Self-Healing Of Aircraft Structures By Effective Arrangement Of Carbon Nano Tubes

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Abstract

Over the past few decades in composite structures cracks are formed due to fatigue, aerodynamic flow etc., and the cracks are detected by using carbon Nano tubes which are electrically resistive or by using sensors. When the cracks are identified, Nano tubes which are pre-implanted in the composite material Subjected to small amount of electricity that will generate heat by the joule's heating principle and quickly seal it up and restoring structural integrity and recovers the crack..

Keywords: *Self healing, Aircraft, composite materials, Ultrasonic sensor, Nano carbon tubes, square cross-sectional grid, healing agents*

1. Introduction

The Advancement in technology made the structure of composite materials stronger than they actually needed to be, so when the damage occurs it will less likely to be catastrophic. This can be equally required for a composite material if the crack is detected that could heal itself, without the help of human interaction, These composite materials have made a good impact on automobiles and aircraft structures [1].
The impact of composite structures from sources that involve wide area contact is of interest due to the tendency to produce internal damage with little or no exterior visibility. Experiments representing GSE impact on a curved stiffened skin structure (five frames, four stringers) at a velocity of 0.6 m/s has shown complete failure of the three frames that were impacted. The exterior skin, however, exhibited no cracks and imperceptible levels of permanent deformation. Modelling methodologies are being established to predict the initiation and propagation of damage from GSE. Similarly, the modelling capability to predict impact damage from high speed ice impacts has been developed and threshold force-based failure criteria have been identified. Large radius metal tip impact-created dents are observed to relax considerably relative to a 25 mm diameter impactor tip.

2. Why self-healing procedure

As we know that Traditional repairs are very expensive and this method of application can be done on aircraft system when they are on ground, this are some of the expensive traditional methods used to repair the cracks in aircraft structures like Aircraft fabric covering, bolted joints in aircraft Structures [3]
In this methods Primary composite structures will involve larger joints, providing new challenges and more expensive test programs. Sense and respond to damage, restore performance without Affecting inherent properties. Their properties are not affected such as mass, Provide early means of detection of damage

Key! No human intervention required.

3. Major cracks formed in aircraft structures

The past 45 years has seen the development of numerous in-situ systems for studying the process of fatigue crack formation/nucleation and the study of microstructural effects on the early stages of crack propagation of aircraft and other structural materials. [4] Crack formatted due to the heavy aerodynamic flow

and gust loads areas which highly effected in aircraft structures are wings, control surfaces, and rudder

Wings: This are highly effected due to aerodynamic flow and fatigue, gust loads have a great impact on the wing structure. The first of these is the heating up and cooling down of the Aircraft surface during each supersonic flight which induces a thermal stress cycle contributing to the general Fatigue damage and critically affecting design at some locations. Same with the control surface and rudder

4. How cracks are identified

Identification of cracks plays main role in the healing system Ultrasonic Inspection Techniques

- **Pulse-Echo Inspection**

In this process transducer **is** used to transmit and receive the ultrasonic pulse. When the ultrasonic pulse are received they are separated by the time it takes the sound to reach the different surfaces from which it is reflected. The size (amplitude) of reflection is related to the size of the reflecting surface the pulse-echo ultrasonic response pattern is analysed on the basis of signal amplitude and separation.

- **Through-Transmission inspection**

This inspection employs two types of transducers, First one is to generate the ultrasound and a second one is to receive the ultrasound. The defects in the sound path in- between two transducers will interrupt the sound transmission. The magnitude (the change in the sound pulse amplitude) of the interruption is used to evaluate some test results. Which includes transmission inspection is less sensitive to small defects than is pulse-echo inspection.

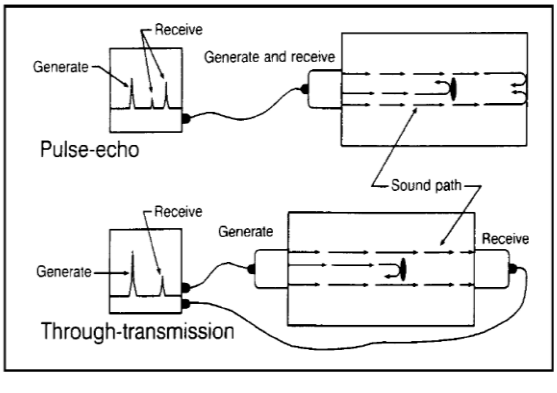

Figure (1) Ultrasonic Inspection

5. How self-healing works

Carbon nanotubes are allotropes of carbon with a cylindrical nanostructures. These cylindrical carbon molecules have unusual properties like thermal conductivity and mechanical and electrical properties

