

LIGHTNING STRIKE TESTING RESULTS ON HONEYCOMB PANELS PROTECTED WITH A SERIES OF DEXMET MICROGRID® PRODUCTS

Abstract

As the application of composite aero structures has increased, the effect of lightning strike damage and the structural tolerance necessary to absorb this damage has required further test investigation. To enhance the damage tolerance capability of composite sandwich structures used for commercial nacelle applications subjected to lightning strike effects, it has been an industry practice to use a series of external metal mesh products such as copper, aluminum, phosphorous bronze wire interwoven with carbon, nickel coated interwoven carbon fiber, and nickel coated non-woven veils. Certain configurations also employed various isolation materials, usually fiberglass. These protective materials have produced varying levels of post-strike damage results.

This paper, [which has been abridged from the original](#)¹, explores the comparative results of performing lightning strike damage testing on a series of thin skinned honeycomb panels using protective metal mesh materials. Damage assessments were performed using ultrasonic and visual non-destructive inspection methods.

Conclusions

- 1) Any honeycomb panel subject to a Zone 1A or Zone 1B lightning strike needs to be protected with a form of lightning strike protection so as to avoid significant damage to the load carrying facings. Statistical probability and historical environment cannot always predict where a composite panel might be struck by lightning. If the potential exists at all, to be subject to a lightning strike, it is better to supply protection than to have to repair large scale damage that affects service or dispatch.
- 2) All Dexmet metal mesh products in this study work to reduce the damage caused by a lightning strike event.

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1. INTRODUCTION

Lightning strikes on transport aircraft happen periodically depending on many parameters including atmospheric conditions and operational characteristics of the airplane. Most recent nacelle fleet history, circa 2002-2005, has shown that lightning strike damage has occurred more frequently on shorter mission commercial aircraft equipped with composite panels than prior configurations of nacelle panels. It should be noted that the greatest frequency of reported lightning strike damage on composite nacelle structure occurred along the Midwestern corridor of the continental United States.

An aircraft is divided into zones of severity of potential lightning strike damage. The two most severe categories of zoned lightning strike damage for nacelle products are Zone 1A and Zone 1B requirements, per SAE ARP5414. An example of the types of damage being witnessed on shorter mission commercial airplane nacelle products is shown in Figure 1. This particular structure did not have protective materials in its configuration.



Figure 1: A generic thrust reverser panel with lightning strike damage

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To emulate the damage shown in Figure 1, testing on a variety of honeycomb panels was performed using Zone 1A and 1B criteria. The individual components and values for Zone 1A and Zone 1B are shown in Figure 2, and are defined in SAE ARP5412

Zone 1A		Zone 1B	
A component	Peak Amplitude of 200K-Amps Action Integral of 2.5×10^6 Amps ² -sec	A component	Peak Amplitude of 200K-Amps Action Integral of 2.5×10^6 Amps ² -sec
B component	Average Amplitude of 2K-Amps Max Charge Transfer of 10 Coulombs	B component	Average Amplitude of 2K-Amps Max Charge Transfer of 10 Coulombs
C component	Average Amplitude of 500-Amps Max Charge Transfer of 20 Coulombs	C component	Average Amplitude of 500-Amps Max Charge Transfer of 200 Coulombs
		D component	Peak Amplitude of 100K-Amps Action Integral of 0.25×10^6 Amps ² -sec

Figure 2: Zone 1A and Zone 1B components and values used in testing

The representative coupons on which lightning strike testing would be performed had to emulate the laminate, core, adhesive, and protective mesh configurations common to nacelle panels subject to lightning strike. Figure 3 illustrates a standard cross-section for nacelle panels subject to lightning strike events.

