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Comparison of Analytical and Numerical Methods for Delaminated Composite Beams

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ABSTRACT
In this thesis, the effects of delamination length on the deformations, stresses, stress intensity factors for composite beams are analyzed using Ansys software. The composite materials considered are E Glass Fiber, S2 Glass and Aramid Fiber. Static and Fracture analyses are done on the composite beam by varying number of layers 3, 5 & 7. By this the effect of delamination is determined. Numerical calculations are also done to compare with that of analytical results.

DELAMINATION

Delamination 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. Delamination also occurs in reinforced concrete structures subject to reinforcement corrosion, in which case the oxidized metal of the reinforcement is greater in volume than the original metal. The oxidized metal therefore requires greater space than the original reinforcing bars, which causes a wedge-like stress on the concrete. This force eventually overcomes the relatively weak tensile strength of concrete, resulting in a separation (or delamination) of the concrete above and below the reinforcing bars.

The cause of fiber pull-out (another form of failure mechanism) and delamination is weak bonding. Thus, delamination is an insidious kind of failure as it develops inside of the material, without being obvious on the surface, much like metal fatigue.

Delamination failure may be detected in the material by its sound; solid composite has bright sound, while delaminated part sounds dull, reinforced concrete sounds solid, whereas delaminated concrete will have a light drum-like sound when exposed to a dragged chain pulled across its surface. Bridge decks in cold climate countries which use de-icing salts and chemicals are commonly subject to delamination and as such are typically scheduled for annual inspection by chain-dragging as well as subsequent patch repairs of the surface. Other nondestructive testing methods are used, including embedding optical fibers coupled with optical time domain reflect meter testing of their state, testing with ultrasound, radiographic imagining, and infrared imaging.

LITERATURE SURVEY

Nicholas H. Erdelyi and Seyed M. Hashemi [1], 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

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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. **Bin Huang, Heung Soo Kim [2],** 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 layerwise 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.

STATIC AND FRACTURE ANALYSIS OF DELAMINATED BEAMS

Composite beam with delamination

Fig – 3D model of delaminated composite beam

Fig – 3D model of delaminated composite beam in wireframe

Delamination length/length of beam = 0.1, 0.5, 0.8

No. of layers – 3, 5, 7

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

MATERIAL - E-GLASS EPOXY

NO. OF LAYERS – 3 (DELAMINATION LENGTH – 0.1mm)

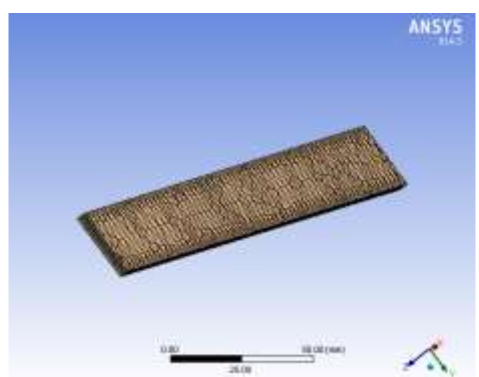

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Fig: Meshed model of the delaminated composite beam with number of layers 3 and delamination length 0.1mm

