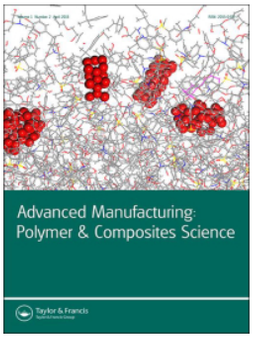

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In-situ analysis of cocured scarf patch repairs

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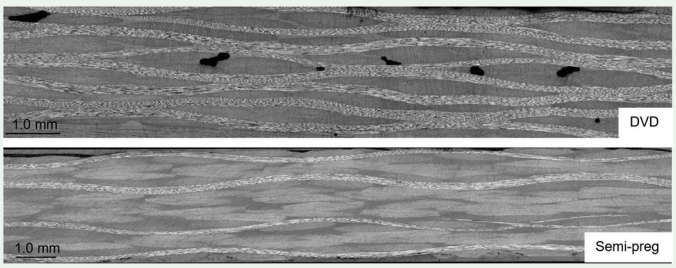
ABSTRACT

To address the need for high-quality in-field repair of composite structures, a vacuum-bag-only (VBO) prepreg was designed, produced, and evaluated. The prepreg featured semi-preg formatting and a room-temperature-stable resin. The format provided a multitude of pathways with much shorter breathe-out distances relative to conventional, edge-breathing VBO prepregs, and thus enhanced through-thickness air permeability. A custom-built scarfed repair tool with an *in-situ* observation window was designed and employed to analyze the cure process during a repair. Microstructural quality, interlaminar shear strength, and glass transition temperature of semi-preg panels were compared to wet-laid epoxy panels processed with double vacuum debulking (DVD). The semi-preg formatting effectively reduced porosity for in-field scarf panels, and when used with the new material system, presents a viable alternative to DVD and wet layup.

KEYWORDS

Prepreg composites; out-of-autoclave prepregs; in-situ analysis; semi-preg formatting; composite repair

GRAPHICAL ABSTRACT



1. Introduction

The objective of the present work was to employ in-situ analysis to assess the effect of semi-preg formatting on air evacuation and porosity for in-field scarf patch repair conditions. A custom-built tool featuring a transparent window was designed and deployed to provide new insights into the curing process of a scarfed patch. Semi-preg featuring a discontinuous pattern of room-temperature-stable resin on a woven fiber bed was produced and used to simulate in-field repairs. Panels fabricated using vacuum-bag-only (VBO) processing of the semi-pregs were evaluated for quality and performance compared to wet laid panels processed by double vacuum debulking (DVD). The visual observation of DVD processing has never been done before, providing novel insights into processing.

Carbon fiber composites exhibit high specific strength, stiffness, and resistance to fatigue and environmental degradation by moisture and solvents [1–3]. However, damage to composite structures can occur at different length scales, ranging from fine cracks in the matrix to ply delaminations to broad structural damage [4,5]. Historically, damaged parts have been completely replaced to reduce risk to performance [6]. Complex structures render this practice impractical, especially in aerospace applications. Therefore, procedures for on-aircraft repair are sometimes required to complement part removal and reinstallation depending on where damage is located [7].

Composite repairs follow a multi-step process that begins with assessment and inspection. After inspection, typically by ultrasonic scanning, the damaged area is then removed and prepared for adhesive bonding to a patch, usually through abrasive grinding [8]. Adhesive bonding allows restoration of full strength, when performed correctly [9]. For bonding, a scarf joint is most widely practiced, and is preferable to a lap or stepped bondline because of greater strength [10,11]. However, poor surface preparation, inappropriate material selection,

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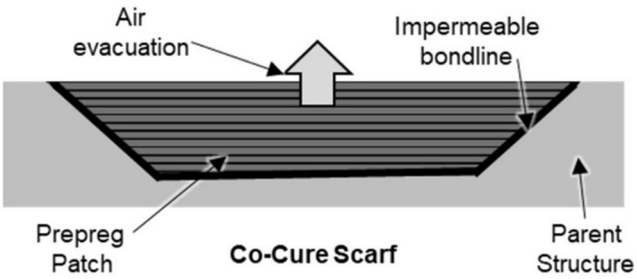


Figure 1. Schematic of direction of gas evacuation for semi-preg material.

