EEFFECT OF NANO FILLER ADHESIVE IN SINGLE LAP JOINT BONDED STRUCTURES

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Abstract

This work focuses on developing new adhesive formulations based on epoxy/nanostructures carbon forms. Different types of Nano fillers were dispersed in an epoxy matrix for developing toughened epoxy paste aeronautic adhesives. The reinforced adhesives were used for bonding glass fiber/epoxy composite adherents. Data were also compared to the result obtained both for the unfilled adhesive and/or adherents. Single lap joint sample were prepared to measure mechanical strength and adhesion properties of the joint configurations to analyze the types of failure mode using Acoustic emission testing.

Keywords: Glass/Epoxy composite, Adhesively bonded joints- Graphene nanoplatlets (GNP), Tensile test, Acoustic Emission (AE).

1. INTRODUCTION

Adhesive bonded aircraft structures and joints have demonstrated considerable variation in their reliability of service performance. The failure to recognize the cause of such bond failures has meant the continued use of deficient bonding processes both in the manufacture of defective components and the use of poor repair technology. Further, the lack of knowledge of bond failure mechanisms has resulted in inappropriate test methods being used to assist selection of bonding materials and processes [1]. This study will address the essential elements of adhesive bonding technology and will present examples of bond failures which characterize the results of inappropriate bonding practices, based on extensive service experiences with bonded panels and repairs2. The objective is to encourage better bonding practices by identification of the real causes of adhesive bond failure and to refute many fallacies frequently used to explain unexpected bond failures. Clear identification of the failure mode plays an
important role in determining the cause of bond failure[2, 3].

During the past three decades, application of composite materials is continuously increasing from traditional application areas such as military aircraft, commercial aircraft to various engineering fields including automobiles, robotic arms and even architecture. Due to its superior properties, composites have been one of the materials used for repairing the existing structures [3]. It is shown that continuum mechanics can be employed to analyze the behavior of these model composites and used to predict the minimum flake dimensions and optimum number of layers for good reinforcement [4]. When crack arrests, the bonded joint can sustain a higher load and thus benefits from some of the intrinsic properties of the adherents (e.g. the plasticity of metal adherends) to enhance energy absorption and toughness [5]. The basic requirements of an on-aircraft surface preparation are, primarily, it must produce a durable bond which must be validated using exactly the same procedures and materials. It must be succinctly robust and transportable that it can be performed in non-ideal conditions. It should not cause secondary damage to the surrounding structure, such as corrosion. The basic principles for adhesive bonding for repair under depot or level maintenance are essentially the same as for production [6]. Fibers do not act as an effective reinforcing material when the adhesion is weak. Also, the adhesion between phases can be easily degraded in aggressive environmental conditions such as high temperatures and/or elevated moisture, and by the stress fields to which the material may be exposed. Many efforts have been done to improve polymer-glass fiber adhesion by compatibility enhancement [7]. Composite structures, used to meet the demand for lightweight, high strength/stiffness and corrosion resistant materials in domestic appliances, aircraft industries and fields of engineering composites, have been one of the materials used for repairing the existing structures owing to its superior mechanical properties. Applications of composite materials have been extended to various fields, including aerospace structures, automobiles and robot systems [8]. Next generation aircraft engines and pipelines are common application areas of these adhesives. In order, however, to ensure the safe use of epoxy adhesives in such structures, computational analyses must be conducted to simulate eventual failure mechanisms[9]. The major structural integrity issue is to assure that disbonding of the patch due to environmental degradation will not occur during the required service life. Methods based on a combined safe-life/damage tolerance approach can be applied to the patch system where bond environment durability is not a concern, based on patch system fatigue allowable and knockdown factors. It is proposed that the BWT should be adopted as the principal accelerated test for quality control for bonding surface treatment [10].

2. EXPERIMENTAL DETAILS

2.1 Materials and Methods

GNP was procured from Javanthee Enterprises Pvt. Ltd. And also the resin and hardener are (GY-257), (2963) from Araldite Pvt. Ltd. Commercial High strength Bi-directional E-Glass fiber was used in the current study. Epoxy resin was used to form matrix material. By using the vacuum infusion bagging method to form a two different thickness of laminate plate, adding the GNP to the normal epoxy mixer ultrasonic heater is used[1]. Three different single lap joints were done, in the ratio of (0.25%wt, 0.5%wt) and the other one is normal epoxy resin [1].