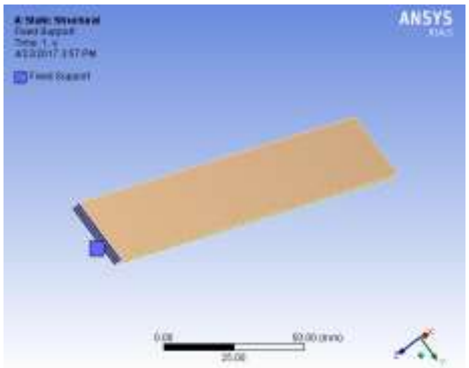

Fig: Fixed support is applied on one end of the beam

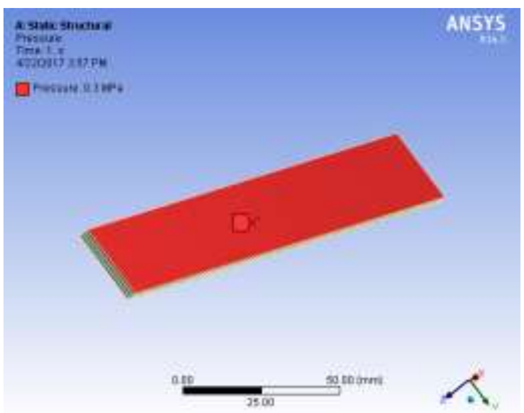

Fig: Pressure is applied on top of beam

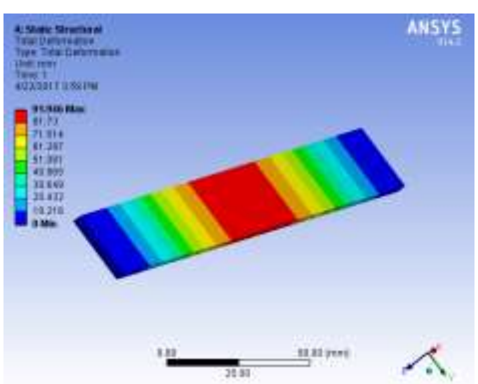

Fig:- Total deformation of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

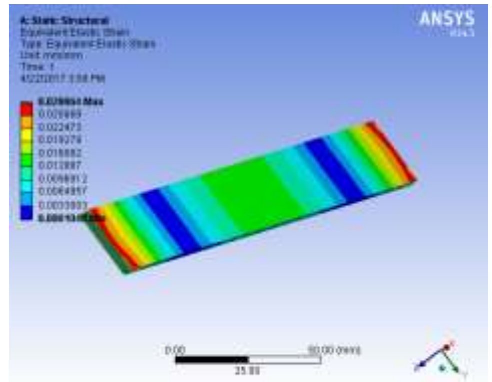

Fig:- Equivalent elastic strain of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

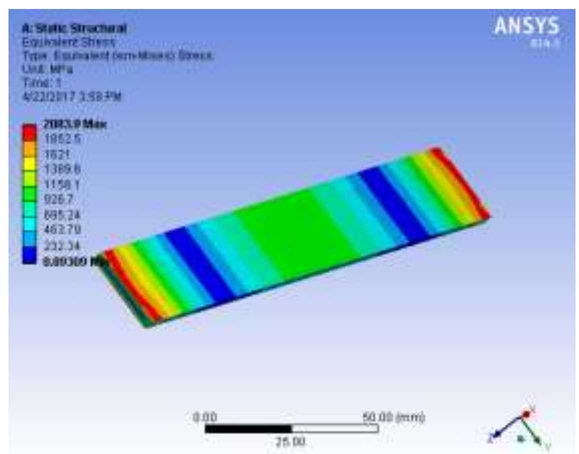

Fig:- Equivalent Stress of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

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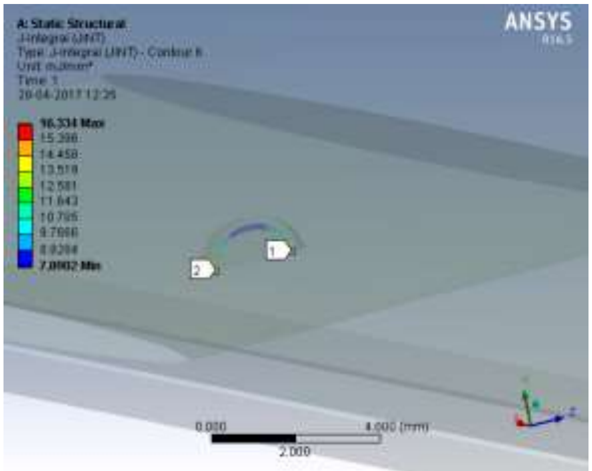


