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Fracture Analysis of Delaminated Composite Beams

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ABSTRACT

De-lamination is a mode of failure for composite materials. Modes of failure are also known as 'failure mechanisms'. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness. Some manufacturers of carbon composite bike frames suggest disposing of the expensive frame after a particularly bad crash, because the impact could develop defects inside the material. Due to increasing use of composite materials in aviation, de-lamination is increasingly an air safety concern, especially in the tail sections of the airplanes.

In this thesis, the effects of de-lamination length on the deformations, stresses, stress intensity factors and frequencies for composite beams are analyzed using ANSYS software. The composite materials considered are S Glass Fiber, Glass Fiber. Static, Fracture and Frequency analysis are done on the composite beam by considering different layers 5, 7 & 9. By this the effect of de-lamination is determined.

1. INTRODUCTION TO BEAM

A beam is a structural element that is capable of withstanding load primarily by resisting bending. [1]The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment. Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

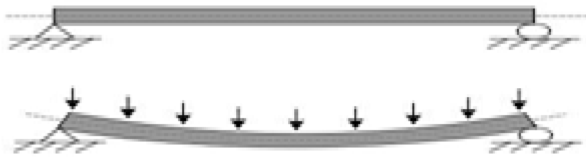

Fig.1.1: A statically determinate beam, bending (sagging) under an evenly distributed load

1.1 Overview

Historically beams were squared timbers but are also metal, stone, or combinations of wood and metal such as a flitch beam. Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (e.g., loads due to an earthquake or wind or in tension to resist rafter thrust as a tie beam or (usually) compression as a collar beam). [2]The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members. In light frame construction joists may rest on beams.In carpentry a beam is called a plate as in a sill plate or wall plate, beam as in a summer beam or dragon beam.

1.2 Types of beams

In engineering, beams are of several types:
Simply supported - a beam supported on the ends which are free to rotate and have no moment resistance. Fixed - a beam supported on both ends and restrained from rotation. Over hanging - a simple beam extending beyond its support on one end. Double overhanging - a simple beam with both ends extending beyond its supports on both.

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2. LITERATURE SURVEY

2.1 Vibration analysis of delaminated composite beams using analytical and FEM models by Çallioğlu, Hasan, Atlihan, Gökmen

In this study, the effects of delamination length and orientation angle on the natural frequency of symmetric composite beams are investigated, analytically and numerically. The analytical method is developed using the Timoshenko beam theory. [3]The transverse shear effect and the rotary inertia terms are taken into account in the governing equations of vibration. Two dimensional finite element models of the delaminated beams are established using contact element at the ANSYS. The values of the natural frequency in laminated beams are obtained using the normal penalty stiffness that is chosen as the elasticity modulus for the contact element of the delamination region. When the analytical results are compared with numerical results and the results in literature, it is seen that the results are very close to each other. It is shown that natural frequencies decrease when delamination length in the beam increases and the natural frequencies change with the change of orientation angle.

2.2 A Dynamic Stiffness Element for Free Vibration Analysis of Delaminated Layered Beams by Nicholas H. Erdelyi and Seyed M. Hashemi

A dynamic stiffness element for flexural vibration analysis of delaminated multilayer beams is developed and subsequently used to investigate the natural frequencies and modes of two-layer beam configurations. Using the Euler-Bernoulli bending beam theory, the governing differential equations are exploited and representative, [4] frequency-dependent, field variables are chosen based on the closed form solution to these equations. The boundary conditions are then imposed to formulate the dynamic stiffness matrix (DSM), which relates harmonically varying loads to harmonically varying displacements at the beam ends. The bending vibration of an illustrative example problem, characterized by delamination zone of variable length, is investigated. Two computer codes, based on the conventional Finite Element Method (FEM) and the analytical solutions reported in the literature, are also developed and used for comparison. The intact and defective beam natural frequencies and modes obtained from the proposed DSM method are presented along with the FEM and analytical results and those available in the literature.

3. SURFACE MODEL OF BEAM WITH DELAMINATION

The dimensions are taken from the journal paper "Vibration analysis of delaminated composite beams using analytical and FEM models [5]by Çallioğlu, Hasan, Atlihan, Gökmen" NOPR NISCAIR PUBLICATIONS Research Journals Indian Journal of Engineering and Materials Sciences (IJEMS) IJEMS Vol.18 [2011] IJEMS Vol.18(1) [February 2011] specified as [1] in References chapter

Length of the beam – 400mm

Width of beam – 20mm

Thickness of beam – 3.3mm

No. of layers – 5,7,9

Delamination Length – 40mm

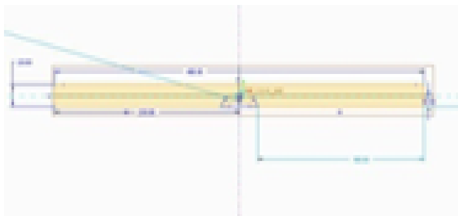

Fig 3.1: Sketch of beam

3.1 Static Structural Analysis Of Composite Beam

Open ANSYS>Open work bench 14.5>select static structural >double click on it.

