Impact Resistance Analysis of Hybrid Composite Material for Aircraft Fuselage

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Abstract:
Most of the aircraft fuselage till date was made out of aluminium fiber glass sandwich material. Invention of stronger and lighter composite materials combined with the growth of aircraft industry and rise in fuels prices demanded lighter more fuel efficient aircrafts. As a substitute to aluminium fiber glass sandwich, carbon fiber reinforced plastic is used in aircraft fuselage since it had high strength to weight ratio. The using experience of the composite aircraft structures showed that it is very sensitive to impact damage. During impact loads it can shatter and/or delaminate. Which are of great harm and will lead to serious degradation of the mechanical properties of laminated structures and substantial reducing of residual strength of the structure. As these damages are internal to the material, it may not be observed in visible inspection, which further increases the risk associated. Aircraft structure on the other hand, is very prone to high impacts loads, resulting from the high speeds at which they are usually operated. Kevlar helps to disperse the energy and deform the projectile to minimize blunt force trauma. The solution for this problem is to increase the impact resistance. Based on the literature review, it was observed that, impact resistance can be increased by incorporating a few layers of Kevlar on the impact side. As a result of polymer structure and intermolecular hydrogen bonding present in Kevlar, it has high fracture toughness and abrasion resistance making it an integral part of bullet proof vests. This project aims to propose an optimized combination of carbon fiber and Kevlar suitable for aircraft fuselage.

Keywords: Impact analysis, Hybrid composite, Aircraft, fuselage, structural analysis.

1. INTRODUCTION
The study and testing of composite materials suitable for aircraft structure becomes more and more important as the number of such impacts is increasing with the growth of aircraft industry. Common damages for aircraft structures are impact damages, caused by hail stones, birds or even tools during maintenance. Even the low energy impact will produce invisible internal impact damage of the composite materials, such as matrix cracking, delaminating and fiber breakage. Especially, the decline of residual compressive strength is particularly significant. Majorly composite materials are nowadays used in high-performance applications such as aerospace, marine, industrial, commercial and even recreational structures. All these structures require very high strength and stiffness without excess weight. Carbon fiber and Kevlar have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. Carbon fiber has a high ultimate strength (the force required to break it) and a very high stiffness (the amount it stretches/bends when force is applied to it). This makes carbon fiber ideal for strong, light and stiff structures. Compared to Kevlar, carbon fiber is brittle, can easily cut with scissors, carbon fiber cracks easily particularly when the force is quickly applied, such as impacts. Kevlar on the other hand have high fracture toughness much harder to crack, difficult to cut even with sharp scissors and stand well to impact loads. Reinforcement of composites with Kevlar fibers can significantly improve the impact damage tolerance if used in place of or in conjunction with carbon fibers. Once the failure strain of the brittle layers (carbon fiber) is reached in an inter-laminar hybrid, the load can be transferred to the ductile layers (Kevlar) if bonding between the laminates is sufficient. On the impact side, the very top 0, 5, 10, 15, 20, 25 and 30 % layers of carbon fiber may be replaced with Kevlar, which shows better impact properties. Low energy impacts show, since even in the absence of fiber breakage; the mechanical performance of can be drastically affected in case of carbon fiber alone. To improve upon the impact properties while maintaining the high stiffness, lightweight nature of the carbon fiber, Kevlar is introduced.

2. GEOMETRIC MODEL
The selected geometry is a square slab of sides 1000mm and thickness 50mm for the material and a sphere of diameter 50mm for the projectile.