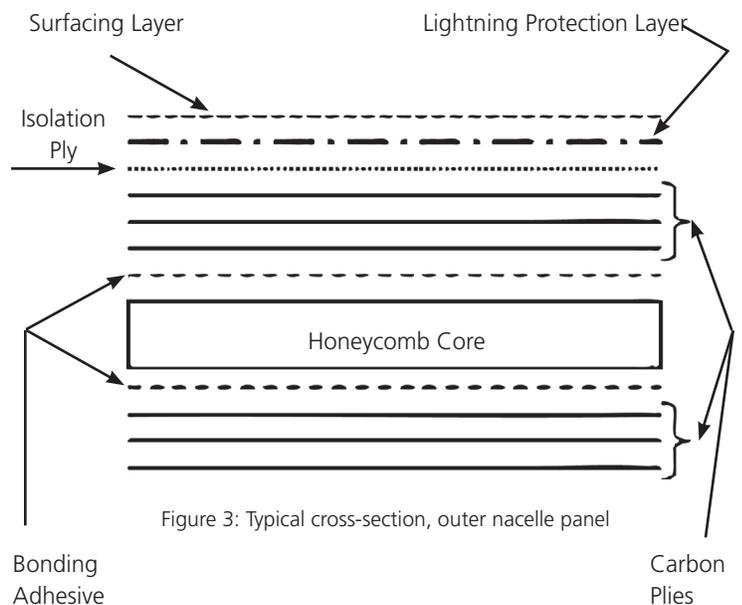


Figure 3: Typical cross-section, outer nacelle panel

1. TEST PANEL CONFIGURATIONS AND TEST MATRIX

2.1 Test Panel Configurations

All test panels were constructed identically, based upon a plan dimension of 60.96cm (24 inches by 24 inches) square. Lightning strike protective materials were the first configuration consideration for lightning strike damage comparative testing. The metal mesh products evaluated, included Dexmet copper and Dexmet aluminum mesh, and phos-bronze interwoven wire (IWWF) from another supplier. The metal mesh products of aluminum ([Dexmet Product code 4AL8-080F](#)) and copper ([Dexmet Product Code 2CU4-100A](#)) were both 78g/m² (0.016lb/ft²) density, which resulted in a thickness of approximately 0.10mm (0.004in). The phos-bronze interwoven wire product used a 0.10mm (0.004in) diameter

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wire that was interwoven with every tow of a carbon fabric, resulting in approximately ten tows (and wires) to every 25mm (1 inch). For the application to nacelle products constructed by Spirit AeroSystems, aluminum metal mesh products carried an isolation ply between the carbon skins, and the metal mesh.

Two isolation materials were explored; E-glass and S-2 glass, in fabric pre-preg forms, were combined with the various metal mesh protection candidates. Due to the variety of panels used on a commercial nacelle product, several families of honeycomb cores were employed in the lightning strike test coupons. Three distinct families of core are used on the Nacelle hardware:

- 1) Aramid paper core with phenolic resin
- 2) Fiberglass fabric core with phenolic resin
- 3) Phos-anodized aluminum core

The selected cores for evaluation were the:

- 3mm (1/8 inch) cell, 0.048mg/m³ (3.0 lb/ft³) Korex core
- 9mm (3/8 inch) cell, 0.072mg/m³ (4.5 lb/ft³) fiberglass core
- 9mm (3/8 inch) cell, 0.0672mg/m³ (4.2 lb/ft³) phos-anodized aluminum core

These core combinations represented all the core types that are consistently damaged by lightning strike on Spirit commercial nacelle products. Additionally, the correlation of small core cell size 3.16mm (1/8 inch), versus larger cell size 9.48mm (3/8 inch), could be explored relative to lightning strike damage resistance. Most of the outer structure of commercial nacelle hardware uses 25mm (1 inch) thick honeycomb core. Certain large airplane fan cowl panels use honeycomb core greater than 25mm (1 inch), but the largest number of outer nacelle panels can be represented by 25mm (1 inch) thick panels. As stated prior, it was theorized that damage might be larger for honeycomb core panels thinner than the baseline 25mm (1 inch) thickness. Four panels addressing this concern were represented using 12.5mm (0.5 inch) core to evaluate the effect of core thickness on lightning strike damage resistance.

2.1.1 Test Panel Configurations

To summarize, three types of honeycomb cores were tested, two core thicknesses were evaluated, three types of protective metal mesh applied to the different core configurations, two types of surfacing material, three types of isolation materials were included, and two splicing configurations rounded out the test coupon configurations. Several configurations having no protection were also tested to illustrate the effect of lightning strike damage when no mesh, or protection, is employed. Panels were named "Lightning Strike Panel" (LSP) and enumerated from 001 thru 027, with 29 total panels having been tested. [Figure 4 outlines the entire family of test panel configurations to be evaluated with Zone 1A and Zone 1B simulated lightning strike damage events.](#)

Panel Name	Core Type and Thickness	Metal Mesh with Sufacer	Isolation Ply Type	Text Category
LSP-001	1/8 cell, Aramid, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-002	1/8 cell, Aramid, 25mm thick	A1 - 905	E-glass, St 108	Zone 1A
LSP-003	1/8 cell, Aramid, 25mm thick	A1 - 905	Polyester	Zone 1A
LSP-004	1/8 cell, Aramid, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1B
LSP-005	1/8 cell, Aramid, 25mm thick	Al - 905	E-glass, St 108	Zone 1B
LSP-006	1/8 cell, Aramid, 25mm thick	Al - 1515	S-2 glass, 1581	Zone 1A
LSP-007A	1/8 cell, Aramid, 25mm thick	Al α 1515	S-2 glass, 1581	Zone 1A
LSP-007B	1/8 cell, Aramid, 25mm thick	Al - 1515	S-2 glass, 1581	Zone 1B
LSP-008	1/8 cell, Aramid, 25mm thick	Cu - 905	None	Zone 1A
LSP-009	1/8 cell, Aramid, 25mm thick	IWWF-905	None	Zone 1A
LSP-010	1/8 cell, Aramid, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1 A
LSP-011	3/8 cell, Fiberglass 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-012	3/8 cell, Fiberglass, 25mm thick	A1 - 905	E-glass, St 108	Zone 1A
LSP-013	3/8 cell, 5056 A1, 25mm thick	None	None	Zone 1A
LSP-014	3/8 cell, Fiberglass, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1B
LSP-015	3/8 cell, Fiberglass, 25mm thick	A1 - 905	E-glass, St 108	Zone 1B

