Lightning Strike Protection and Electromagnetic Interference Shielding of Composite Structures using Conductive Submicron Films

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ABSTRACT

Carbon fibers have very good mechanical properties with the best strength-to-weight ratios, but are very poor conductors of electricity, especially when embedded with a resin system. These fibers should be further studied to increase the electrical conductivity of the aircraft structures and enhance the surface conductance of the fiber reinforced composites. The present study deals with the preparation of composite sandwich structures of carbon fibers with submicron copper films and subjecting those to lightning strike effects and EMI shielding. During the tests, the voltages on the conductive composite surfaces were found to be low; hence, an increase in current would help reduce the damage on composite panels after the lightning strikes. The same theory would be applicable to the EMI shielding. When lightning strikes were applied to composite coupons, the resulting damage from the currents was considerably reduced on those with metallic submicron films. Inspection results for the area of damage were correlated with results pertaining to lightning strikes and electromagnetic interference.

Keywords: lightning strike, EMI shielding, composite structures, conductive submicron films.

1 INTRODUCTION

Advances in the fabrication and design of new materials have led to a complete shift in the avionics industries. Metals are being replaced with composite materials as efficient engineering solutions for airplane structures. Composites are being studied extensively in the aerospace, energy and automotive industries [1]. Their unique physical properties, such as high specific modulus, good corrosion resistance, and better strength, have led many industries to consider replacing traditional metals with composite materials. These properties can be customized based on applications and needs for fiber and the resin systems. This replacement of metals with composites has resulted in some major problems, such as damage on the composite structure due to lightning strikes and electromagnetic interference (EMI). EMI usually refers to the reflection and/or adsorption of electromagnetic radiation, thereby acting as a shield against the penetration of the radiation [2-7].

On average, it is been estimated that each airplane in the U.S. commercial fleet is struck by lightning more than once a year [1]. Lightning is usually triggered in the atmosphere due to heavily charged particles in the clouds. When an airplane flies through a heavily charged region, lightning strikes can result in, causing potential damages to the composite structures of the airplane and creating many problems, such as delamination, rupturing, resin vaporization, etc. In the U.S, the last confirmed commercial plane crash attributed to a lightning strike was in 1967, which caused a catastrophic explosion of the fuel tank [1]. Since then, many studies by avionics industries and research scientists have been performed on lightning strike protection systems for the composite structures. If the crew and passengers in an airplane hear a loud noise and see a lightning flash, and if nothing serious happens, then likely it is because of lightning strike protection (LSP) techniques that had been engineered into the aircraft and its sensitive components [8-10].

The evolution of composites and their replacement with traditional metals has once again opened up a new area of LSP research, because composite structures are better insulating materials than metals. The initial idea of using composites in airplanes was to reduce the weight. Now research is involving the laying of thin metals on top of composites as well as introducing metal meshes, but at the expense of the initial idea of reducing the weight of airplanes [1]. The growing influence of electronics has resulted in unwanted signals, which can degrade the performance of electronic equipment in an airplane in the long run. Both internal and external sources of electronic signals may lead to jamming sensitive navigation and tactical equipment, even disrupting an airplane's control system. EMI may even scuttle an airplane's landing or takeoff. EMI includes high-frequency waves such as radio waves, like those emanating from cellular phones, which tend to interfere with electronics (e.g., computers). The importance of EMI shielding relates to the high demand of today's society for reliable electronics and the rapid growth of radio frequency radiation sources [11-16].

2 EXPERIMENT

2.1 Materials

Unidirectional carbon fiber prepreg, CYCOM 5320-1 T650-35, was chosen to fabricate composite panels. Commercially available submicron coper films (500-700 nm) and adhesive films were purchased and used without any modifications. Figure 1 shows the submicorn copper film co-cored on the fiber composite surface.

