientation plays a major role in the determination of the flexural strength of a compositematerial.

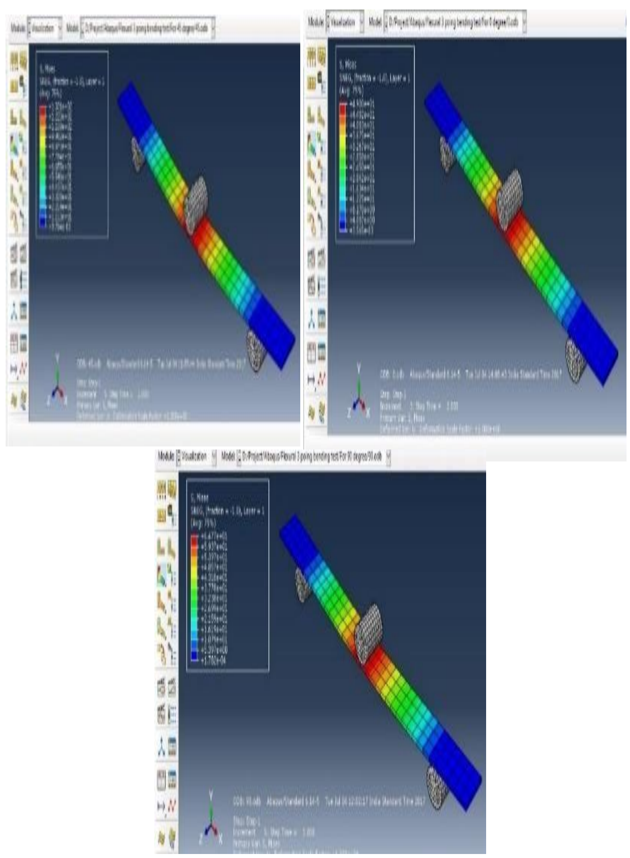


Fig 4: Flexural Analysis in ABAQUS for 0^0, 135^0, 90^0

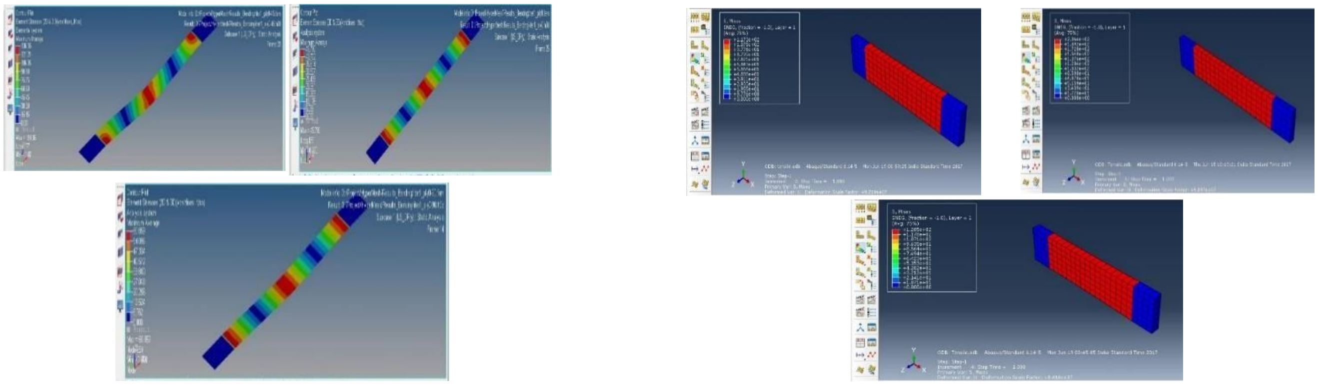
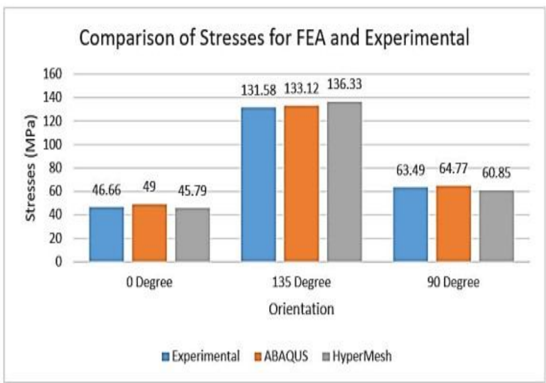