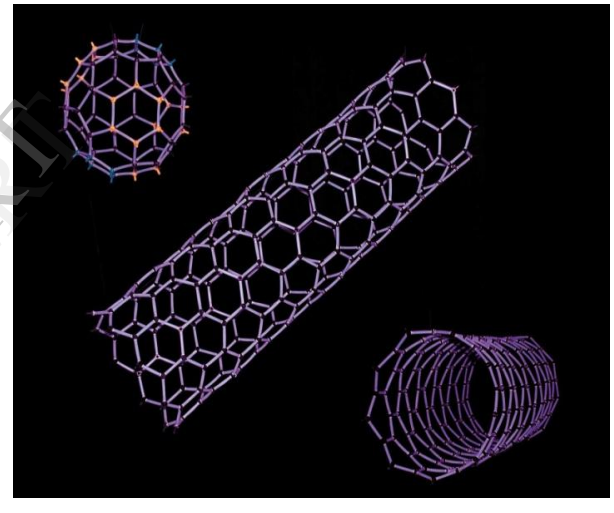

Figure (2) Carbon Nano tube Structure

By implanting a polymer with electrically conductive carbon nanotubes, and then monitoring of the structure's which are electrically resistive, Once a crack is identified, then we can send a short electric charge to the area in order to heat up the carbon nanotubes and in turn melt an embedded healing agent that will flow into and seal the crack with a 70 percent recovery in strength.

A structure from common epoxy, this kind is used to manufacture everything from the lightweight frames of fighter jet wings to countless devices and components used in manufacturing but they added enough of multi-walled carbon nanotubes to comprise 1 percent of the structure's total weight. They mechanically mix some liquid epoxy to ensure the carbon nanotubes were properly dispersed throughout the structure as it dried in a mold.

When the composite structure are introduced with a series of wires in the form of a grid, which can be used to measure electrically resistive and also apply control voltages to the structure. By giving a small amount of electricity through the carbon nanotubes, the research team could be able to measure the electrical resistance between any two points on the wire grid. Then they create a tiny crack in the structure, and measured the electrical resistance in between two nearest grid points. Hence the electrical current has to travel around the crack to get from one point to another, the electrical resistance. As longer as the crack grew, electrical resistance between the two points increased.

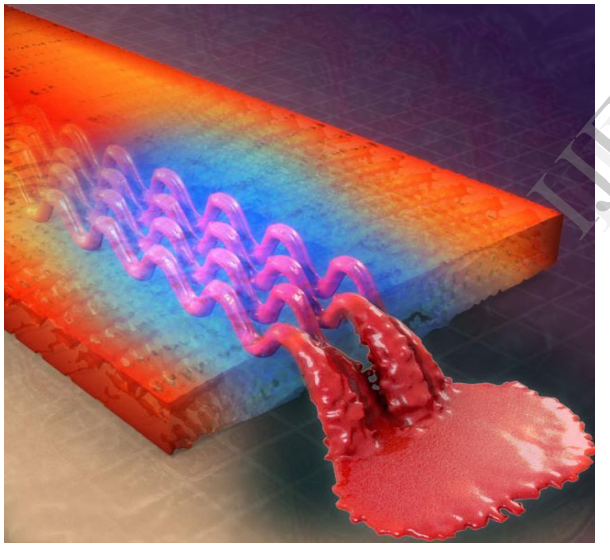

Figure (3) Flow of Healing agent

This method are effective with larger structures. Where the nanotubes are ubiquitous through the structures, this type of technique can be used to monitor or analyze any portion of the structure by performing simple resistance measurements without the need to mount external sensors or sophisticated electronics.

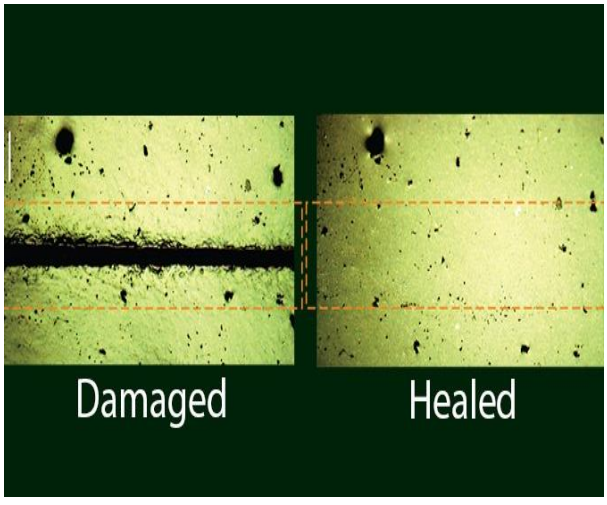

Figure (4) Damaged Structure Healed

6. Self-healing agents

Development of submicron capsules and nano capsules filled with healing agent will allow for the incorporation of healing functionality in composites with interstitial spacing smaller than capsules prepared using previous methods. Submicron capsules and particles have been prepared previously for encapsulation of inorganic particles such as magnetite in polystyrene [6], pressure sensitive adhesives [7], and melamine-formaldehyde capsules containing cyclohexane and n-octadecane [8].

