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Technical Paper

Controlling cure cycle during honeycomb core splicing for increased expansion and reduced rework

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Abstract

While honeycomb core composites are used across aircraft interior applications for their low weight and high stiffness, efficient and consistent core splicing remains a major design challenge. This paper explores how honeycomb core splicing and finishing can be enhanced by controlling variables of the cure cycle. Tests demonstrating the effects of various curing ramps on splice film expansion are presented, and the curing ramp and film thickness needed for best results are discussed. With the correct splice film and cure cycle, optimal splicing performance can be achieved without major gains in film area mass or final part weight. This opens the door to consistent, repeatable manufacture with reduced rework costs, enhanced efficiency and expanded design flexibility.

Introduction

First patented for aircraft use in 1915, honeycomb core composites have seen widespread use across interior, structural, engine and other aircraft applications [1]. Comprising a thin outer skin layer encasing a low density honeycomb core, they leverage the high strength-to-weight ratios of honeycomb structures to enable stiff, lightweight aircraft parts capable of withstanding high force loads [2]. As the aerospace industry strives to enhance efficiency and achieve net zero carbon emissions by 2050, honeycomb core composites will be invaluable towards lightweighting aircraft designs and contributing towards emission reduction goals [3].

Honeycomb core composites are built on a foundation of consistent, repeatable and cost-effective core splicing. This is the process of bonding pieces of core using a film or liquid adhesive; related processes include core reinforcement, edge splicing and edge filling. Due to the three-dimensional shapes and intricate curvatures of many aircraft composite parts — radomes, ceiling panels, overhead storage bin doors and more — core splicing can become quite complex, requiring labor-intensive rework whenever honeycombs at the splicing area are not fully filled. Adhesives with insufficient expansion or excessive vertical slump are common causes of rework.

Minimizing rework and enhancing core splicing efficiency is essential towards cost efficient manufacturing of lightweight, high strength composite parts that make modern aircraft design possible. This paper investigates how performance across core splicing adhesive films can be enhanced by controlling curing ramp, maximum temperature and other variables of the cure cycle. It is shown that, with the correct cure cycle, 3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST provides an exceptional 230% expansion ratio and enables optimal honeycomb core splicing performance.

Maximizing splice film expansion by controlling curing ramp

To assess how film expansion ratio is impacted by various cure cycles, tests were conducted at the 3M Customer Technical Center in Cergy, Val-d'Oise, France. Two core splice films from 3M were tested:

- 3M™ Scotch-Weld™ Structural Core Splice Film AF 3024 (legacy product and historical baseline)
- 3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST (new product)

Samples of each film were cut into 10×10 cm squares and cured in an oven with no vacuum. Samples were cured at free expansion; no honeycomb material was used. Curing time was 60 minutes. Curing ramp ranged from 1 °C/min to 3 °C/min. Maximum temperature ranged from 125 °C to 145 °C.

After curing, expansion ratio and vertical slump for each sample were measured. Following NF EN 2667-3:2019, expansion ratio was defined as the increase in thickness after curing, expressed as a percentage of the uncured thickness [4]. Following DIN EN 2667-4:1997, vertical slump was defined as the difference between bottom thickness and top thickness of the cured sample [5].

3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST

This is a low density, heat curing, thermally expanding epoxy adhesive film with excellent mechanical performance and FST (Fire, Smoke and Toxicity) properties.

Figure 1: 3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST.

Depending on the cure cycle, it can more than triple its volume during cure. At free expansion, densities as low as 0.4 g/cm3 are possible. With a curing range of 120–180 °C (248–356 °F), it is cocurable with structural adhesive films and prepregs.

It provides good tack, excellent shop handling and a long shop life of up to 30 days storage at room temperature outside the protective bag.