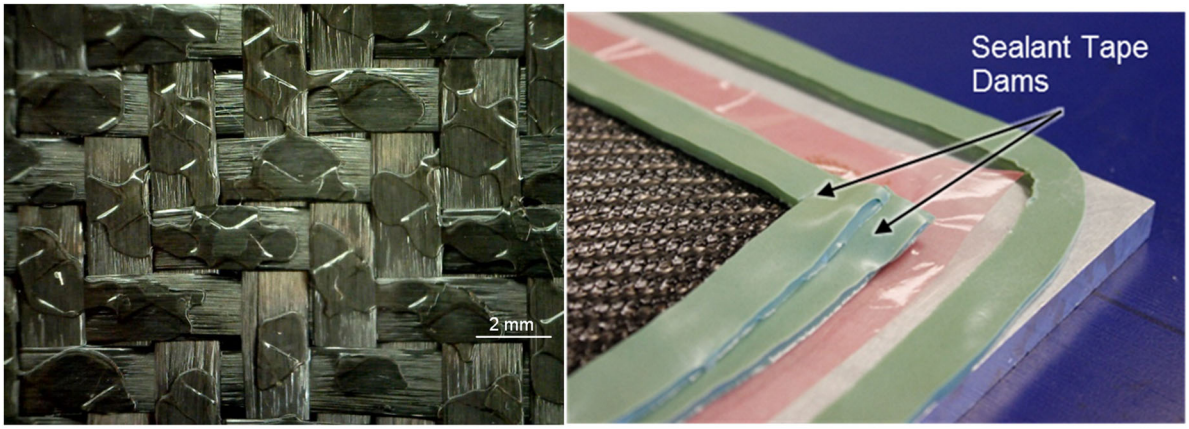
and improper execution of a repair will result in a patch with less strength than the parent material [12]. Properties such as Tg can be affected even when the same resin is used in the patch. Experiments and modeling have guided efforts to optimize scarf repairs, including scarf angle and procedures to maximize adhesion to the parent surface [13]. Scarf angles rangins from 3° to 7° have been shown to retain maximum strength, with the lower scarf angle having the highest strength retention [14,15]. To date, there has not been systematic effort to tailor the material systems for the conditions under which repairs are typically performed. This is compounded with inability to reliably measure joint quality, resulting in inability for repaired laminates to become certified.

During VBO cure of prepregs, voids can form within fiber tows (microvoids) or between tows (macrovoids) as a result of improper processing or environmental conditions [16,17]. Mitigating voids in composite parts, both in the bulk and on surfaces, has been studied for OOA prepregs [16,17]. Partially impregnated prepregs produced specifically for OOA processing demonstrate lower porosity compared to fully saturated prepregs [18]. The mechanism responsible for the lower porosity stems from engineered vacuum channels (EVaCs) that promote in-plane air evacuation [19]. The EVaCs, which are dry regions of fiber tows, become impregnated during the cure cycle, driven by pressure differences instrinsic to vacuum bagging [20]. Various resin distributions are featured in commercial OOA prepregs, yet all rely on similar EVaCs for gas removal and consolidating plies [21]. Consequently, they all rely on edge breathing to achieve gas egress to the vacuum outlet. However, edge breathing is impaired and EVaCs can be occluded when complex contours or embedded plies are present.

Repairs typically do not allow edge breathing due to the impermeable bondline at the scarf (Figure 1). The absence of edge breathing normally precludes the use of OoA prepregs in repairs, since conventional OoA prepregs require edge breathing for gas egress. Alternative measures include breathable adhesives, resin infusion, and other methods to simulate edge breathing in repair environments [22,23]. One method commonly employed for repairs is double vacuum debulking (DVD) [24]. During DVD, a rigid closed structure is placed around the vacuum-bagged laminate. A separate vacuum is applied to the enclosing structure, allowing for gas removal during debulk without laminate consolidation (atmospheric pressure can hinder air evacuation). The DVD approach reduces porosity in laminates compared to equivalent single-vacuum-bagged samples [25,26]. DVD is effective, but is generally difficult to implement, particularly on curved surfaces, and does not guarantee void-free parts [27].

The challenges associated with OOA processing are magnified when repairs are performed in the field, because the resources and infrastructure available in production or repair facility environments are generally absent. In particular, freezer storage is generally absent in the field, precluding the possibilitiy of maintaining a supply of prepregs for repairs. Low-temperature storage is required to retard the cure reaction that progresses even at room temperature [28]. Nevertheless, repairs often must be performed in the field to reduce downtime in service depots. Consequently, in-field repairs commonly rely on wet layup, sacrificing the uniformity and consistency intrinsic to prepreg laminates [29]. DVD processing partially mitigates these challenges, but sometimes is difficult to deploy in the field due to the complicated structures and equipment required [30], and sacrifices flexibility. In-field repairs have the greatest flexibility, yet cannot be consistently deployed, because commercial OOA prepregs are not compatible with in-field conditions.

A new material system is presented that addresses the issues with in-field repairs describe above. The material is a semi-preg that features a resin format that imparts through-thickness gas permeability [31, 32]. The format (resin distribution) expedites gas egress, eliminates reliance on edge breathing, and effectively suppresses porosity in composite parts, especially in repair conditions. Furthermore, the semi-preg format allows for conventional vacuum bagging, eliminating the need for DVD processing. In addition, the material system features a vinyl hybrid resin that is stable at room temperature and



(a) (b)

Figure 2. a) Semi-preg formatting on prepreg surface b) sealed edges of test panels.

does not require freezer storage. These features – semi-preg that does not require freezer storage – are particularly well-suited to in-field repairs of composite structures.

