Effect of thermal aging and fatigue on failure resistance of aerospace composite materials

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Overview

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  o Mechanical Fatigue
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• Conclusions
Introduction

The composite materials under study have been in use in a variety of aeronautical applications the past years.

Some of the issues that these materials face are caused by exposure to high temperatures, large temperature variations (-50 to +40 °C) and mechanical fatigue due to pressure difference and vibrations of various structural components during a flight.

The prementioned are main damage sources, in terms of crack initiation and propagation and they are responsible for the material’s degradation.
Aim of Study

The aim of the current work is to estimate the effect of:

- Thermal fatigue
- Mechanical fatigue
- Thermal aging

on the mechanical performance of carbon fibre laminate composites
Mechanical Fatigue

The materials involved in this study are two carbon fibers (CF) composites with RTM6-resin for the first and BMI-resin for the second, each one with two different layouts; [0/90/0/90]s and [0₂/90₂]s

A series of tension-tension fatigue loading experiments was carried out on all samples in order to study the development of transverse intralaminar cracks in terms of cracks density as a function of number of cycles.

The Fatigue tests parameters used were:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>10Hz</td>
</tr>
<tr>
<td>$\sigma_{\text{min}}$</td>
<td>13 MPa (RTM6) and 11.5 MPa (BMI)</td>
</tr>
<tr>
<td>$\sigma_{\text{max}}$</td>
<td>130 MPa (RTM6) and 115 MPa (BMI)</td>
</tr>
<tr>
<td>Pre-strain</td>
<td>0.4% strain</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.1</td>
</tr>
<tr>
<td>Number of cycles</td>
<td>1    50    500    5000    20000</td>
</tr>
</tbody>
</table>
Mechanical Fatigue

Crack Density comparison between layouts for RTM6 composites

Crack Density comparison between layouts for BMI composites
Thermal Fatigue

- The material used was CF epoxy [0/90]_s cross-ply laminate, manufactured using prepreg technique, at 120°C for one hour.
- Each sample was subjected to 100 thermal cycles from -100 to +100 °C.
- All samples were loaded in tension up to certain strain level and unloaded to count the number of cracks and estimate the crack density.
Thermal Fatigue

Dependence of Crack Density on the number of thermal cycles

Temperature profile for thermal cycling
Thermal Stresses

- In the frame of the current study, the thermal and curing stresses were established by measuring the change of the curvature in a \([0/90_2]_T\) CF laminate plate for stepwise elevating temperature.

Curvature dependence on the temperature
The curing temperature of the composite plate was 120°C. However, the extrapolation of the experimental values for the curvature, indicate that the stress free condition is not at curing temperature, but a lot higher at 235 °C.
Thermal Aging

The material used was CF cross-ply laminate $[0/90_2]_s$ and the aging was carried out at 110°C for two time intervals; 250 and 400 hours.

After the aging process, each sample was subjected to stepwise tensile loading. The strain level was increased every each step and between every loading it was examined under optical microscope for transverse cracks.
Thermal Aging

Crack Density dependence on aging time and applied strain
Conclusions

• For the mechanical fatigue, the actual stacking sequence is of great importance, since for both materials the crack density is proportional to the transverse layer’s thickness.

• The thermal cycling along with the thermal aging provide a good understanding of the material’s behaviour at different working temperatures.

• Thermal aging does not affect the structural integrity of the material in terms of crack density, when the material is subjected to low strain levels (first cracks appear at about the same applied strain). The increase of the stress introduces cracks, the number of which increases with elevating strain level.

• The crack density is a clear function of aging time, indicating the mentioned matrix and interface degradation over time.
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End of Presentation

Thank you
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