Fig:-J-Internal (JNIT) of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

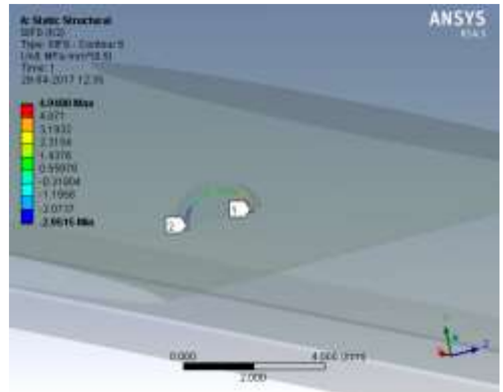


Fig:- Stress intensity factor (K2) of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

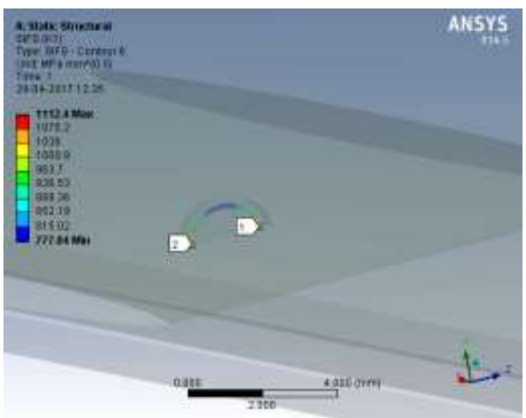


Fig:- Stress intensity factor (K1) of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

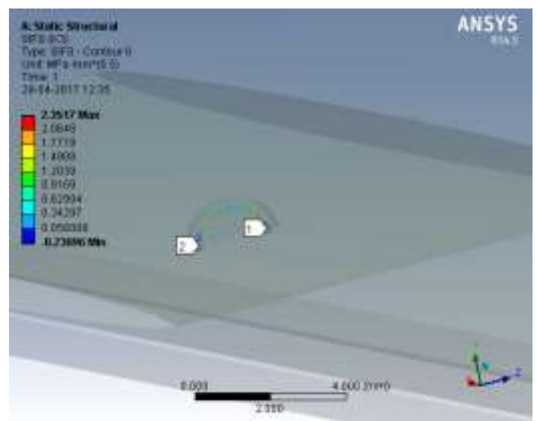


Fig:- Stress intensity factor (K3) of the delaminated composite beam with number of layers 3 and delamination length 0.1mm using E Glass Epoxy

RESULT TABLE

Static analysis

Material	No. layers	Deformation (mm)	Stress (MPa)	Strain
E-Glass epoxy	**3**	91.946	2083.9	0.028864
	5	20.358	758.73	0.010508
	7	7.7539	87.71	0.012027

Aramid fiber	**3**	612.79	2160.3	0.19682
	5	137.16	1744.2	0.15858
	7	47.317	383.74	0.035301
S-2 glass	**3**	130.16	2496	0.049443
	5	26.114	761.52	0.013893
	7	9.7985	386.2	0.0070219

Fracture analysis

Material	No. layers	JINT	SIFS-K1	SIFS-K2	SIFS-K3
e-glass epoxy	**3**	16.334	1112.4	4.9488	2.3517
	5	0.44308	156.39	0.68813	1.4584
	7	0.11775	54.583	0.34487	0.71329
Aramid fiber	**3**	81.322	900.45	4.7799	3.3335
	5	5.1458	146.95	0.98712	1.8224
	7	0.16855	53.844	0.18053	0.38261
S-2 glass	**3**	21.266	1109.1	1.0614	2.8774
	5	0.28459	155.74	0.53741	0.86462
	7	0.084047	55.124	0.22473	0.53727