Select engineering data> window will be open in that enter required material properties> Update project and return to the project.

3.2 Material - Glass Fiber

No. Of layers – 5

Material properties: - Glass Fiber

Density:-1.75g/cc

Young's modulus: - 20616 MPa

Poisson's ratio:-0.13

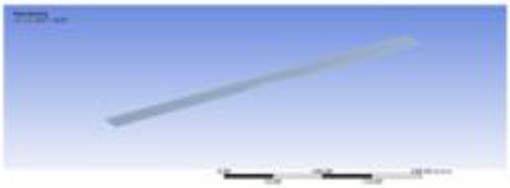

Fig 3.3: Geometry

Working Sheet
Glass Fiber -1.1
3.3/5=0.66mm

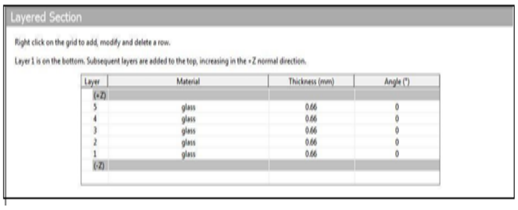

Fig :**3.5:** Layered section

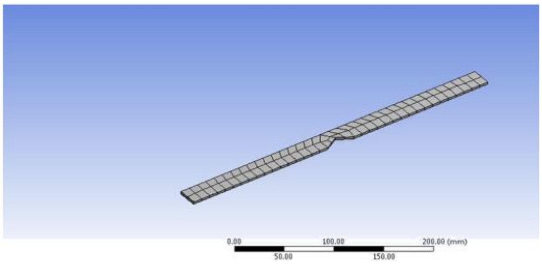

Fig 3.6: Meshing

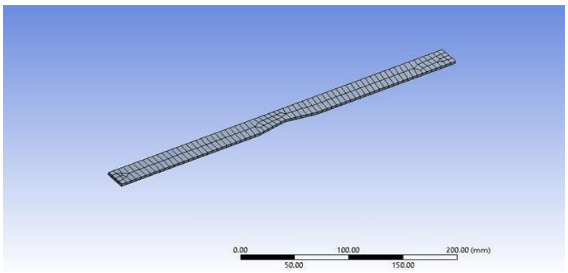

Fig 3.7: Fixed support

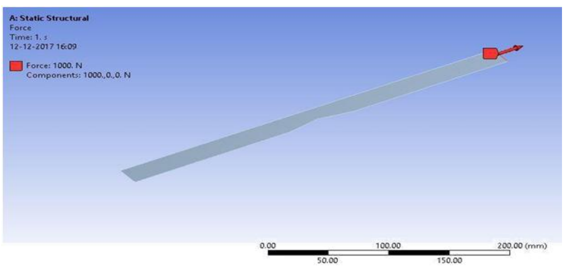

Fig 3.8: Force

3.3 Results Table

	5-Layers	7-Layers	9-Layers
Stress (MPa)	9.8592	20.569	36.522
Strain	0.00047858	0.000994846	0.00177343

Table 3.1: Glass fiber results

S-Glass Fiber

	5-Layers	7-Layers	9-Layers
Stress (MPa)	45.871	91.227	157.08
Strain	0.00053376	0.0010615	0.0018278

Table 3.2: S-Glass fiber

Graphs

GRAPHS

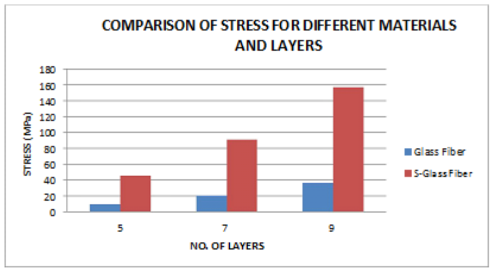

Fig 3.50: comparison of stress for different materials and layers

3.4 MODAL ANALYSIS

Glass Fiber

		5	7	9
Mode 1	Frequency (Hz)	36.134	48.816	62.382
	Deformation (mm)	242	231.32	222.86
Mode 2	Frequency (Hz)	79.196	89.201	101.66
	Deformation (mm)	294.62	290.29	286.31
Mode 3	Frequency (Hz)	125.03	160.47	199.48
	Deformation (mm)	281.51	262.25	248.32