Figure 1. Model and Meshing
The boundary conditions selected are, fixed support for all the four edges of square slab and 250 m/s (900 km/hr) velocity for projectile.
4. MATERIAL PROPERTIES

Table 1. Comparison of Mechanical Properties of Kevlar and Carbon fibre

<table>
<thead>
<tr>
<th>Material</th>
<th>Kevlar</th>
<th>Carbon fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (Kg/m³)</td>
<td>1400</td>
<td>1600</td>
</tr>
<tr>
<td>EXX (MPa)</td>
<td>351000</td>
<td>209000</td>
</tr>
<tr>
<td>EYY (MPa)</td>
<td>10560</td>
<td>9450</td>
</tr>
<tr>
<td>EZZ (MPa)</td>
<td>10560</td>
<td>9450</td>
</tr>
<tr>
<td>GXY (MPa)</td>
<td>10500</td>
<td>5500</td>
</tr>
<tr>
<td>GYZ (MPa)</td>
<td>3900</td>
<td>3900</td>
</tr>
<tr>
<td>GZX (MPa)</td>
<td>10500</td>
<td>5500</td>
</tr>
<tr>
<td>ʋXY</td>
<td>0.3</td>
<td>0.27</td>
</tr>
<tr>
<td>ʋYZ</td>
<td>0.42</td>
<td>0.4</td>
</tr>
<tr>
<td>ʋZX</td>
<td>0.3</td>
<td>0.27</td>
</tr>
</tbody>
</table>

5. RESULTS AND DISCUSSION

The analysis has been carried in 7 steps changing the thickness of Kevlar on the impact face in steps of 5% from 0% to 30%. As the thickness of Kevlar reached 20% difference properties became negligible.

STRESS DISTRIBUTION
As the thickness of Kevlar increased concentrated nature of stress reduced and started to get distributed over the entire area. Maximum stress experienced at the point of impact is also reduced gradually along with the increase in impact energy distribution. Maximum stress experienced for 0% Kevlar is 970.64 N/mm² (highest) and for 30% Kevlar is 629.95 N/mm² (lowest). At 0% thickness, the structure completely failed. Since 20% even though permanent deformation is there material failure is avoided.
As the thickness of Kevlar increased the deformation started to widespread over the entire area. The energy of impact is found to get transferred to the edges, accordingly maximum deformation experienced at the point of impact reduced. Maximum deformation experienced for 0% Kevlar is 105.53 mm (highest), the material completely failed and got penetrated by the projectile at this level and 30% Kevlar is 19.117 mm (lowest).
### 6. CONCLUSIONS

- As the thickness of Kevlar increased the deformation reduced and impact strength increased in a parabolic manner.
- The difference in properties reduced as the percentage of Kevlar increased and properties started to stabilize around 20%.
- The variation of properties among 20, 25, 30% of Kevlar are negligible. Therefore the optimal thickness may be considered as 20% of Kevlar on the impact side.
- The use of Kevlar also reduces the total weight of the structure since the density of Kevlar is lower than that of carbon fibre.
- The lower density also allows using a thicker structure without increasing the weight.
- Compared to carbon fibre, Kevlar is cheaper; therefore the use of Kevlar may be recommended in the economic point of view.
- The fracture toughness and abrasion resistance also reduces the frequency and difficulties in maintenance and inspection. Avoiding the frequent testing required by the carbon fibre will allow the aircraft to be operational for more time.
- Kevlar is also expected to provide the aircraft a longer service life due to the reduced chances of damages.

### 7. REFERENCE


[3]. S. BAZHENOV Institute of Chemical Physics, Kosygino Street 4, 117977 Moscow, Russia “Dissipation of energy by bullet proof aramid fabric” Journal of Materials Science 32, pp. 4167—4173


[5]. S. Xu and P. H. Chen Nanjing University of Aeronautics and Astronautics, 29 Yudao Street, Nanjing, 210016, China “Prediction of low velocity impact damage in carbon/epoxy laminates” Procedia Engineering 67 (2013) 489 – 496


[7]. Shi-Xun Wang, Lin-Zhi Wu and Li Ma “Low – velocity impact and residual tensile strength analysis to carbon fiber composite laminates” Center for Composite Materials, Harbin Institute of Technology, Harbin 150001, China Materials and Design 31(2010)118 – 125