2.2 Composite Fabrication

Composite panels were prepared through a Vacuum Bagging Process. The Vacuum Infusion Process (VIP) is a technique that uses vacuum pressure to drive resin into a laminate [5]. In the ratio of (100:45) resin and the hardener were mixed. Figure 1 shows the 30mmX30mm fiber sheet is used in this process. Vacuum Bagging Equipment and Techniques for Room-Temp Applications. So, the curing process is also normal and the duration is 24 hrs.
2.3 Mechanical Characterization

GNP and the normal epoxy resin mixer ratio are 0.25%wt, 0.5%wt) table 1. The tensile tests were performed on samples as per ASTM D638 standard using computer controlled Universal Testing Machine. And also to analyze the failure modes of the specimen by using Acoustic Emission (AE) testing method. Tests were carried out on six series of sample, each one characterized by different combination between adherents and adhesive formulations. ASTM D5868-01 standard tensile specimens of size 125x25x2mm and 125x25x4mm were cut using water-jet cutting to avoid machining defects and to maintain good surface finish from the fabricated laminates as shown in figure 2 (a), (b). The adherent surfaces cleaned with acetone were bonded for single lap joint specimen Figure 3.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Glass fiber + Epoxy</td>
</tr>
<tr>
<td>S2</td>
<td>Glass fiber + Epoxy+(0.25% GNP)</td>
</tr>
<tr>
<td>S3</td>
<td>Glassfiber+ Epoxy+(0.5% GNP)</td>
</tr>
</tbody>
</table>

Table: 1 GNP mixing ratio

The result was confirmed, by the end of 1996, by a team at Fermi-lab.

3. RESULTS AND DISCUSSIONS

3.1 Tensile Properties

Figure 5, 6 shows the load–displacement curves of the glass fiber reinforced with neat and the modified epoxy matrix under the uniaxial tensile testing. For the 2mm thickness and 4mm thickness single lap joint specimen.
Figure: 4 testing the specimen in the universal testing machine.

One can observe from Table.2 and Table.3 that the tensile strength value increased from 5kN to 7KN. It clearly indicates that the ratio of GNP and the epoxy resin, exhibited better ultimate strength when one compared with other fillers.

Table: 2 (2mm) load factor

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Ultimate Load (KN)</th>
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<tbody>
<tr>
<td>S1 (Glass fiber + Epoxy)</td>
<td>5.04</td>
</tr>
<tr>
<td>S2 (Glass fiber + Epoxy+(0.25% GNP)</td>
<td>7.1</td>
</tr>
<tr>
<td>S3(Glass fiber+ Epoxy+(0.5% GNP)</td>
<td>6.9</td>
</tr>
</tbody>
</table>

4. ACOUSTIC EMISSION TESTING

The failure modes in GFRP composite adhesively bonded joints are identified using various AE parameters such as The range of peak frequency pertaining to the below failure modes of composite laminates obtained from different orientation during the conduct of tensile test with acoustic emission monitoring are obtained. The relevant frequency ranges are: 80-110 kHz corresponding to matrix failure (Adhesive), 130-200 kHz to fiber matrix failure (thin layer cohesive failure), and 230-250 kHz to fiber tear failure I and 250-300 kHz to fiber failure respectively as shown in the figure 7 and table 3.

Table: 3 (4mm) load factor

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Figure: 6 Frequency range and failure modes of bonded lap joints for two different thickness (2mm, 4mm) plates.
Figure: 7 Percentage of frequency range of bonded lap joints for two different thickness (2mm, 4mm) plates.

5. CONCLUSION

In the present paper, the addition of GNP into an epoxy adhesive formulation caused an improvement in the bonded strength of the joints. The response of single lap joints with composite adherend subjected to tensile load was investigated for two different thickness laminates.

In this case the most relevant enhancement in mechanical performances were achieved by using lower Nano filler (0.25wt/wt. %) content in epoxy matrix adherents for 2mm and 4mm thickness lab joints, comparing to the higher Nano filler (0.5wt/wt.% ) content in epoxy matrix.

The precisely composite bonded joints analysis method must be able to predict failure modes in GFRP composite, and also identified using various AE parameters.

References