THEORETICAL CALCULATIONS

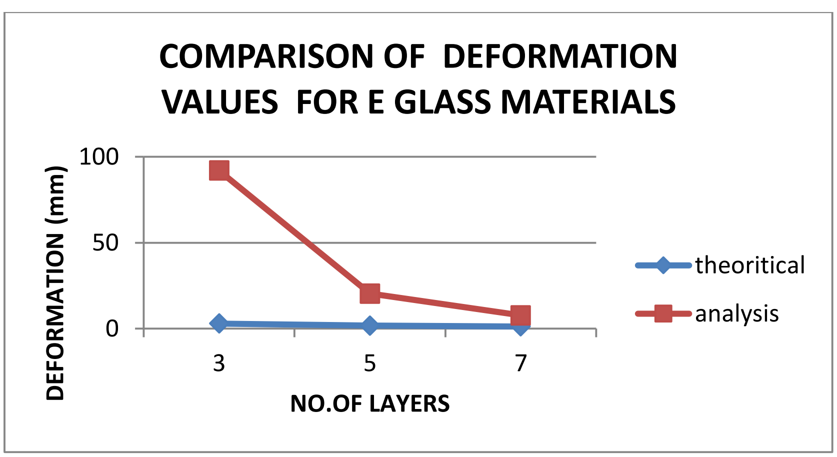
$I_{yy} = \{BD^3/12\}$

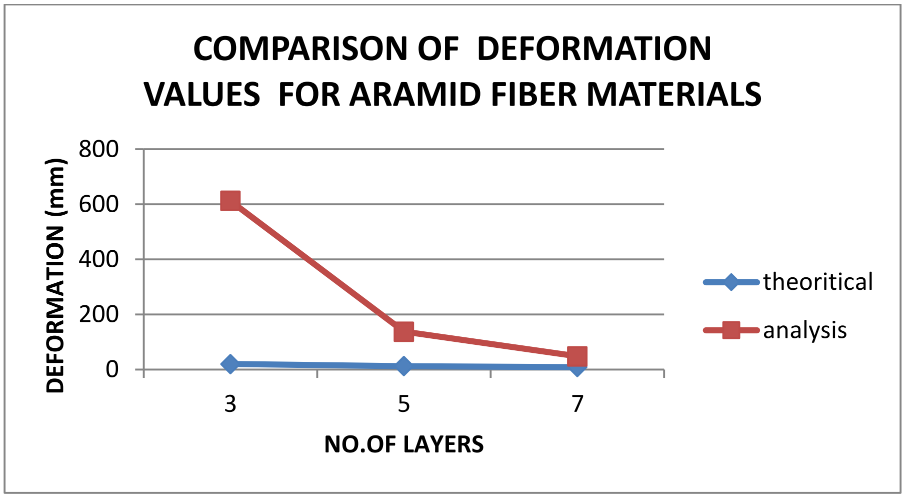
Displacement $W_{max} = \frac{f_t\, L^4}{8EI_{yy}}$

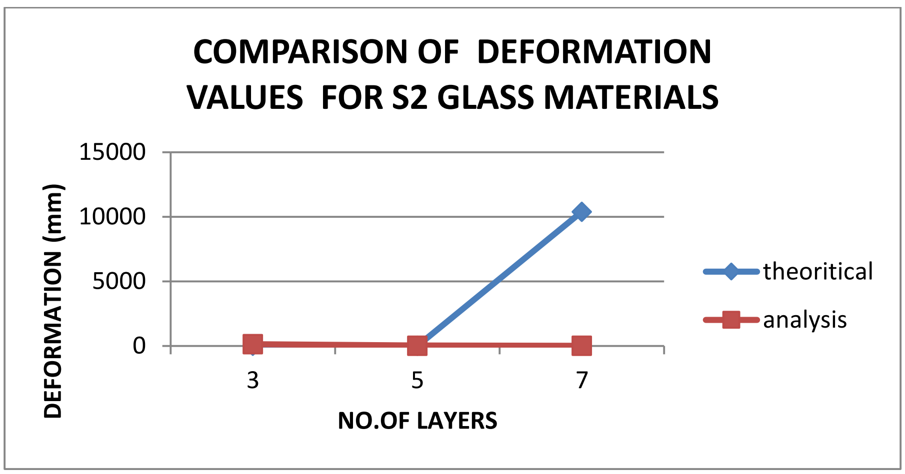
Shear coefficient factor $k = \frac{10(1\pm v)}{12\pm 11(v)}$