This study describes the processing of a semi-preg system tailored to repair-relevant VBO conditions and analyzed with *in-situ* observation. The material system was contrasted with the conventional repair procedures of wet layup and DVD. A custom tool was employed to provide new insights into gas removal mechanisms and to assess the effectiveness of semi-preg formatting in eliminating porosity in scarf patch repairs. Composite repair patches with negligible porosity were produced with the semi-preg system, and direct observations of the cure process revealed the mechanisms responsible for the effectiveness of the semi-preg format for scarf repairs.

2. Experiments

Two matrix materials were employed for this study, a vinyl hybrid resin and a two-part epoxy resin for wet layup. Using these resins, four types of panels were produced and analyzed. Two panels (A and B) were produced using the semi-preg featuring the prototype (vinyl hybrid) resin and VBO processing, heretofore referred to as semi-preg panels A and B. Two more panels (C and D) were produced using the epoxy resin and wet layup/DVD, which will be referred to as DVD panels C and D. Panels A and C were cured on a flat tool plate, while Panels B and D were cured on the custom tool that simulated scarf repair and an observation window. Thus the four panels were A (semi-preg tool plate), B (semi-preg repair), C (DVD tool plate), and D (DVD repair). The DVD panels (C and D) were fabricated using current state-of-the-art procedures for in-field repair, while the semi-preg panels (A and B) were cured using VBO processing. Panel quality was evaluated by porosity measurements of polished sections and by ultrasonic C-scans. Videos of the panels cured on the scarf repair tool were recorded to document mechanisms of gas removal and resin flow. Mechanical performance of the panels was evaluated through measurements of interlaminar shear strength (ILSS) and glass transition temperature (T_g).

All panels were prepared using a carbon fiber 2×2 twill fabric with 6k tows (DowAksa A-38) and a resin content of 35%. An 8-ply quasi-isotropic stacking sequence of $[0°/45°]_{2s}$ was employed for all the panels. The DVD panels employed an epoxy adhesive paste commonly used for co-cured scarf repairs (Henkel Loctite EA 9390) [23]. The layup procedure was performed using techniques commonly used for wet layup repairs, including the use of DVD [14]. Panels fabricated from semi-preg featured a vinyl hybrid resin (VH-37, Polynt) with discontinuous resin formatting (Tipton Goss Advanced Materials Company) [15, 31]. The 2×2 twill fabric yielded a resin pattern comprised of islands of resin on the surface, as shown in Figure 2a. The formatting allows for edges to be sealed as seen in Figure 2b.

For Panel C (DVD over tool plate), nonperforated fluorinated ethylene propylene (FEP) release film (Airtech A4000) was taped to an aluminum tool plate and a layer of Teflon-coated fiberglass peel ply was layered on top. Eight dry plies (420×420mm) were laid up in a quasi-isotropic stacking sequence $[0°/45°]_{2s}$ with a layer of resin (EA 9390) between each ply. Perforated release film (Airtech A4000 P8) and a peel ply was placed on top of the laminate. Edge-breathing was allowed, and fiberglass bleeder plies were employed, with nylon breather cloth (Airtech Airweave N10) covering the laminate. Vacuum bagging was then overlaid on the surface and sealed with sealant tape (Airtech GS213-3). A wooden box with an open end was

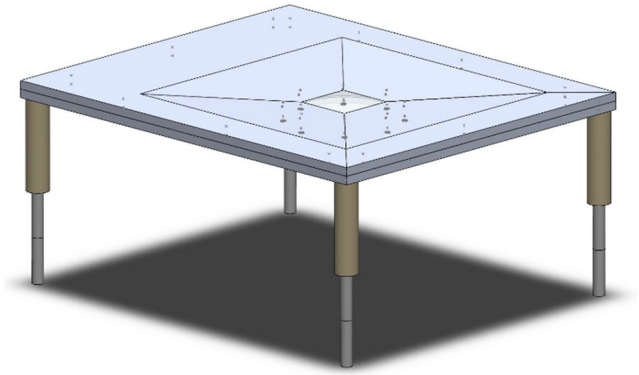


Figure 3. Schematic of repair tool plate with an *in-situ* observation window.

placed over this setup with a breather blanket on top. A second vacuum bag was placed over top of the box. While under the DVD box, the three cycles were applied to the laminate - debulking, compaction, and cure. Vacuum was applied to both bags, and the debulk step was 50 °C for 60 min. The debulk box vacuum was then vented to allow for compaction for 30 min. Final cure was achieved in an oven with 2 °C/min ramp to 118 °C and held for 150 min.