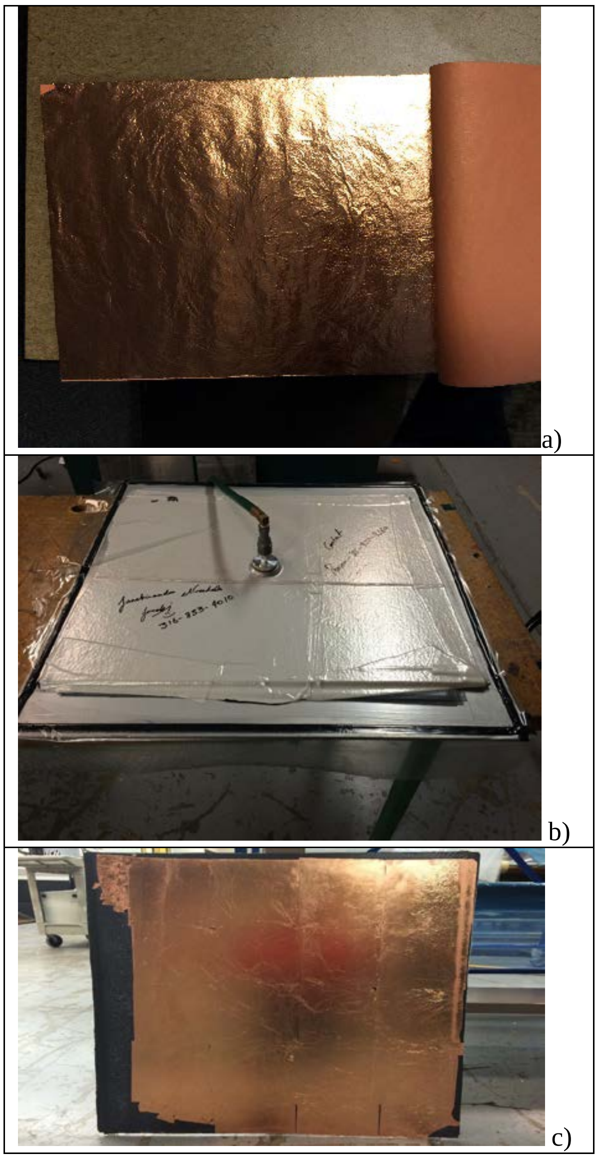

Figure 1: a) The submicorn copper film, b) vacuum bagging and c) co-cored submicron copper films on fiber composite surface.

2.2 Methods

The unidirectional carbon fiber prepreg composites were stacked at 0/90° orientation with 16 plies (30x30 cm) and debulked at 30 psi for 20 hrs. Then, adhesive films were uniformly placed on top of the debulked composites followed by submicron copper films. Composite panels were co-cured with the metallic films using the curing cycled of the prepreg composites in vacuum curing oven. Before and after the curing process, surface conductivity of the co-cured composites were measured. The lightning strike tests were conducted on the prepared composite panels using the procedures and environments defined in the standards [1]. Visual inspection tests were performed on the samples before and after the lightning strike tests.

3 RESULTS AND DISCUSSION

The test panel with carbon prepregs was initiated with a full lightning current of 200 amps. The type of damage was observed on both front and the back side of the composite test panels. The area of damage depends on various parameters, such as surface conductivity and coating thickness on the composite panel. The amount of damage on the surface of the panel was concentrated, i.e., the arc root dispersion that usually forms during the lightning was not observed. The major damages were on the front side of the panels.

The test panel with copper films was also initiated with a full lightning current of 200 amps. Damage was mainly observed on the front side of the composite test panels. The area of damage are considerably low compared to the previous samples without any metallic films. The corona effect was observed, but the back of the composite test panel was found to be free of damage (considerably low). Puncture damage was concentered on the top face of the composite panel, as well.

Based on the lightning test results, three components (A, B and C) were very important for lightning strike and EMI shielding [1]. The component A had an amplitude with a good curve, but the amplitude was observed to be less compared to that of the calibrated sample. The curve was smooth, and no sharp peak was observed. The electrical conductivity of the copper-laid composite was observed to be minimal. Component B is not of much importance for composites, but the curve/intensity was found to be minimal. The Component C curve was not smooth and very inconsistent, the same as other tests, but traveled a shorter distance. There is always the possibility of a return stroke on the composite panel, as the Component C curve likes to attract charges towards it. Higher electrical conductivity will considerably reduce the EMI effects on the avionics of the aircraft.

Currently, composite structures are protected using metallic meshes of aluminum or copper, which are bound to the outer surface of the composite structure. Other metallic meshes like nickel and phosphorus bronze are also used, but they are less accepted compared to aluminum and copper. However, the additional weight of metals in this application counterbalances the whole purpose of employing composites because they are lightweight. Not only the increase in weight is an issue, but studies have concluded that galvanic corrosions will occur on composite structures, due to the flow of electrons in the presence of an electrolyte [1].

The present work discussed about the potential engineering solutions for lightning strike protection for composites that could meet the present guidelines and regulations yet remain lightweight and financially cost effective. Here, metal meshes were replaced with very lightweight submicron scale metallic films. Impregnating the polymer matrices of the composite with metallic films improves both the electrical conductivity and other mechanical properties. These metallic films not only provide a comprehensive solution to lightning strikes but also to electromagnetic interference, where the electromagnetic waves signals can be reflected outright, thus reducing entry points rather than absorbing and dissipating the signals through the skin of the composite and grounding through the aircraft.

4 CONCLUSIONS

The main purpose of this study was to design and evaluate a new methodology that would optimize lightning strike and electromagnetic interference effects on composite structures and provide airworthiness solutions. Submicron copper films were co-cured on the composite panels and tested for lightning strike tests. The composites coated with submicron metallic coatings drastically reduced the overall weight of the composites, and enhanced the lightning strike protection and EMI shielding abilities. This process may open up new possibilities to extend this project on other micro and nanoscale conductive films on the aircraft composites.

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