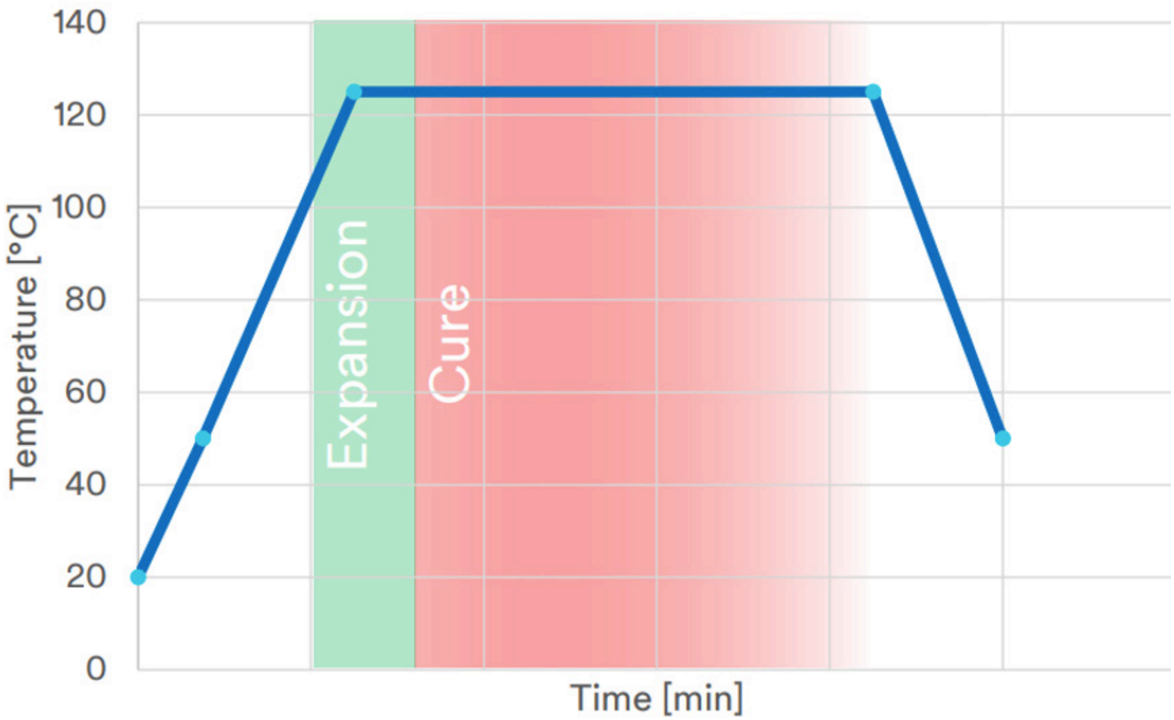

Figure 2: A cure cycle with curing ramp of 3 °C/min and maximum temperature of 125 °C.

Five cycles were conducted. Expansion ratio results are shown in Table 1. Vertical slump results are shown in Table 2.

Cure cycle	Curing ramp (°C/min)	Temperature (°C)	3M AF 3024 (%)	3M AF 3074 FST (%)
Cycle 1	3	125	128.01	229.88
Cycle 2	3	145	139.7	227.2
Cycle 3	2	135	131.8	165.4
Cycle 4	1	145	127.09	126.18
Cycle 5	1	125	113.8	118.8

Table 1: Expansion ratio after cure.

Cure cycle	Curing ramp (°C/min)	Temperature (°C)	3M AF 3024 (cm)	3M AF 3074 FST (cm)
Cycle 1	3	125	0.110	0.482
Cycle 2	3	145	0.249	0.556
Cycle 3	2	135	0.181	0.252
Cycle 4	1	145	0.116	0.263
Cycle 5	1	125	0.170	0.166

Table 2: Vertical slump after cure.

These results show that cure cycle — curing ramp in particular — significantly impacts both expansion ratio and vertical slump. Cycle 1 with 3M AF 3074 FST produced best results: an extremely high expansion ratio of nearly 230% (more than tripling the uncured volume) and a vertical slump of 0.48 cm, which is acceptable for most vertical applications of the film. Depending on application requirements, different cure cycles (cycle 3, for instance) can be implemented to reduce slump while maintaining high expansion.

Optimizing core splicing while managing area mass and weight

To illustrate the enhanced core splicing capabilities of 3M AF 3074 FST compared with the legacy product, further tests were conducted in which film samples of differing thicknesses were applied to aramid honeycombs (Figure 3). Sample thicknesses ranged from 60 mil to 100 mil (1.5–2.5 mm). The 60 mil samples were created by stacking two 30 mil samples; the 80 mil samples were created by stacking one 30 mil and one 50 mil sample.

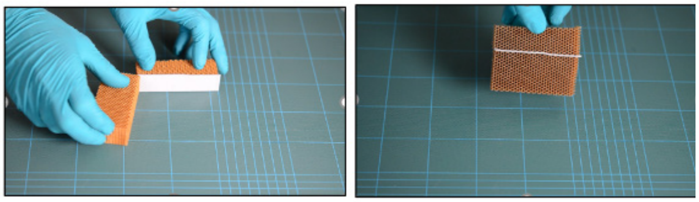

Figure 3: Samples of 3M AF 3074 FST (sheet cut into stripes or die cut) were manually applied to pieces of aramid honeycomb core.