Panel A (semi-preg on tool plate) was fabricated using VBO layup and bagging. Prepreg plies measuring 380 × 380mm were laid up in the same stacking sequence as the DVD panel. Unlike the DVD panel, edge breathing was prevented by sealing the edges of the prepreg using sealant tape. The intent was to simulate the conditions of a scarfed repair, with restricted air evacuation. Two layers of sealant tape were used to fully seal the edges of the panel (Figure 2b). There was first a room temperature debulk for 30 min followed by a 1.1 °C ramp to 93 °C and held for 30 min. A second ramp of 1.1 °C until 121 °C was done and held for 60 min. A cool down of 1.1 °C/min was done until room temperature was reached.

To allow *in-situ* observation of resin flow and void formation, a tool plate featuring an observation window was custom-built. The aluminum base plates were machined to simulate a scarf profile and to accommodate a glass observation window (Figure 3), which was clamped and sealed to prevent air leakage.

The distinctive features were the observation window and the 3° scarf incline. The legs of the tool accommodated video camera and illumination during the cure cycles. Images were recorded at 1 Hz during the early cure stages, and every ten seconds thereafter until resin flow ceased.

Similar procedures were employed for Panels B and D (semi-preg and DVD panels) with the scarf repair tool with the following differences. Instead of 420 × 420 mm plies, the dimensions of the observation window (50 × 50mm) was the starting point for ply sizing to enable observation. While repairs can be large in practice, the dimensions of these patches are large enough to show the effects of blocked off edge dams. Each successive ply was cut proportionally large to account for the 3° scarf incline chosen to replicate best practices for repairs [14,15]. Instead of an opaque FEP release film, a transparent release agent (Frekote® 700-NC) was employed. Finally, a heat blanket (Briskheat SR512018X18C) was employed to achieve the same cure cycles as Panels A and C respectively.

Panel quality was assessed by ultrasound and polished sections. Ultrasonic C-scans were performed on the Panels A and C to assess microstructural uniformity (NDT Automation UPK-T36). A transducer with a 10 MHz frequency scanned the panel while being gated by the echo from a glass reflector plate. Polished sections (25 × 13 mm) were prepared from from all four panels for microscopic inspection to assess porosity. Void content was estimated by measuring the ratio of void area to total area of each sample using image processing software on the microscope (Keyence VHX 600). The void areas were selected by dark area filters on the microscope which were the same for each sample and verified visually.

Panel properties were assessed by measuring T_g and shear strength. Dynamic mechanical analysis (DMA, TA Instruments Q800) was used to measure glass transition temperature (T_g) of cured panels. Samples (60 × 12 mm) were cut from each of the two tool plate panels and tested in dual cantilever mode while heating at 3 °C/min to 200 °C. The value of T_g were identified as the peak of the tangent delta curve. Interlaminar shear strength was measured using the short-beam-shear (SBS) method outlined in ASTM D2344. Samples cut from the two tool plate panels were tested using a load frame (Instron 5585H).

3. Results

Tool plate

Representative ultrasonic C-scans of the DVD and semi-preg panels are shown in Figure 4.

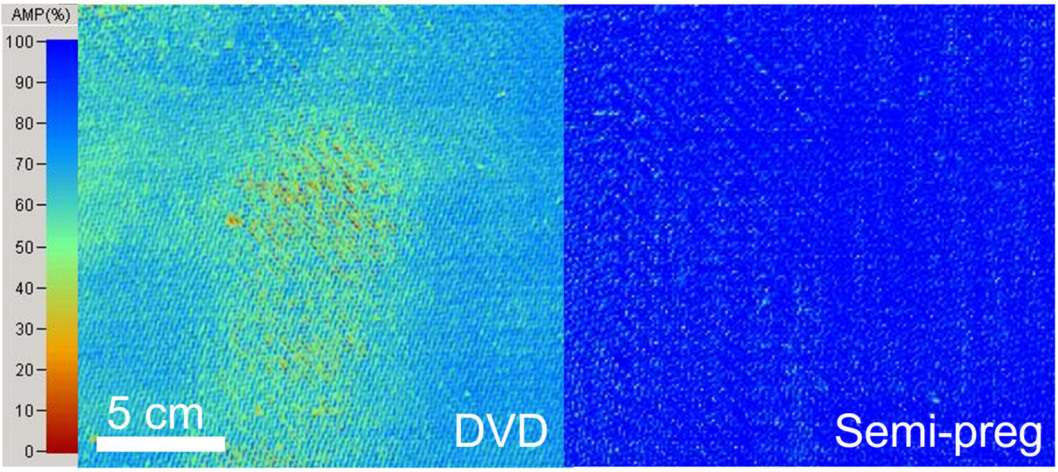


Figure 4. Ultrasound images of Panels A and C (semi-preg and DVD).