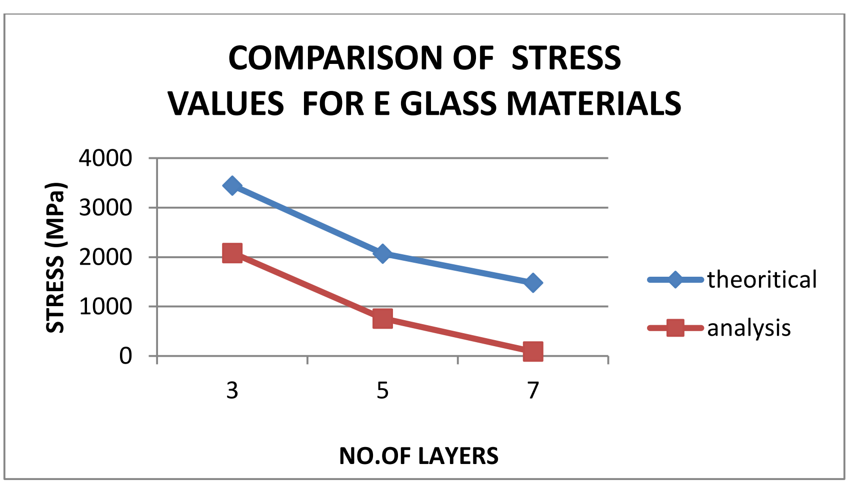
Strain $\epsilon = 0.5k(w_\alpha - \psi_\alpha)$

Comparison graphs




COMPARISON OF DEFORMATION VALUES FOR ARAMID FIBER MATERIALS
DEFORMATION (mm)
800
600
400
200
0
3
5
7
NO.OF LAYERS
theoritical
analysis


COMPARISON OF DEFORMATION VALUES FOR S2 GLASS MATERIALS
DEFORMATION (mm)
15000
10000
5000
0
3
5
7
NO.OF LAYERS
theoritical
analysis


COMPARISON OF STRESS VALUES FOR E GLASS MATERIALS
STRESS (MPa)
4000
3000
2000
1000
0
3
5
7
NO.OF LAYERS
theoritical
analysis

