Fracture Analysis Of Delaminated Composite Beams

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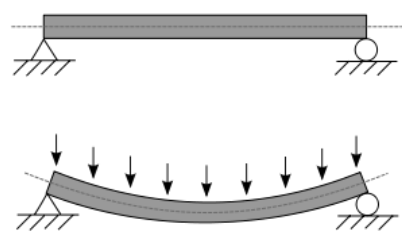
ABSTRACT

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

INTRODUCTION

A beam is a structural element that is capable of withstanding load primarily by resisting bending. 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.



A statically determinate beam, bending (sagging) under an evenly distributed load

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 ends.

Continuous - a beam extending over more than two supports
Cantilever - a projecting beam fixed only at one end.
Trussed - a beam

LITERATURE REVIEW

PAPER 1 - 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, 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.

PAPER 2 - Frequency response analysis of a delaminated smart composite plate by Bin Huang, Heung Soo Kim

A frequency analysis of smart composite plate with delamination at ply interface was investigated in this article. The modeling was based on an electro-mechanical coupled improved layer wise theory, with implementing finite element method. Four-node plate elements with Lagrange and Hermite cubic interpolation functions were used for in-plane structural unknowns, electric unknowns, and out-of-plane structural unknowns. The general modal reduction method was applied to solve the second-order differential equation. Numerical results showed significant shift of natural frequencies in the frequency response of tip displacement and three sensor outputs due to the presence of delamination. It is found that the delamination locations also influence the natural frequencies of smart composite structure. Thus, the proposed methodology could be a useful tool to develop system identification and structural health monitoring techniques of smart composite structure.

PAPER 3 - Vibration Analysis of Delaminated Composite Laminates in Prebuckled States Based on a New Constrained Model by Hsin-Piao Chen, John J. Tracy, RamonNonato

An analytical model of free vibration of a delaminated composite laminate in prebaked states has been developed. The formulation is based on a new constrained model which includes both effects of the compressive force and bending-extension coupling. These two effects on the natural frequency of delaminated plates have not been studied by such a model before. It is found that the compressive force, laminate lay-up, delamination length, and delamination locations in the thickness-wise and span wise directions are significant factors to determine the vibration characteristics. Experiments have been conducted to validate this analytical model. Good agreements between the analytical results and test data have been obtained.

PAPER 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

A closed form solution is presented in this paper to study the dynamics of a composite beam with a single delamination under the action of a moving constant force. The delaminated beam is divided into four interconnected beams using the delamination limits as their boundaries. Governing motion equations are derived in which the differential stretching and the bending-extension coupling are considered. The method of modal analysis is adopted to derive analytically the dynamic response of each beam. The obtained results for the free vibrations of delaminated beam are verified against reported similar results in the literature. Moreover, the maximum dynamic response of such a beam is compared with a healthy beam. The effects of different parameters such as the force velocity, different ply configuration and the size, depth and span wise location of the single delamination on the dynamic response of the beam are studied. It is noticed that the presence of delamination has significant influence on the dynamic response of the beam.

THEORETICAL CALCULATIONS

Material: - E - Glass fiber

SOLUTIONS

(i) 5 Layers , b=1*5= 5mm

I_{yy} = 6510.42 mm^4

Displacement

$W_{max} = \frac{f_{tL^4}}{8EI_{yy}}$

= 1.99 mm

Shear Coefficient Factor

$K = \frac{10(1\pm v)}{12\pm 11(v)}$

=0.8163

$\frac{\mathbf{E}}{\mathbf{R}} = \frac{\mathbf{M}}{\mathbf{I}} = \frac{\boldsymbol{\sigma}}{\mathbf{Y}}$

Where, $\mathbf{Y} = \frac{D}{2}$

Stress $\boldsymbol{\sigma} = \frac{\mathbf{EY}}{\mathbf{R}} = \frac{74000}{401.48} X \frac{25}{2}$

Stress $\boldsymbol{\sigma}$ = 2363.98MPa

STATIC, MODAL AND FRACTURE ANALYSIS OF DELAMINATED BEAMS

Composite beam with delamination

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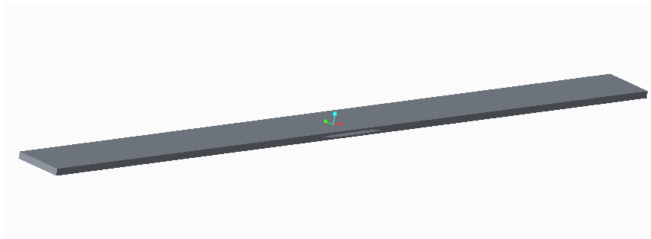

