Structural and vibration analysis of delaminated composite beams

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ABSTRACT:

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. Some manufacturers of carbon composite bike frames suggest to dispose 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, delamination is increasingly an air safety concern, especially in the tail sections of the airplanes.

In this thesis, the effects of delamination length on the stresses and natural frequency of symmetric composite beams are analyzed using Ansys software. The composite material considered is carbon fiber. Structural and Frequency analysis are done on the composite beam by varying the delamination lengths.

I. INTRODUCTION

- Introduction to beam

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.

Figure 1. Beam figure

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

- 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., due to an earthquake or wind or in tension to resist rafter thrust as a tie beam or (usually) compression as a collar beam). 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.
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.

II. DELAMINATION LENGTHS

1.1 Structural analysis of delaminated beam

2.1.1 Carbon fiber

![Figure 2: Displacement](image2)

![Figure 3: Stress](image3)

![Figure 4: Strain](image4)

2.1.2 Kevlar

![Figure 5: Displacement](image5)

![Figure 6: Stress](image6)

![Figure 7: Strain](image7)

2.1.3 Fluora polymer

![Figure 8: Displacement](image8)

![Figure 9: Stress](image9)

![Figure 10: Strain](image10)
1.2 Structural analysis of changed delaminated beam

2.2 Structural analysis – solid element

2.2.1 Carbon fiber

2.2.2 Kevlar

2.2.3 Floura polymer

2.3 Shell element – 5 layers
2.3.1 Carbon fiber

Figure 21. Layer stacking

Figure 21. Displacement

Figure 22. Stress

Figure 23. Strain

2.3.2 Kevlar

Figure 24. Displacement

Figure 25. Stress

Figure 26. Strain

2.3.3 Flouro polymer

Figure 27. Displacement

Figure 28. Stress

Figure 29. Strain

2.4 Changing lengths

2.4.1 Carbon fiber

Figure 30. Displacement

Figure 31. Stress

Figure 32. Strain
2.4.2 Kevlar

Figure 33. Displacement  
Figure 34. Stress  
Figure 35. Strain

2.4.3 Floura polymer

Figure 36. Displacement  
Figure 37. Stress  
Figure 38. Strain

III. RESULTS TABLE

3.1 Delamination length – 381mm

<table>
<thead>
<tr>
<th>Material</th>
<th>Displacement (mm)</th>
<th>Stress (N/mm²)</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon fiber</td>
<td>0.413526</td>
<td>161.252</td>
<td>0.769</td>
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<tr>
<td>Kevlar</td>
<td>1.10706</td>
<td>161.252</td>
<td>0.002059</td>
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<td>Floura polymer</td>
<td>1.01506</td>
<td>170.69</td>
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Table 1. Results of Displacement – Stress-Strain

3.2 Delamination length – 400mm

<table>
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<th>Strain</th>
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<tbody>
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<td>2683.45</td>
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<tr>
<td>Kevlar</td>
<td>58.1869</td>
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<td>Floura polymer</td>
<td>58.6524</td>
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Table 2. Results of Shell element

3.3 Delamination length – 400mm

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<th>Strain</th>
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<td>Kevlar</td>
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<td>Floura polymer</td>
<td>53.6854</td>
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<td>0.28418</td>
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</tbody>
</table>

Table 3. Results of Displacement – Stress-Strain

IV. CONCLUSION

In this thesis, structural analysis and modal analysis is done to determine the stresses and the natural frequency of simply supported composite beam with single-edge delamination. The analysis is done by taking two delamination lengths. The delamination lengths considered are 381mm and 400mm. The analysis is done for 3 composite materials to determine the effect of delamination using solid element. Finite element analysis is done in Ansys. By observing the structural analysis results, the displacements and stresses are increased by increasing the delamination length. So the composite materials fail when the delamination increases. Modal analysis is done to determine the natural frequencies. By observing the analysis results, the natural frequencies decrease when length of delamination on the beam increase.
Analysis is also done by taking shell element by considering 5 layers. By observing the analysis results, the displacements and stresses are increased by increasing the delamination length.

REFERENCES
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