Chart continued on next page 4

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Chart continued from page 3

Panel Name	Core Type and Thickness	Metal Mesh with Sufacer	Isolation Ply Type	Text Category
LSP-016A	3/8 cell, Fiberglass, 25mm thick	A1 - 1515	S-2 glass, 1581	Zone 1A
LSP-016B	3/8 cell, Fiberglass, 25mm thick	A1 - 1515	S-2 glass, 1581	Zone 1B
LSP-017	3/8 cell, Fiberglass, 25mm thick	A1 - 1515	S-2 glass, 1581	Zone 1B
LSP-018	3/8 cell, Fiberglass, 25mm thick	Cu - 905	None	Zone 1A
LSP-019	3/8 cell, Fiberglass, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-020	3/8 cell, 5056 Al, 25mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-021	3/8 cell, 5056 Al, 25mm thick	A1 - 905	E-glass, St 108	Zone 1A
LSP-022	1/8 cell, Aramid, 12.5mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-023	1/8 cell, Aramid, 12.5mm thick	A1 - 905	E-glass, St 108	Zone 1A
LSP-024	3/8 cell, Fiberglass, 12.5mm thick	A1 - 905	S-2 glass, 1581	Zone 1A
LSP-025	3/8 cell, Fiberglass, 12.5mm thick	A1 - 905	E-glass, St 108	Zone 1A
LSP-026	1/8 cell, Aramid, 25mm thick	None	None	Zone 1A
LSP-027	3/8 cell, Fiberglass, 25mm thick	None	None	Zone 1A

Figure 4: Lightning strike test panel configuration matrix

Results from the testing included visual examination of the exterior damage, and non-destructive inspection using primarily thru-transmission ultrasonic (TTU) methods.

3.1 Test Set-up and Panel Strike Location

1. TESTING RESULTS

Each of the 60.96cm (24 inch by 24 inch) square coupons was placed beneath an electrode, such that the Zone 1A or Zone 1B emulated strike would be at the center of the panel. Grounding straps held the panel in place at all four edges of each coupon. The coupons were also configured, during the construction, with a layer of aluminum tape closing out the edges of the panel, between 3cm and 5cm (1.5 to 2 inches) wide. This provision of aluminum tape was for better ground strap engagement. Figure 5 illustrates the test set-up.

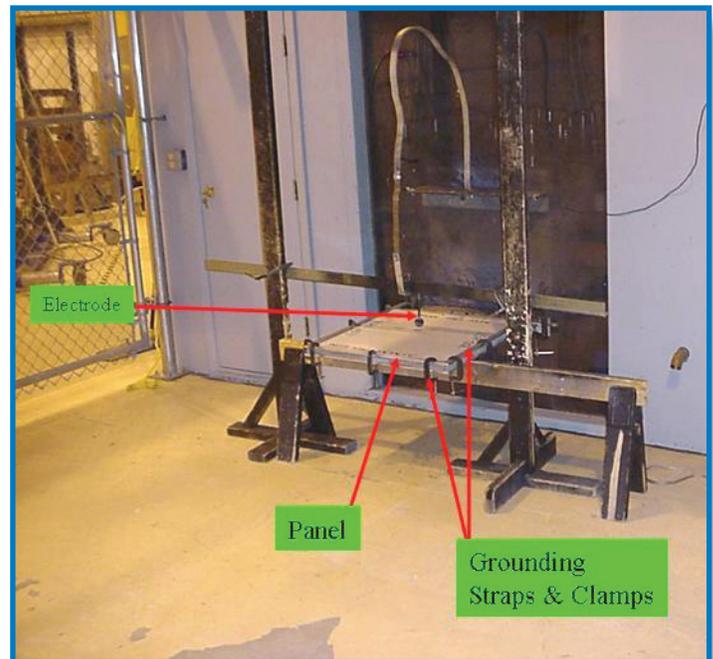


Figure 5: lightning strike test set-up with panels in place

3.2 Test Results

Each of the 60.96cm (24 inch by 24 inch) square coupons was struck in accordance with Figure 2. Results from the testing included visual examination of the exterior damage, and non-destructive inspection using primarily thru-transmission ultrasonic (TTU) methods. For the following sections comparing different parameters of panel configuration, both Zone 1A and Zone 1B effects are shown. Figure 6 illustrates a typical panel prior to testing.

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Figure 7 illustrates the exact same panel immediately after the emulated strike. Damage was to the outer layer of surfacing adhesive as it burned away during the event, the metal mesh was still in tact; however it was disbonded from the isolation ply. For LSP-001, the substrate carbon/epoxy plies, were still attached to the core, and in serviceable condition. No penetration of the panel was observed.

To further illustrate the effect of the lightning strike, Figure 8, provides a close-up view of LSP-001 after the emulated strike event. The aluminum mesh can be observed in the close-up view of LSP-001. Now compare, the unprotected panel LSP-026, and the subsequent damage in Figure 9. The strike event penetrated through LSP-026 panel, damaging the core by burning and puncturing both facings of a 25mm (1 inch) thick panel. The difference in damage resistance between a protected and unprotected panel is dramatic.