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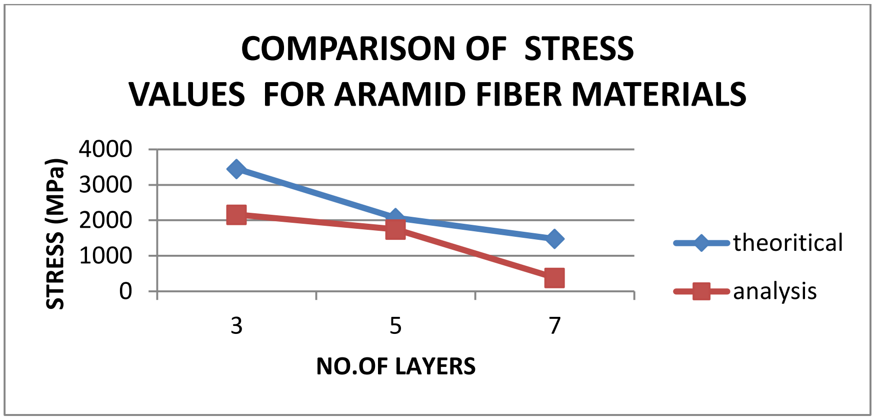
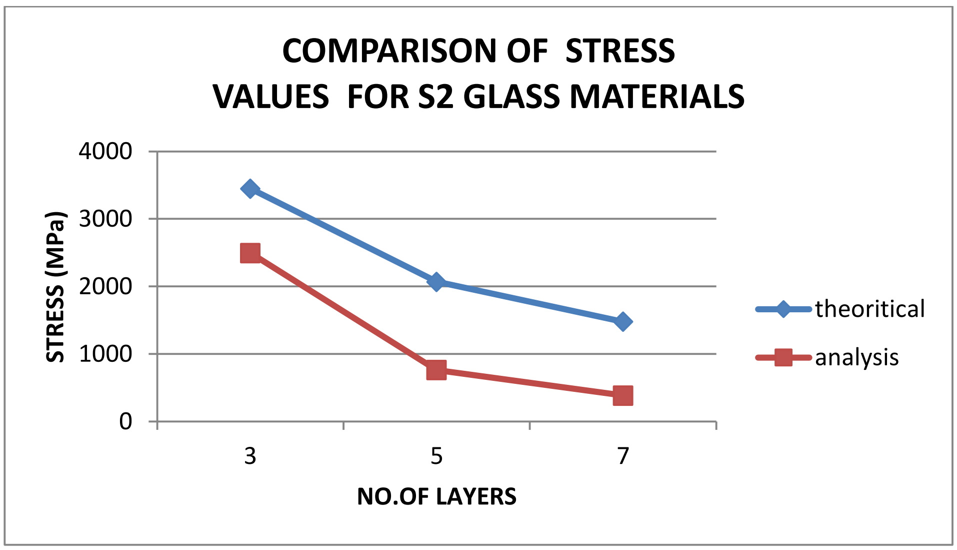
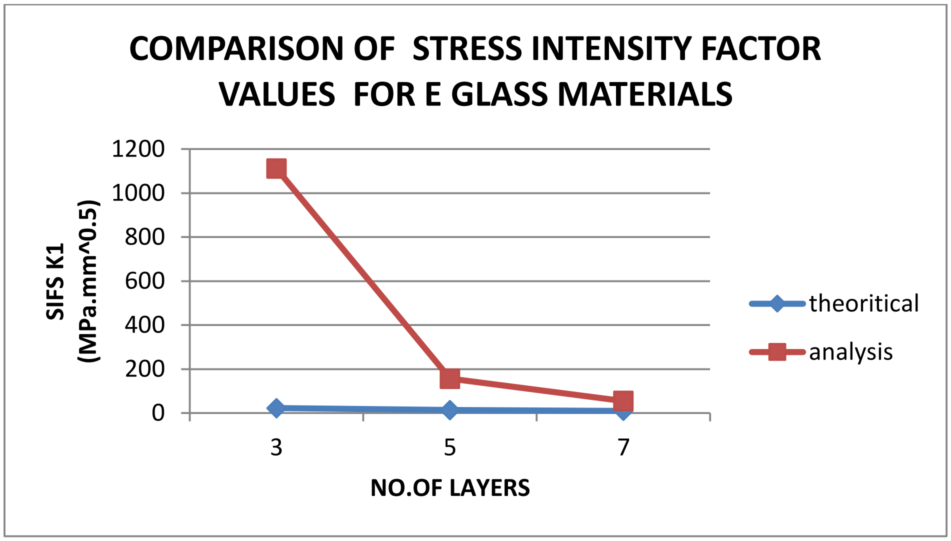
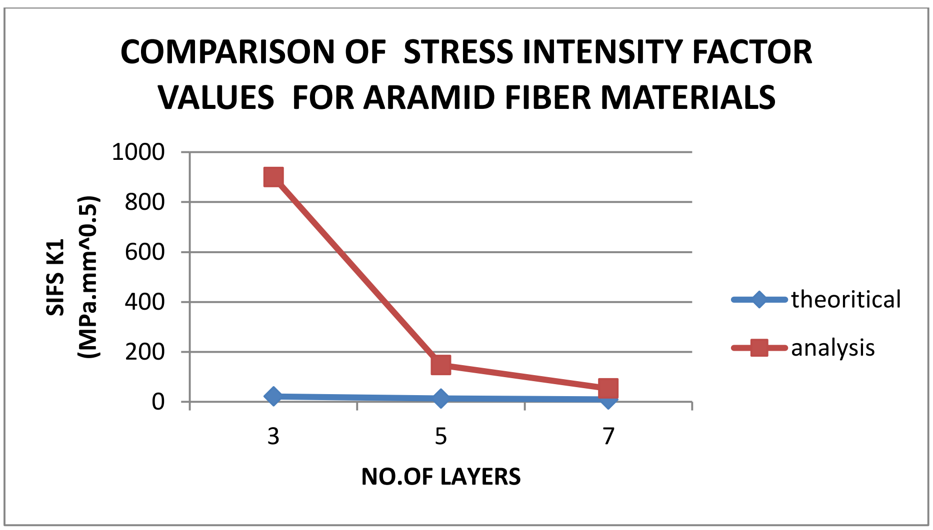
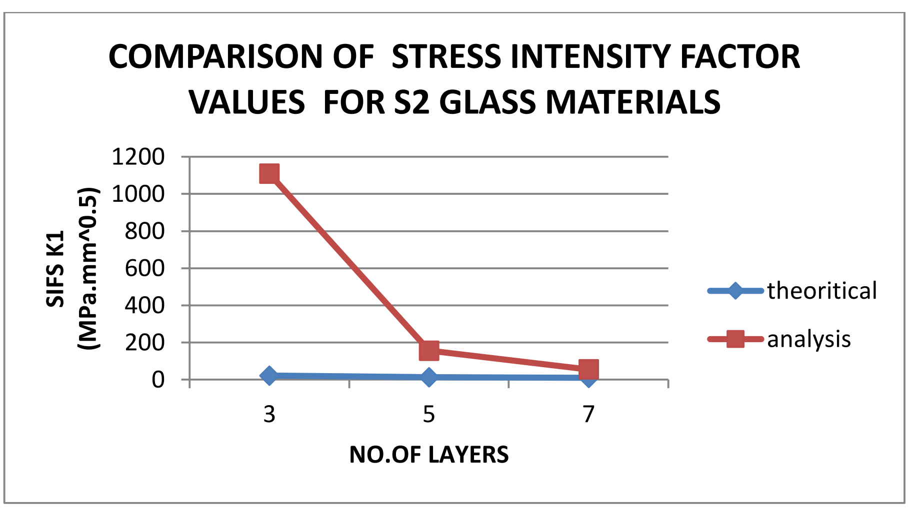