The process of in situ polymerization has been used to produce microcapsules as described in the previous works of Brown et al. [5], Ni et al. [7], and Alexandridrou et al. [11]. The addition of particulate fillers, such as capsules, to an epoxy resin can have a significant influence on the mechanical properties of a material.

7. Microencapsulated Healing

The conventional strategy was achieved by embedding a microencapsulated liquid healing agent and solid catalytic chemical materials within a polymer matrix. Then the damage upon-induced cracking in the matrix, the microcapsules are ready to release their encapsulated liquid healing agent into the crack planes. All the involved materials must be carefully engineered. For examples, the encapsulation process should be chemically compatible with the reactive healing agent, and the liquid healing agent they must not be diffuse out of the capsule .At the same time, the microcapsule walls must be resistant enough to processing conditions of the host composite, by maintaining the excellent adhesions with the cured

polymer matrix[12] to ensure that the capsules rupture upon composite fracture.

Autonomic healing concept incorporating encapsulated healing agent and embedded catalyst particles in a polymer matrix. Damage event causes crack formation in the matrix. Crack ruptures the microcapsules, and allows the liquid healing agent to flow into the crack plane. Healing agent polymerizes upon contact with embedded catalyst, bonding crack closed Typical SEM image of the urea-formaldehyde microcapsules containing dicyclopentadiene prepared by emulsion in situ microencapsulation.

Figure (4) Microencapsulated Healing process

8. Effective arrangement of carbon nanotubes

Effective arrangement of Carbon nanotubes in the aircraft structures should be in square grid cross-section, hence it reduces the diameter of the carbon nanotube and the healing agents are implanted in geometric points of the square grid. Even the increase in mass doesn't affect the physical properties of the material and the carbon nano tubes are electrically resistance

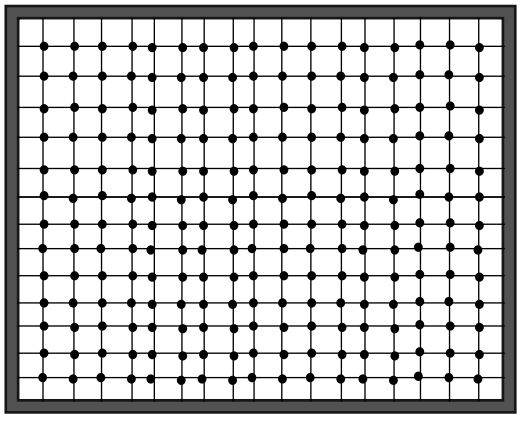

Figure (5) square grid cross section

The healing agents will melt with the increase in voltage at a certain grid point where crack is formed. The healing agent will melt within in the fraction of seconds and flows through the crack and fill up the crack.

9. Advantages and Disadvantages

They have demonstrated that composite panels prepared using hollow fibers containing repairing agents can restore up to 97% of its initial flexural strength [13]. The release and infiltration of fluorescent dye from fractured hollow fibers into the crack plane was also demonstrated. The approach of self-healing material design offers some advantages, which detailed are as follows

- Generally we use higher volume of healing agent which are available to repair the damages
- Different types of activation methods/types of resin can be used to heal the crack
- Visual inspection can be done with the damaged site is feasible.
- Hollow fibers are easily mixed and tailored with the conventional reinforcing fibers.

Besides the above advantages, this approach has the following disadvantages as well

- The broken fiber tends to release the healing agent
- Low-viscosity resin is used to facilitate fiber infiltration.
- Multi-step fabrication is the main requirement

10. Conclusion

The cracks are formed due to tiny holes rear and tear of structures and by aero dynamical flow, gust loads. They are self-healed by implanting carbon nanotubes in structure, this cracks are identified by using carbon nano sensors and ultrasonic, x-rays when cracks are detected small amount of electricity is passes to the grid which are arranged in the composite materials this created electrical resistance in between two nearest grid points. Because of the electrical current it has to travel around the crack to get from one point to another, the electrical resistance will melts the healing agent which flows through the crack and it is automatically healed.

Effective arrangement of Carbon nanotubes in the aircraft structures should be in square grid cross-section, hence it reduces the diameter of the carbon nanotube and the healing agents are implanted in geometric points of the square grid.

The carbon nano tubes are helping in increase the lifetime, safety, and cost effectiveness of structures. There is also evidence that carbon nanotubes play a passive role in suppressing the rate at which micro cracks grow in structures.

As well as the obvious safety benefits, this could make it possible to design lighter aero planes. This would lead to fuel savings and reducing carbon emissions.

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