Figure 6: LSP-001 prior to lightning strike test

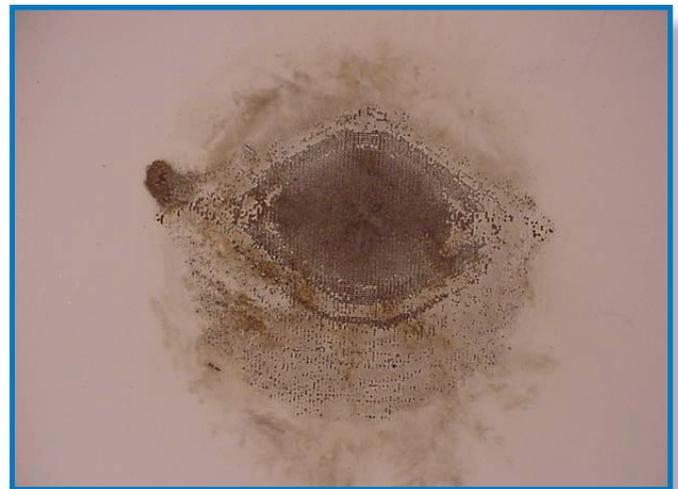


Figure 8: LSP-001 close-up view



Figure 7: LSP-001 immediately after lightning strike test



Figure 9: LSP-026 close-up view, identical to LSP-001 except no protection

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3.2.1 Comparative test results metal mesh performance

A group of panels from the test matrix were constructed to evaluate how different protective metal mesh products perform relative to each other when comparing equivalent weights and thicknesses of Dexmet expanded copper, Dexmet expanded aluminum, and phos-bronze interwoven wire. Figure 10 compares aluminum mesh and copper mesh on identical core reinforced panels.



Figure 10: LSP-001 with aluminum mesh compared to LSP-008 with copper mesh

The damage periphery with the copper mesh on LSP-008 is larger, measuring between 17-18cm (8 to 9 inches) in diameter. The aluminum mesh "diamond" shaped burn area from this Zone 1A emulated strike is 7-8cm (3 to 3.5 inches) at the widest points.

Figure 11 compares the Dexmet aluminum mesh and phos-bronze interwoven wire on identical core reinforced panels.

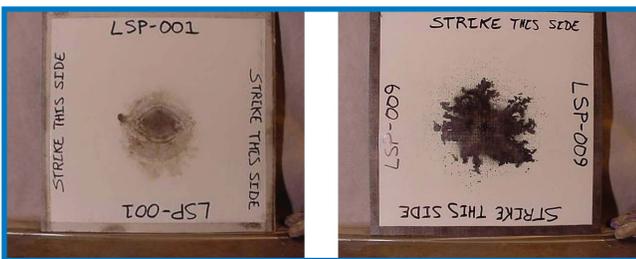


Figure 11: LSP-001 with aluminum mesh compared to LSP-009 phos-bronze IWWF

The damage periphery with the phos-bronze IWWF on LSP-009 is obviously larger, measuring between 14-15cm (5 to 6 inches) in an approximate diameter. The Dexmet aluminum mesh "diamond" shaped burn area from this Zone 1A emulated strike is 7-8cm (3 to 3.5 inches) at the widest points. The phos-bronze panel had less damage to the surface area than the copper mesh panel, however, the phos-bronze panel (LSP-009) exhibited a multitude of ruptures of the interwoven wire throughout the surface area of the panel. The phenomenon of interwoven wire rupturing in a multitude of locations during a Zone 1A lightning strike event, may influence the decision of how much total surface area damage requires repair.

3.2.4 Comparative test results zone 1A and Zone 1B damage

The lightning strike testing characterized both Zone 1A and Zone 1B testing and the effect it would have on the individual panels. The primary concern for honeycomb panels in this application was Zone 1A damage tolerance, however, Zone 1B was characterized to show the difference in the response of the panels tested. The primary difference between Zone 1A and Zone 1B is the charge transfer of the "C component" and the existence in Zone 1B of a "D component". Reference Figure 2 for further detail. Two sets of panels were duplicated to perform identical Zone 1A and Zone 1B testing for comparative analysis. LSP-007A and LSP-007B for 3mm cell core and LSP-016A and LSP-016B for 9mm cell core were subjected to Zone 1A and Zone 1B testing. Figure 20 shows the side-by-side differences between realized damage from a Zone 1A event and Zone 1B event on a 25mm thick honeycomb panel with aluminum mesh protection. The Zone 1A damage is on the left, the Zone 1B damage is on the right.

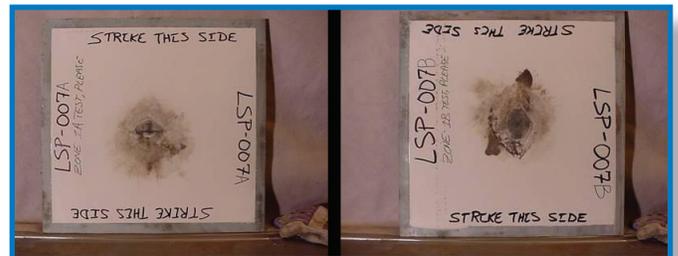


Figure 20: LSP-007A (Zone 1A) and LSP-007B (Zone1B)

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The Zone 1B damage periphery is greater than the Zone 1A damage periphery. This was an expected result due to the higher energy transferred and longer duration of the charge transfer for a Zone 1B event. Although the damage area was increased, (11-12cm for Zone 1B versus 79cm for Zone 1A) the damage depth was almost equivalent with some damage to the fiberglass isolation ply, though no disbonding from the substrate carbon plies was observed. The substrate carbon plies and core-to-adhesive bond was maintained and undamaged. Figure 21 shows Zone 1A and Zone 1B damage for 9mm cell core.