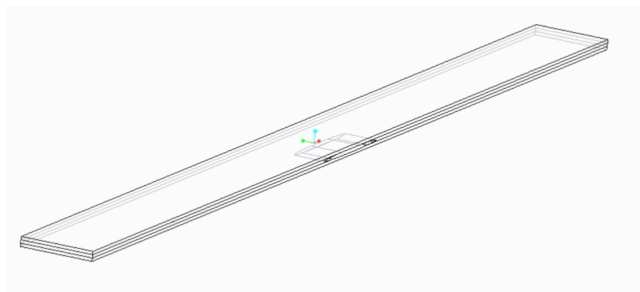

MATERIAL - GLASS FIBER
NO. OF LAYERS–5 (DELAMINATION LENGTH – 40mm)

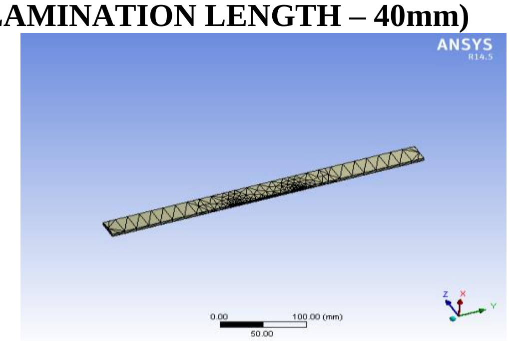

Fig: Meshed model

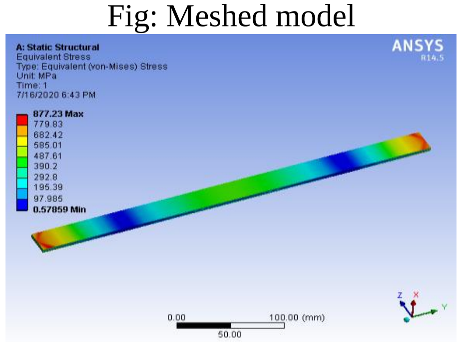

Fig:- Equivalent Stress

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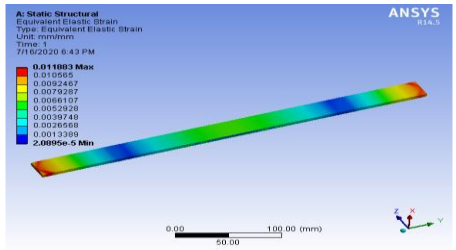

Fig:- equivalent elastic strain

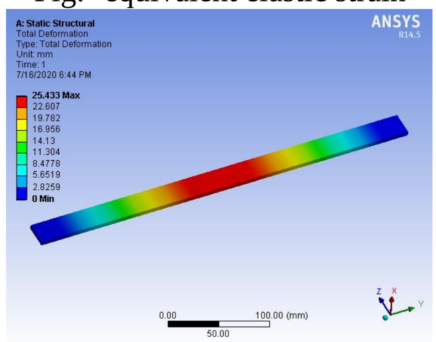

Fig:- total deformation

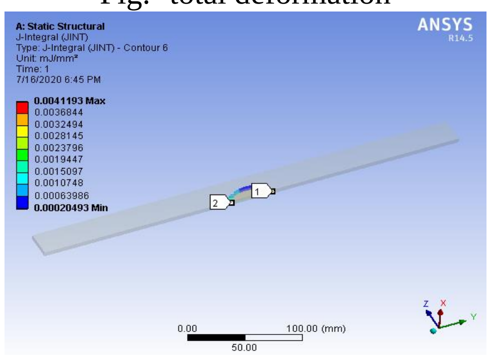

Fig:-J-Internal (JNIT)

NO. OF LAYERS – 7 (DELAMINATION LENGTH – 40mm)

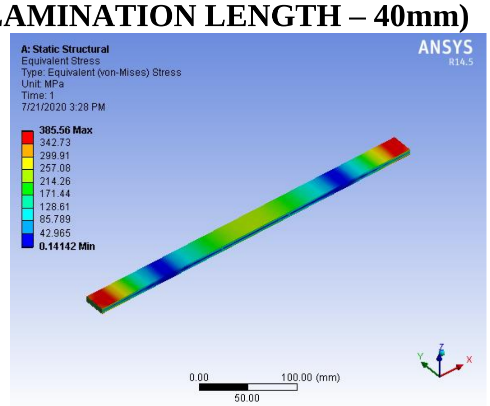

Fig:- Equivalent Stress

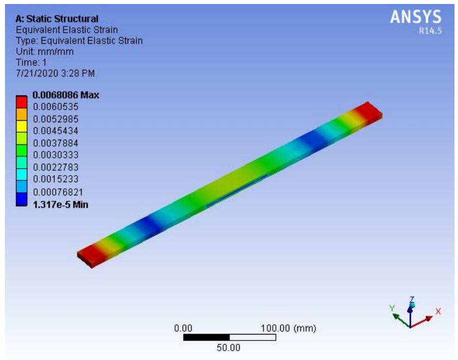

Fig:- equivalent elastic strain

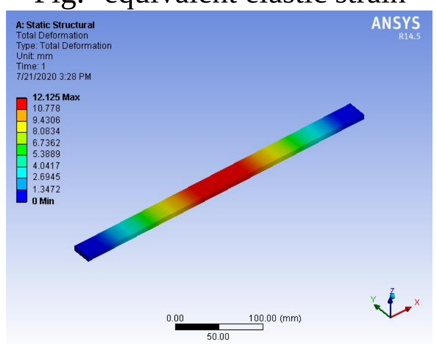

Fig:- total deformation

RESULT TABLE

Static analysis

Delamination length – 40mm

Material	No. of layers	Deformation (mm)	Stress (MPa)	Strain
Glass fiber	5	25.433	877.23	0.011883
	7	9.3317		0.0052888
	9	4.4207	243.25	0.0033147
S Glass fiber	5	33.146	878.39	0.015508
	7	12.125	385.56	0.0068086
	9	5.7464	238.21	0.0042353