Samples were cured in autoclave for 90 minutes, with curing ramp ranging from 0.5 °C/min to 3 °C/min. Maximum temperature was 135 °C for all samples. Results are shown in Figure 4.

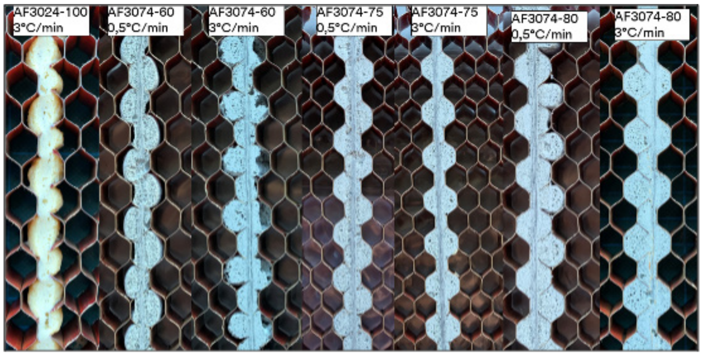

Figure 4: Core splicing test results.

Optimal core splicing was achieved with 3M AF 3074 FST at 75 mil thickness and a curing ramp of 3 °C/min. Honeycombs at the splicing area were filled with no visible gaps (Figure 4, middle right). Thus, with the correct thickness and cure cycle, 3M AF 3074 FST enabled robust and consistent core splicing performance compared with the legacy product 3M AF 3024 (Figure 4, far left).

Furthermore, 3M AF 3074 FST can be implemented without significant gains in film area mass. While it is true that 3M AF 3074 FST averages 30–40% greater area mass than 3M AF 3024 of the same thickness, its high expansion ratio enables the usage of far lower thicknesses. As seen in Figure 4, the performance of 3M AF 3074 FST at 75 mil (2503 g/m2) far surpassed that of 3M AF 3024 at 100 mil (2300 g/m2). Core splicing can thus be optimized while film area mass and final part weight can be effectively managed.

Thickness (mil)	3M AF 3074 FST (g/m2)	3M AF 3024 (g/m2)
25	-	610
30	950	-
50	1600	1220
60 (theoretical)	1900	-
75	2503	-
80 (theoretical)	2640	-
100	3300	2300

Table 3: Area mass by thickness for 3M AF 3074 and 3M AF 3024.

Conclusion

By controlling curing ramp and maximum temperature, composite part manufacturers can minimize rework and optimize core splicing operations without major gains in film area mass or final part weight.

Though 3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST exhibits a higher area mass than the legacy product of the same thickness, its high expansion ratio of up to 230% enables exceptional results with far lower thicknesses. With a curing ramp of 3 °C/min and maximum temperature of 135 °C, optimal core splicing can be achieved at 75 mil thickness and an area mass of 2503 g/m2. With proper expansion control, a wide range of honeycombs from 3.2 mm to 9.6 mm in diameter can be spliced. If area mass is a concern, lower thicknesses can be used and curing can be adjusted to maximize expansion.

In this way, consistent, repeatable manufacture of lightweight honeycomb core composite parts can be achieved while opening the door to major process improvements and cost savings, greater versatility during the core splicing process, and expanded design flexibility. 3M AF 3074 FST is a fully developed and globally available product that can be used in both structural and interior applications. It is easily implemented with standard shop tools and curing processes. 3M is committed to working closely with our aerospace industry customers to help determine the appropriate cure cycle and ensure successful implementation.

Standards and qualifications

3M™ Scotch-Weld™ Core Splice Adhesive Film AF 3074 FST is being evaluated for qualification to major aircraft OEM specifications. It is flame retardant and has met the following requirements:

- 14 CFR /CS §25.853 (a), Appendix F, Part I (a) (1) (ii), 12-second Vertical burn*
- 14 CFR /§CS 25.853 (d), Appendix F, Part V
- Airbus ABD0031, Section 7.4 (Reference AITM 3-0005)

** Tested in accordance with 14 CFR 25.853 (a), Appendix F, Part I (a) (1) (ii), 12-second vertical burn per FAA Policy Statement PS-ANM-25.853-01-R2, Reference 23, Option 1 (in a stand-alone mode, cured test plaque of nominal size: 0.25" x 3" x 12"). Installation approval is the responsibility of the design approval holder or the aircraft owner/operator.*

For more information, please see the product detail page [6] and technical data sheet [7].

Authorization to use

Ensure products meet all applicable specifications, standards, and maintenance manual requirements for the platform being worked on and validate all aircraft approvals against current technical documentation.

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