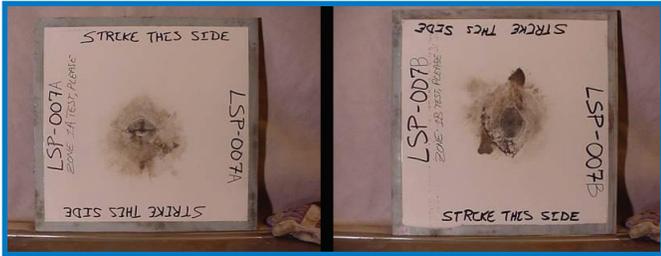


Figure 21: LSP-016A (Zone 1A) and LSP-016B (Zone 1B)

3.2.5 Comparative Test Results Different Isolation Ply

When using metal mesh protective schemes, certain manufacturers will employ an isolation ply of fiberglass. The purpose of this ply is to ensure that certain metal mesh products will not come into contact with the carbon substrate plies and consequently begin to corrode. Two types of isolation ply were explored by the testing. The evaluation and result of the isolation ply effect was characterized by LSP-002 and LSP-003 compared to LSP-001 for Zone 1A, and LSP-005 compared to LSP-004 for Zone 1B. In general, the E-glass style 108 product performed identically to the S-2 glass style 1581 product for isolation ply effect on lightning strike damage resistance in terms of reacting to the electrical charge. There was some difference in terms of overall panel response due to the fact that the 1581 S-2 glass provided an overall thicker facing surface which added a modicum of bending stiffness and puncture resistance, when compared to the much thinner E-glass style 108 isolation ply.

3.2 Non-Destructive Inspection Results

Each of the panels was evaluated for damage periphery and depth. One of the analysis tools available, for characterizing non-destructively the level of damage on a given panel, is the use of thru-transmission ultrasonic inspection to reveal unseen damage. All panels were later destructively characterized to ensure that the depth of damage was consistent with the NDI findings. Although TTU can not yet be readily used in evaluating a fleet lightning strike event, TTU characterizations can be correlated to bond-master detection, and other NDI techniques that are more portable. Therefore, it is important to understand the NDI “signature” of a lightning strike damage event on a variety of protected and un-protected panels.

3.2.1 Comparative NDI Scans of Damaged Panels

The purpose of performing NDI on each of the lightning strike test panels is to validate the damage periphery and depth of penetration of the lightning strike emulated event. Additionally, an understanding of the NDI “signature” can be developed for a known set of configurations, when struck by a simulated lightning strike event. Figure 23 shows LSP-001 on the left and the NDI scan of LSP-001 on the right. This panel was a 3 mm cell core, with aluminum mesh, and S-2 isolation ply for galvanic protection.



Figure 23: NDI via TTU of LSP-001 (NDI to the right)

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When evaluating Figure 23, a noticeable characteristic begins to evolve for this panel since the NDI pattern of damage is actually smaller than the visually obvious area of burned away surfacing film. Follow on destructive investigation confirmed that damage was limited to just the surfacing film and the aluminum mesh protection. Figure 24 illustrates an NDI signature for an unprotected panel represented by LSP-026.



Figure 24: NDI via TTU of LSP-026 (NDI to the right)

The LSP-026 was identical to LSP-001, except with no metal mesh protection. The damage on the LSP-026 punctured panel is slightly larger than what is obvious from visual inspection. This panel was damaged all the way through both facings and core. Additionally, from the NDI scan, the damage extended another 2-3cm around the visual damage periphery. Figure 25 illustrates an NDI signature for a Dexmet metal mesh protected panel, using 9mm cell core, represented by LSP-011.

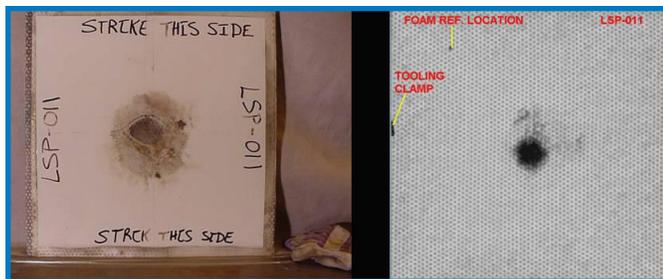


Figure 25: NDI via TTU of LSP-011 (NDI to the right)

The NDI scan on the right, of LSP-011 reveals slightly less perimeter damage than the visual burning evident on the panel. Damage penetration was limited to surfacing material burned away, and the metal mesh being delaminated. The isolation ply material and substrate carbon plies remained undamaged. Figure 26 shows an NDI scan of an unprotected panel identical to LSP-011, except no metal mesh exists on LSP-027.