Table 3.3: Glass fiber modal analysis

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		5	7	9
Mode 1	Frequency (Hz)	64.057	85.058	107.65
	Deformation (mm)	199.83	191.86	188.54
Mode 2	Frequency (Hz)	163.44	153.33	173.89
	Deformation (mm)	244.6	241	237.82
Mode 3	Frequency (Hz)	232.19	278.97	342.33
	Deformation (mm)	219.8	216.97	206.33

Table 3.4: S-Glass fiber modal analysis

GRAPHS

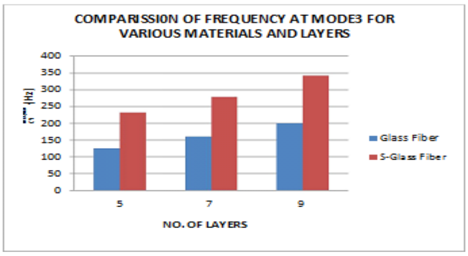

Fig 3.52: comparison of frequency at mode 3 for various materials and layers

3.5 Fracture Analysis Of Composite Beam

Open ANSYS>Open work bench 14.5>select static structural >double click on it.

3.6 Material - Glass Fiber

Select engineering data> window will be open in that enter required material properties> Update project and return to the project.

Material properties

Glass fiber
Density:-1.75g/cc
Young's modulus: - 20616Mpa
Poisson ration:-0.13
Select geometry > right click on it >select import geometry> select file>ok

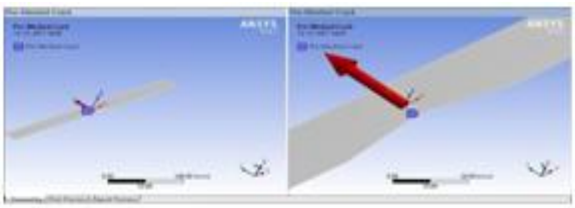

Fig 3.57: Pre- Meshed Crack

4. RESULTS TABLE

Material	No. layers	SIFS-K1	JINT
Glass fiber	5	15.247	-7.9648e-9
	7	22.067	-1.3459e-7
	9	29.091	-2.338e-6
S Glass fiber	5	69.017	-3.3358e-7
	7	98.307	-6.8146e-7
	9	130.41	1.1992e-6

Table 3.5: Results table

4.1 stress intensity factor calculations results table

		5	7	9
Glass Fiber	Theoretical	84.57522661	166.772727	278.05353089
	Analytical	15.247	22.067	29.011
S-Glass	Theoretical	352	695	1184
	Analytical	69.017	98.307	130.555

Table 4.1: Stress intensity factor

5. CONCLUSION

In this thesis, the effects of delamination length on the deformations, stresses, stress intensity factors and frequencies for composite beams are analyzed using Ansys software. The composite materials considered are Glass Fiber and S Glass Fiber. Static, Fracture, Frequency analysis are done on the composite beam by varying number of layers 5, 7 & 9. By this the effect of delamination is determined.

By observing analysis results, the deformation and stress values are decreasing by increasing the number of layers. The stress values are less when Glass Fiber is used. The stresses for 5 layers are reducing by 52% when compared with that of 7 layers and by 73% when compared with that of 9 layers when Glass Fiber is used. The stresses for 5 layers are reducing by 50% when compared with that of 7 layers and by 71% when compared with that of 9 layers when S Glass Fiber is used.

By observing modal analysis results, the frequency values are less when 9 layers are used and when S Glass

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Fiber is used. The frequencies for 5 layers are increased by 6.84% when compared with that of 7 layers and by 11.7 % when compared with that of 9 layers when Glass Fiber is used. The frequencies for 5 layers are increased by 1.2% when compared with that of 7 layers and by 6.12 % when compared with that of 9 layers when Glass Fiber is used.

By observing Random Vibration analysis, the stress intensity factors values are decreasing by increasing the number of layers. The stress values are less when Glass Fiber is used. The stresses for 5 layers are reducing by 30.9% when compared with that of 7 layers and by 47.58% when compared with that of 9 layers when Glass Fiber is used. The stresses for 5 layers are reducing by 29.74% when compared with that of 7 layers and by 47% when compared with that of 9 layers when S Glass Fiber is used.

Numerical calculations are done. Stress intensity factors are less for 5 layers when Glass Fiber is used

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[4].Analytical solution for the dynamic analysis of a delaminated composite beam traversed by a moving constant force by Mohammad H Kargarnovin, Mohammad T Ahmadian, Ramazan- Ali Jafari-Talookolaei

[5]. Free vibration analysis of delaminated composite beams by JaehongLee.