Fig 5: Flexural Analysis in HyperMesh for 0^0, 135^0, 90^0



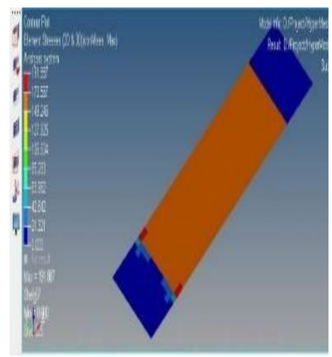


Fig 6: Graphical representation for comparison offlexural test

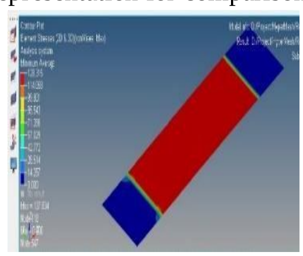


Fig 7: Tensile Analysis in ABAQUS for 0^0, 135^0, 90^0

2) TensileResults

Table 2: Comparison of stresses for Experimentation and FEA.

S. N	Orient	Load	Maximum Stresses (MPa)		
			Experi	ABAQUS	HYPERM
1	$0^0/0^0$	4062.4	203.1	206.44	191.88
2	$0^0/135$	4630.3	123.8	128.52	138.98
3	$0^0/90$	4241.2	113.0	117.30	128.31

ByperformingtensiletestunderASTM-D882testmethod the following results are obtained for GFRP Laminates with different orientation. The results are 203.12MPa, 123.84MPa, 113.07MPa. Tensile test properties for $0^0/0^0$ orientation shows better value of tensile strength 203.12MPa more than $0^0/135^0$ and $0^0/90^0$ orientation compositespecimens.FEAresultsareobtainedfortheFRP laminates for the orientation of $0^0/0^0$, $0^0/135^0$, $0^0/90^0$. There is minor difference from the experimental values from

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experimentation. The comparison of Stresses for the experimental and FEA are shown as graphical representation below. Hence from the comparison of experimentation and FEA valuesconcluded thattheorientationwith$0^0/0^0$issuitableasitishavingload carrying capacity more than the other orientations andalso other tensile properties are greater in the fibre reinforced polymer composite laminates. Tensile strength of GFRP laminate is affected by the fiber orientation distribution more than by the fiber contentratio.

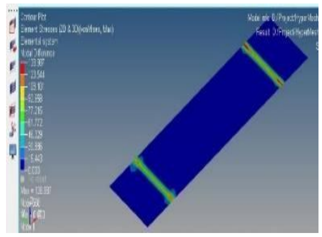

Fig 8: Tensile Analysis in HyperMesh for 0^0, 135^0, 90^0

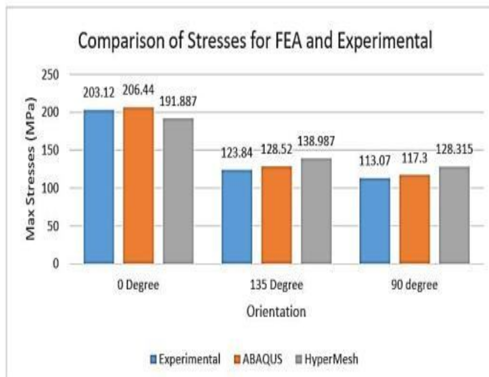

Fig 9: Graphical representation of comparison of Stresses for tensile test

Table 3: ASTM-D 785 Hardness test Experimental results

S.No	Orientation	Hardness
1	$0^0/0^0$	48
2	$0^0/135^0$	54
3	$0^0/90^0$	62

By Performing hardness test under ASTM-D 785 the following results are obtained 48, 54 and 62. The hardness value for $0^0/90^0$ orientation is 62 is more than $0^0/0^0$ & $0^0/135^0$ orientation composite specimens. However, the hardness values are not compared with FEA values. The strength for the orientation $0^0/90^0$ is highest when compared to the rest of the orientations.