Figure 26: NDI via TTU of LSP-027 (NDI to the right)

NDI scan for LSP-027 is a little larger than the visually observed damage. LSP-027 suffered through penetration damage of both facings due to the lightning strike event. The NDI signature for this panel confirms this damage with very high attenuation.

Figure 27 shows the NDI scan of an aluminum metal mesh protected, aluminum honeycomb core panel subjected to lightning strike Zone 1A testing.

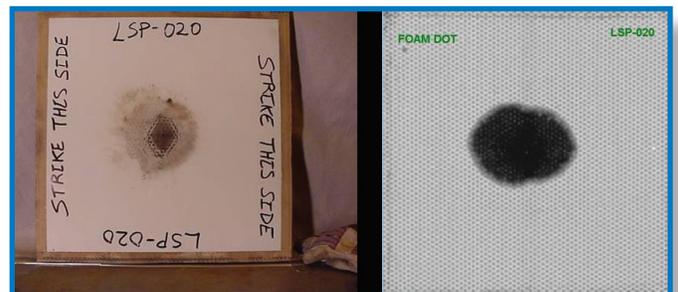


Figure 27: NDI via TTU of LSP-011 (NDI to the right)

In this instance, the NDI scan reveals larger damage than the visual damage periphery on the left. This effect is different than the trend for non-metallic core reinforced panels such as LSP-001 and LSP-011. This larger damage area is attributed to the nature of how an aluminum core panel will react to a lightning strike event, even when protected. Additionally, all plies were delaminated away from the core, which is also

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different than prior non-metallic panel damage resistance to a Zone 1A lightning strike event. In stark contrast, Figure 28 shows the NDI scan for an un-protected, aluminum core panel.

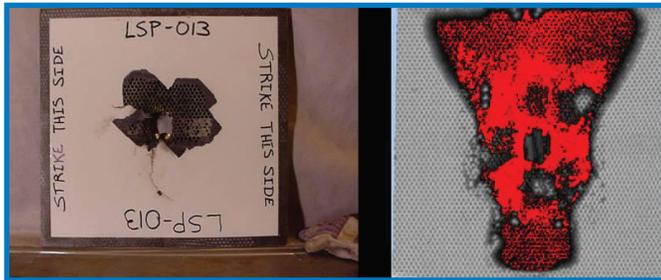


Figure 28: NDI via TTU of LSP-013 (NDI to the right)

The NDI scan for LSP-013 reveals that the damage is far worse than the visual observation. From the NDI scan for LSP-013, it can be seen that the panel is ruptured across the entire width, and completely unable to withstand any type of loading. Both facings were delaminated and broken in the area of high attenuation highlighted by the NDI scan.

Figure 29 shows the NDI scan of a 3mm cell core panel, 25mm thick, using aramid fiber core, and protected with Dexmet copper mesh.



Figure 29: NDI via TTU of LSP-008 (NDI to the right)

The NDI scan for LSP-008 is consistent with the damage exhibited from prior non-metallic core panels. The substrate carbon plies remain attached to the core, and only the copper mesh was delaminated away from the substrate at locations indicated by the attenuation (darker areas). The area of damage is larger for the copper mesh than for the aluminum mesh of prior panels. Both the copper mesh and aluminum mesh in this test were the same area weight.

Figure 30 shows the comparative NDI scan for LSP-009, which is an aramid fiber core, 3mm cell, 25mm thick panel using phos-bronze interwoven wire as protection.

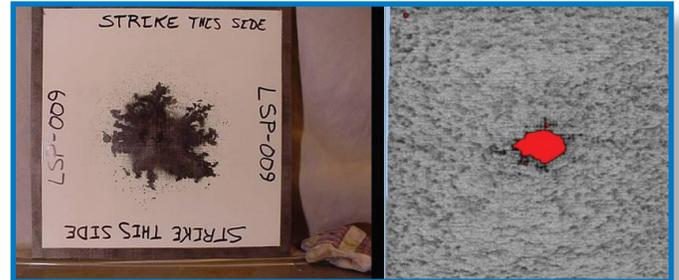


Figure 30: NDI via TTU of LSP-008 (NDI to the right)

The NDI scan reveals an area of disbond smaller than the visually obvious burned area on the left. Additionally, the scan reveals that with the phos-bronze IWWF, a greater depth of penetration occurred for substrate plies, though not completely delaminating from the substrate core. In contrast, where Dexmet copper mesh and Dexmet aluminum mesh protected all the substrate plies, the phos-bronze IWWF allowed a level of penetration into substrate plies that was not evident on the other configurations. Figure 31 shows an NDI scan of 3mm cell aramid core, 12.5mm thick, with aluminum metal mesh protection. This panel was tested to reveal any differences in lightning strike damage resistance on a panel thinner than 25mm.