C-scans from the DVD panel exhibit varying shades of blue, with regions of red and yellow across the panel, indicating non-uniform attenuation and the likelihood of porosity distributed in these regions. The red/yellow areas appear in central regions of the DVD panel. This observation is consistent with findings from composites produced from OoA prepregs, where air bubbles were often trapped near the center of panels because egress pathways to panel edges were partially obstructed (edge breathing is the primary air evacuation mechanism for such prepregs) [33]. The need for technologies addressing this shortcoming of DVD processing is apparent, given that even the relatively small and thin panels produced here (<5mm) exhibited unaacceptable levels of porosity. In contrast, the panels produced from semi-preg were markedly more uniform than the DVD panels. The findings demonstrate the benefit of prepregs with through-thickness gas permeability to laminate quality when curing without autoclave pressure. The reliance on through-thickness gas transport, as opposed to edge breathing, is a distinguishing feature of semi-pregs. The format provides a multitude of much shorter, redundant pathways for gas egress compared to conventional OoA prepregs, and imparts process robustness. Semi-pregs are also compatible with a range of constraints stemming from geometry and cure conditions.

Polished sections of cured laminates afford the opportunity for quantitative analysis of porosity. Representative micrographs from polished sections of Panels A and C are shown in Figure 5.

Panel C (DVD) exhibited average porosity values of 2.2% across different areas of the panel. Both macro- and micro-porosity were evident. Macroporosity resulted from air trapped within the laminate that failed to reach an outlet, while microporosity appeared within the fiber tows and stemmed from insufficient resin flow, either because of insufficient time or insufficiently low viscosity. The relatively low viscosity of the resin argued against the latter possibility (steps were required to prevent excessive resin loss *via* bleeding during cure), and thus both macro- and micro-porosity most likely resulted from entrapped air. Ultrasonic C-scans of the Panel C (DVD) revealed that porosity was distributed throughout the sample, although the concentration was higher in central regions with average porosities of ∼3% in central compared to ∼1% around edges.

Comparison of Panel C (DVD) with Panel A (semi-preg) revealed marked contrasts. The latter panel exhibited a notable absence of both macro- and micro-porosity (< 0.1%). The absence of macroporosity itself was attributed to more efficient air evacuation during cure. In contrast, microporosity present in the DVD panel was attributed to the opposite cause – insufficient gas evacuation. Remarkably, the absence of porosity in panels fabricated with semi-preg was achieved despite both a shorter cure cycle and a much simpler setup than DVD. The contrast demonstrates the effectiveness of the semi-preg format in achieving gas evacuation, even when panel edges are sealed. Furthermore, the low viscosity of the vinyl hybrid resin (relative to conventional epoxies) achieved tow impregnation while preserving multiple pathways for gas egress.

The difference in the surface quality of the two panels fabricated on the tool plate (B and D) is apparent in Figure 6.

Panel B exhibited surface voids in crimp regions between tows. In twill fabrics, the spaces between tows offered pathways of least resistance for pockets of air, and local pressure gradients drove gas bubbles to these sinks. Bubbles were often trapped at these sites and remained as surface defects. Wet layup covered each ply with resin and thus sealed the plies against through-thickness gas transport, resulting in gas bubbles which coalesced in

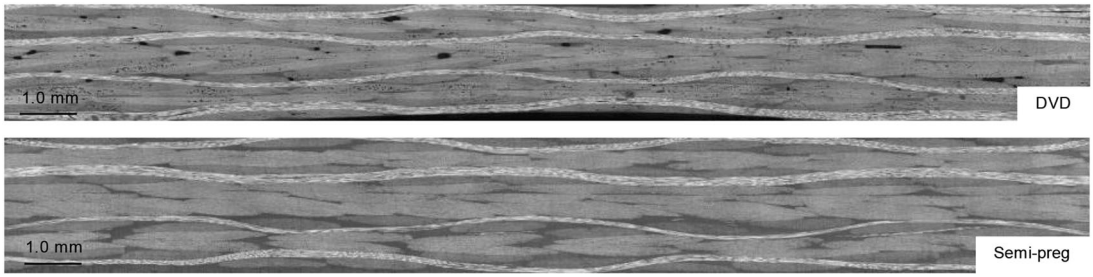


Figure 5. Polished sections of Panels A (semi-preg) and C (DVD).