COMPARISON OF STRESS INTENSITY FACTOR VALUES FOR E GLASS MATERIALS
SIFS K1 (MPa.mm^0.5)
1200
1000
800
600
400
200
0
3
5
7
NO.OF LAYERS
theoritical
analysis


COMPARISON OF STRESS INTENSITY FACTOR VALUES FOR ARAMID FIBER MATERIALS
SIFS K1 (MPa.mm^0.5)
1000
800
600
400
200
0
3
5
7
NO.OF LAYERS
theoritical
analysis


COMPARISON OF STRESS INTENSITY FACTOR VALUES FOR S2 GLASS MATERIALS
SIFS K1 (MPa.mm^0.5)
1200
1000
800
600
400
200
0
3
5
7
NO.OF LAYERS
theoritical
analysis

CONCLUSION

By observing analysis results, the deformation and stress values are decreasing by increasing the number of layers. The values are less for E – Glass with 0.8mm delamination length and with 7 layers. Stress intensity factors are less for Aramid Fiber with 0.8mm delamination length and with 7 layers and J – Integral are less for S2 – Glass with 0.5mm delamination length and with 7 layers. Frequencies are less for Aramid Fiber with 0.5mm delamination length and with 3 layers. By decreasing the frequencies, the vibrations will decrease.

FUTURE SCOPE

This work can further be extended by performing experiments and checking with that of analytical results. The validation of the manufacturing process in terms of cost also needs to be done.

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