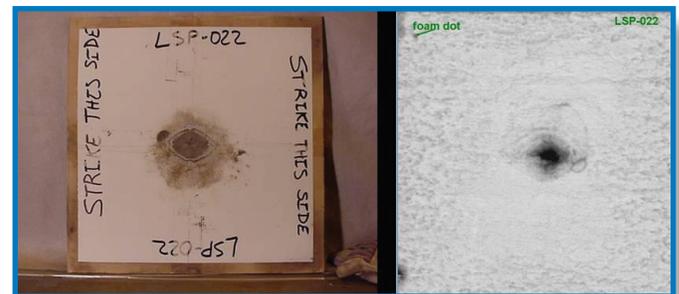


Figure 31: NDI via TTU of LSP-022 (NDI to the right)

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The NDI scan revealed that the damage area was smaller than what visually burned away of the surfacing film. It was also noted, that the NDI scan for LSP-022 had more attenuation (darker areas) than the NDI scan for LSP-001, which is identical to LSP-022, except 25mm thick instead of 12.5mm thick. The reason for this could be that a 25mm panel has more bending stiffness than the 12.5mm panel. The lightning strike event produces a pressure wave that stresses the core and facings while the electrical discharge is occurring. The combination of these events apparently has the ability to produce a deeper penetration into the substrate plies for a thinner 12.5mm panel. But, the penetration is only one additional carbon ply in depth. Results of panel thickness testing were the same for 3mm cell core and 9mm cell core.

3.2.2 Comparative NDI Scans of Zone 1A and Zone 1B Damage

A final consideration was to observe the NDI results of panels struck to Zone 1A and Zone 1B criteria. Figure 3.2.2-1 shows the comparative NDI scans of panels LSP-007A and LSP-007B side by side.

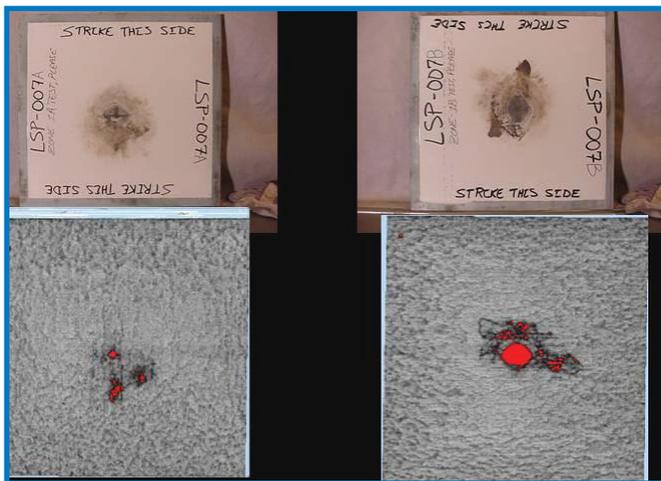


Figure 33: NDI via TTU of LSP-007A (Zone 1A) and LSP-007B (Zone 1B)

The comparative NDI scans of the Zone 1A and Zone 1B damage show that the damage periphery is greater for Zone 1B, than for Zone 1A. It was also found that depth penetration into the fiberglass isolation ply was evident in places on the Zone 1B panel. The NDI confirmed the damage depth determine by the destructive testing. The "grey scale" on the NDI image was adjusted to further illustrate this finding.

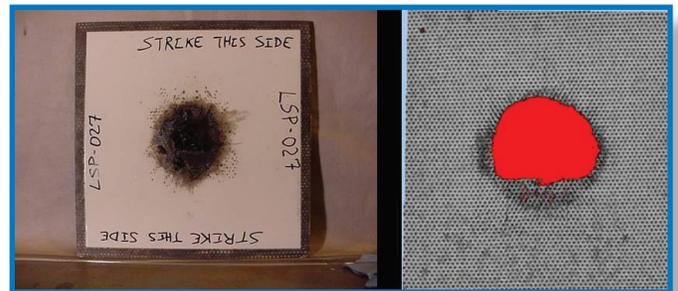


Figure 34 shows the comparative NDI scans of panels LSP-016A and LSP-016B side by side. These panels are identical to LSP-007 panels except they use 9mm cell fiberglass core.

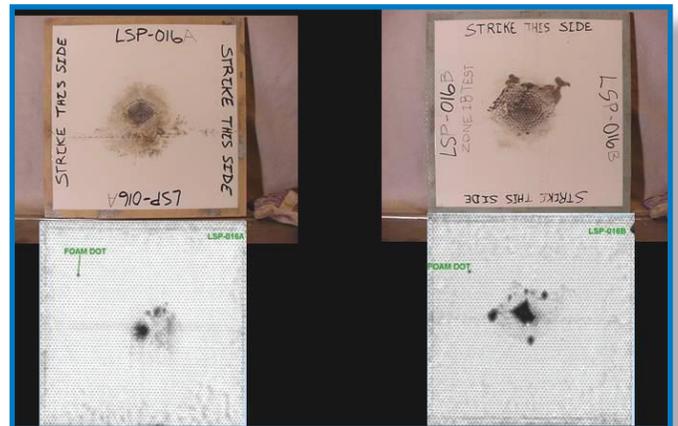


Figure 34: NDI via TTU of LSP-016A (Zone 1A) and LSP-016B (Zone 1B)

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CONCLUSIONS

Two immediate conclusions about the data reviewed for lightning strike damage resistance on thin facing honeycomb panels is:

1) Any honeycomb panel subject to Zone 1A or Zone 1B lightning strike damage needs to be protected with a form of lightning strike protection so as to avoid significant damage to the load carrying facings. Statistical probability and historical environment cannot always predict where a composite panel might be struck by lightning. If the potential exists at all, to be subject to a lightning strike, it is better to supply protection than to have to repair large scale damage that affects service or dispatch.