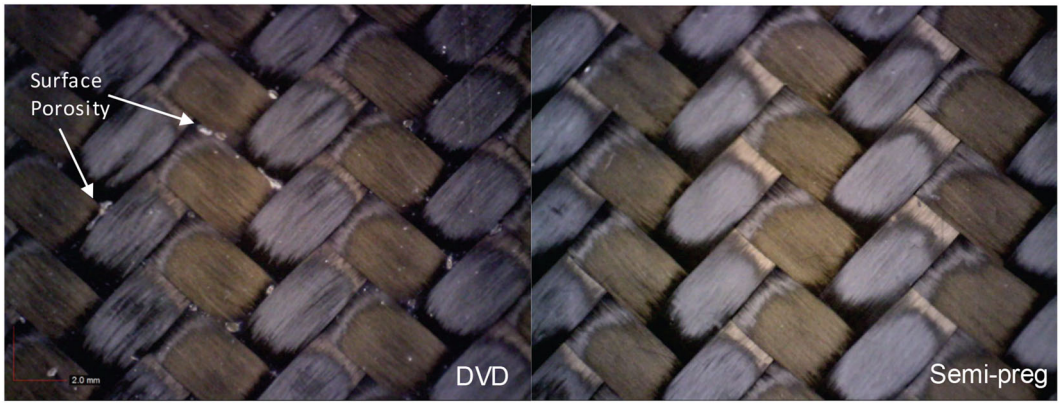


Figure 6. Surface images of Panels D (DVD) and B (semi-preg).

depressions in crimp regions at tow cross-overs. Without through-thickness pathways, gas egress could occur only *via* pathways to ply edges (orders of magnitude farther away). The precise origin of the voids was unclear, however. For this reason, the scarf tool plate was used to furnish insight into gas transport during scarf repair processing. No surface defects were observed in the semi-preg panel (Panel B). The biggest difference between Panels A and B relative to Panels C and D was the ability for air to evacuate in the through-thickness direction in the semi-preg layups. This feature of semi-preg formatting was responsible for the difference in surface quality of the panels.

Repair tool

The images below were selected from video frames recorded during DVD cure on the scarf repair tool plate (Figure 7).

The initial distribution of resin after wet layup in Panel D is shown in Figure 7a. Although some regions were not entirely covered in resin, the distribution did not provide the multitude of redundant, through-thickness air evacuation pathways present in semi-preg layups. When the DVD apparatus was deployed and the cure cycle initiated, the resin wet out the panel, and some uncovered regions began to shrink (Figure 7b). At this stage, the benefit of DVD versus VBO processing for wet laid materials became apparent, as air pockets shrank. In the DVD process, steps were taken to prevent compaction that could potentially block in-plane air evacuation channels. However, air pockets remained in the sample, primarily in gaps between tows. The limits of wet layup for achieving low porosity became apparent, as the nearly continuous layer of resin prevented air evacuation during debulking. A representative air pocket is circled (Figure 7b–d) to highlight movements during cure. In Figure 7c, the air pocket has migrated along inter-tow channels towards the panel edge nearest to the vacuum port. The bubble then settles into its final position (Figure 7d). The final site is separated from the original position by multiple tows, demonstrating that the bubble migrated in-plane (due to the absence of through-thickness permeability). Moreover, the bubble size did not change from Figure 7b–d, indicating that no gas escaped, despite the DVD process, which was intended to reduce ply compaction and in principle, preserve in-plane egress pathways. The wet layup process rendered each ply independent with respect to air evacuation. Similar events occurred in all plies, resulting in internal porosity in the cured laminates.

The images below (Figure 8) demonstrate how semi-pregs differ from prepreg formats that rely on edge breathing and from DVD.

Figure 8a shows the initial distribution of resin in the semi-preg (Panel A), comprised of islands of resin separated by gaps for through-thickness gas egress. During the cure cycle, the resin spread across the sample as compaction began. Although much of the air escaped quickly (especially compared to the