Delamination length – 200mm

Material	No. of layers	Deformation (mm)	Stress (MPa)	Strain
Glass fiber	5	25.203	880.99	0.011949
	7	9.2809	418.01	0.0056524
	9	4.4167	242.73	0.0033347
S Glass fiber	5	27.58	1072.2	0.028017
	7	12.069	416.93	0.0073461
	9	5.7431	241.9	0.0043616

Delamination length – 320mm

Material	No. of layers	Deformation (mm)	Stress (MPa)	Strain
Glass fiber	5	21.21	1068.9	0.021568
	7	8.1001	492.37	0.0096089
	9	4.1035	271.45	0.0052523
S Glass fiber	5	27.58	1072.2	0.028017

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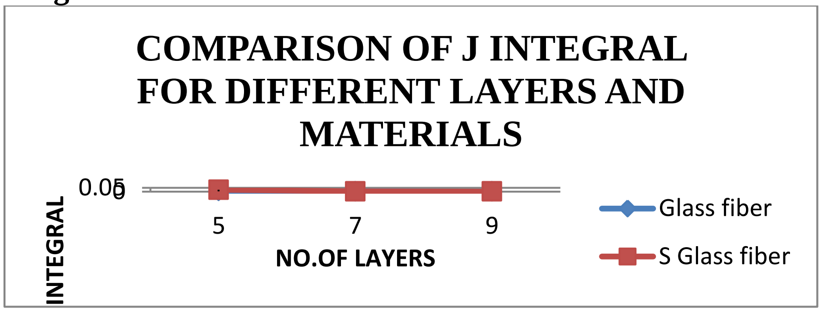
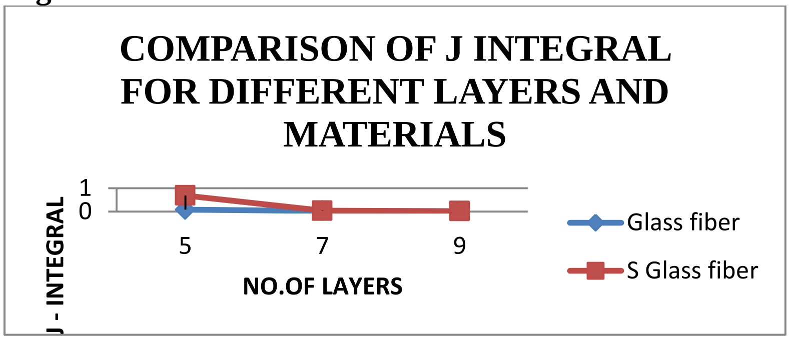
	7	10.524	485.7	0.012356
	9	5.336	273.21	0.0068843

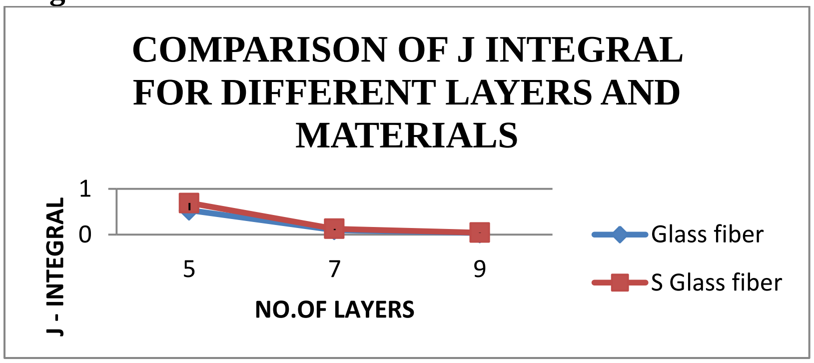
GRAPHS
J - INTEGRAL
A Delamination length – 40mm



B Delamination length – 200mm



C Delamination length – 320mm



CONCLUSION

In this thesis, the effects of delamination length on the deformations, stresses, and stress intensity factors for composite beams are analyzed using Ansys software. The composite materials considered are E Glass Fiber, S2 Glass Fiber. Static and Fracture 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 values are less for E – Glass fiber for all delamination length and with all layers. Stress intensity factors are less for E glass fiber for delamination length and with all layers when compared and even J – Integral are less for E– Glass with all delamination length and with all layers.

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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
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