2) All Dexmet metal mesh products in this study work to reduce the damage caused by a lightning strike event. The large matrix of 29 coupons and repetitive combinations of core type, mesh product type, manufacturing splice evaluation, and isolation ply type, subjected to Zone 1A and Zone 1B lightning strike criteria allow for the ability to plunge into some details of configuration of test panels and make conclusions about the effects witnessed by the test data.

Regarding Core Type

The lightning strike coupons revealed that there was little or no difference in the damage periphery or damage depth of a Zone 1A or Zone 1B strike event dependent on core cell size. However, lightning strike damage was profoundly different for an aluminum core product that is sandwiched with carbon-epoxy facings. An unprotected panel of this nature can fail catastrophically as exhibited by LSP-013. It should also be noted that when this same type of panel, with aluminum core and metal mesh protection, is subjected to a lightning strike event, it performs to a similar damage periphery as any other protected panel.

The damage depth of an aluminum core panel with metal mesh protection is greater, and it should be expected to always de-laminate any substrate material away from the core on the strike side. Core thickness did have an effect, although very subtle, to the damage resistance of a protected panel. This difference was small, being no more than one carbon ply in depth difference and the isolation ply (when used) de-lamination.

Regarding Metal Mesh Products

As stated prior, all Dexmet metal mesh products work to increase the damage resistance of a honeycomb panel subject to lightning strike events. The details captured in comparative testing, of different metal mesh products, is an attempt to understand maximum area damage and the depth of penetration of the lightning strike event. This area-depth relationship then allows a product owner to make decisions about which metal mesh product best fits the application. All metal mesh products in this testing were "treated" by a chemical stabilization process of one type or another. The aluminum mesh was phos-anodized, the bronze interwoven wire was phos-anodized, and the copper mesh was treated with a coating as well. As shown in this testing, the smallest damage area and least penetration depth was achieved by the aluminum mesh product at an area weight of 78g/m² (0.016 lb/ft²). Both the copper mesh and phos-bronze interwoven wire produced damage areas 2 to 3 times larger than the aluminum mesh at the same area weight (for copper).

The copper mesh performed a little better in resisting damage depth penetration than the phos-bronze interwoven wire, which appeared to be the hardest to repair after a strike event. So, the determination of which mesh performed best would depend on the product and its susceptibility to lightning strike damage balanced in combination with cost, weight, and repair capacity. Many factors can also influence this damage resistance assessment such as the combinations of isolation ply configuration (the copper mesh and phos-bronze IWWF had no isolation ply), total ply count of facings, type and weight of adhesive used to bond to core, supported and unsupported adhesive application, for example.

Regarding Isolation Ply

The testing showed no difference between E-glass in a 108 style thickness, and S-2 glass in a 1581 thickness, when considering electrical discharge dampening. The area damaged by Zone 1A and Zone 1B were identical and redundant with the non-metallic lightning strike panel examples shown. The authors noted that S-2 glass may add a modicum of damage resistance due to the added thickness and dielectric properties of that material. Additional reasons exist for choosing S-2 glass instead of E-glass to address metal mesh long term durability

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and galvanic protection. However, the testing reveals that a very thin isolation ply handles the lightning strike event well. Therefore, a thinner version of S-2 glass would address all galvanic or environmental concerns for a metal mesh product applied to protect against lightning strike damage.

Regarding Manufacturing Splice

The reason for testing the response of a butt-splice joint results from experiences gained on larger scale nacelle hardware and production experiences relative to large rate capability and manufacturing velocity. The final form of a metal mesh product rolled together with a surfacing film greatly enhances the application of metal mesh to a composite or metallic tool. The combination of surfacing film/metal mesh provides greater contour conformity and greater adhesion to the tool as compared to the metal mesh by itself. In order to further enhance the manufacturing velocity using this final form product, it became obvious that butt splicing reduces the challenge of the lay-up process for lightning strike protection materials.

The testing showed that a butt splice application produced no ill effect, even at maximum gap, to the damage resistance of a metal mesh protected panel. Additionally, as stated before, butt-splicing the metal mesh produced the least amount of damage on the coupons to which this splice was applied. Only the aluminum metal mesh product was tested in this fashion. Understanding the shape of the expanded aluminum mesh may give some insight as to why the butt-spliced panels performed well.

When the aluminum mesh is slit and then expanded, the resultant shape is a "diamond" geometry. The "peaks" of those diamonds are approximately 1.5mm (0.06 inch) apart, or the same dimension as the butt splice. This is one reasonable explanation as to why the lightning strike charge did not "see" the butt-splice joint as discontinuous, because, for all practical purposes, it was continuous. At the very least, a butt-splice joint on these lightning strike materials presents no detriment to the structure.



For more than 60 years Dexmet Corporation has been providing its customers with expanded foils and polymers of exceptional quality. Our experience, just-in-time manufacturing capability, and superior customer service is why our customers keep coming back.

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