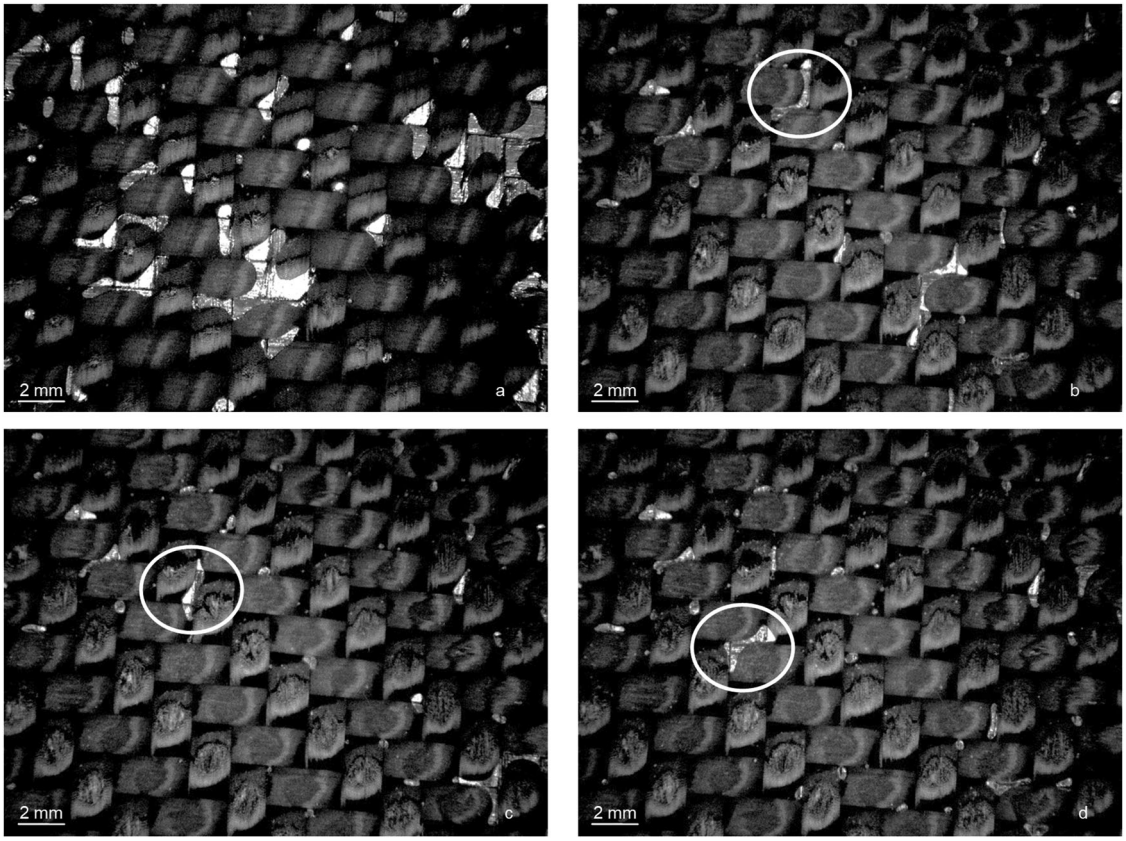


Figure 7. Images acquired *in-situ* during DVD processing (Panel D).

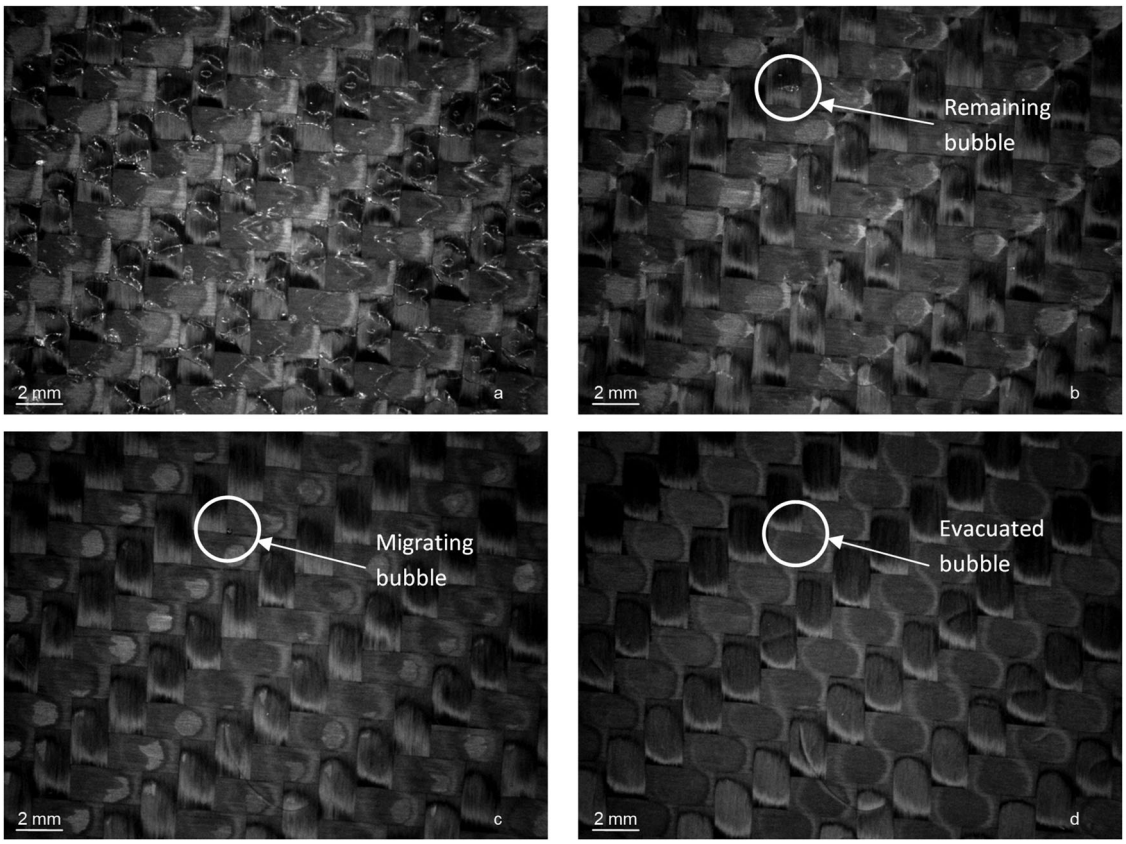


Figure 8. Images acquired *in situ* during semi-preg processing.