IV. CONCLUSIONS

The present investigation of GFRP laminates can be used to enhance good mechanical properties, like tensile, flexural and hardness strengths properties. Experiments were conducted on GFRP laminates with different fibre orientations to characterize the mechanical properties. The test results illustrated in the present analysis showed that the mechanical strength of composites can be increased. The capacity of GFRP composite laminate efficiency varies depending on the test variables such as, fibre orientation, resin content and a fabrication technique. Due to the rolling process the strength of this GFRP Laminates can be increased, as well as the surface waviness of thefabricated composite can be reduced in order to reach good surface profile. The FEA Packages ABAQUS and HyperMesh showedapartialresultvalueswithexperimentalvalues,but the values obtained by the ABAQUS are closing to the experimental result than theHyperMesh.

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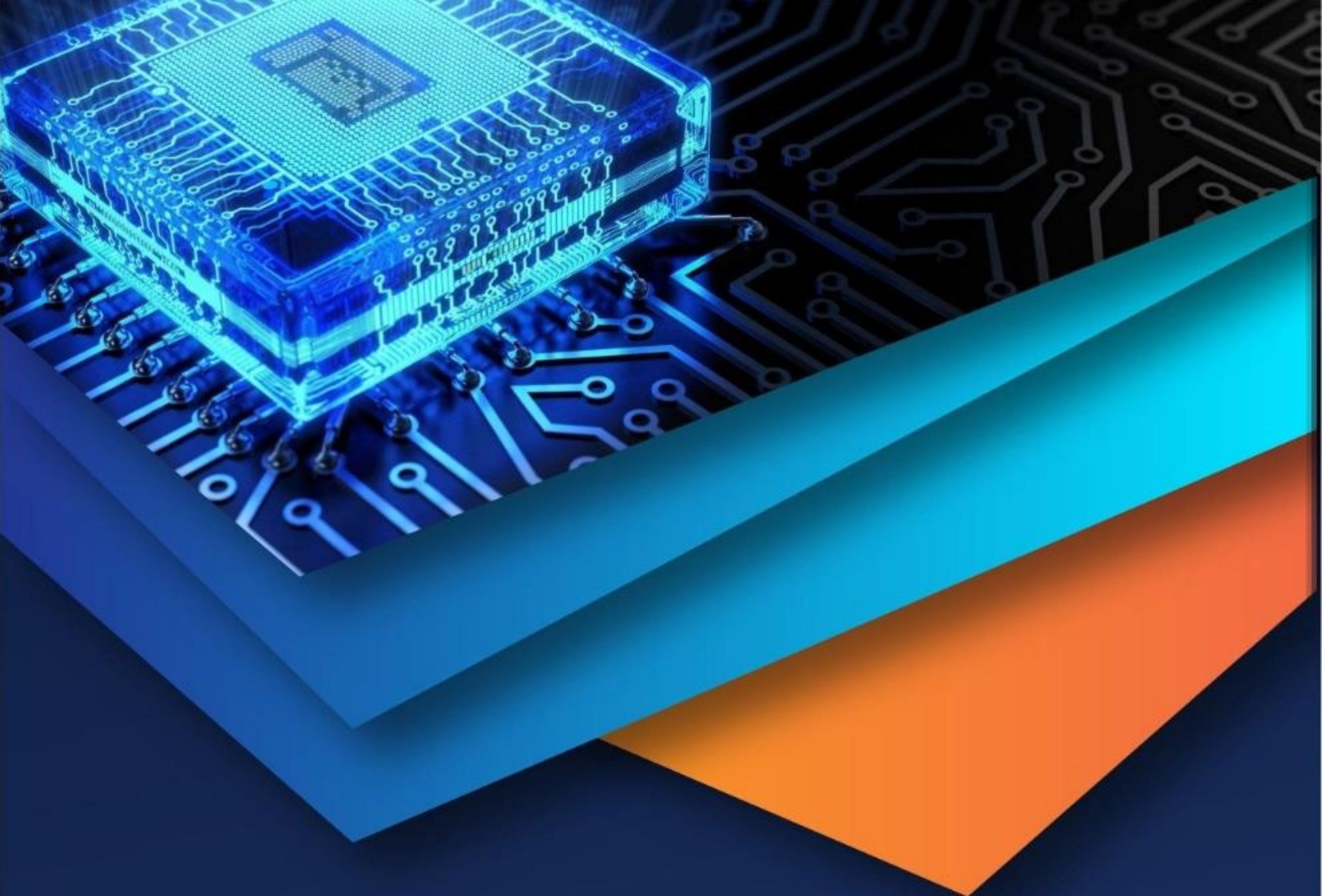

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