DVD panel), some bubbles remained in the resin prior to gelation (circle in Figure 8b and c). The bubble was initially situated squarely in the center of a tow, and this factor prevented rapid removal through gaps and pinholes like all other air pockets. As the resin continued to spread and infiltrate fiber

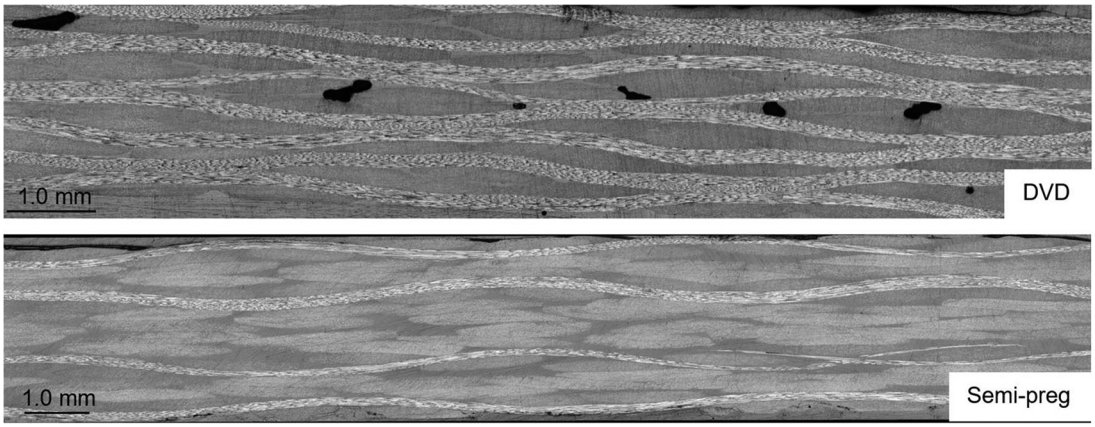


Figure 9. Images of tool Panels B and D.

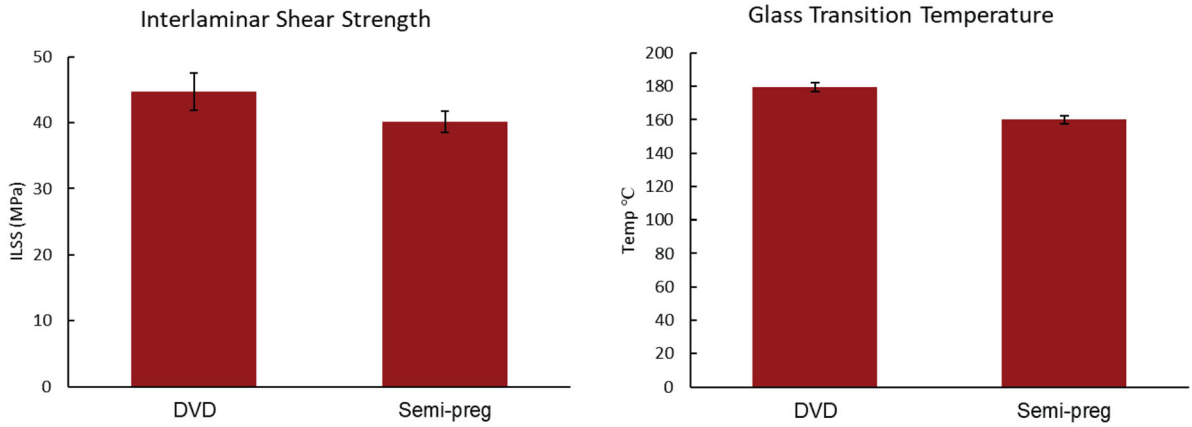


Figure 10. Interlaminar shear strength and glass transition temperatures for Panels A and C.

tows, the bubble migrated to the edge of a tow, elongating in the process. The bubble then migrated between fiber tows until reaching a pinhole at a corner. Immediately upon reaching the corner, the bubble began to shrink such that most of the air in the elongated bubble traveling along the edge escaped before it was able to settle into a roughly hemispherical shape in the corner against the plate. Thus, the bubble was barely perceptible (Figure 8c) in the corner before eventually disappearing.

The elimination of gas bubbles during cure of Panels A and B (semi-preg) demonstrated the effectiveness of discontinuous resin formatting. Figure 8d shows the defect-free surface that remained post-gelation. Gas bubbles were removed much earlier in the cure cycle relative to Panel D (DVD), occurring mostly between 5-10min versus 15-30min for Panel D. Note that gas bubbles migrated *through* the panel, unlike the DVD panel (Figure 7). Polished sections of Panels A and B after cure revealed zero bulk porosity, supporting the contention that bubbles that disappeared from the surface also exited the panel. The resin distribution on the surface ensured that spots at tow corners were among the last to be filled by resin, and therefore acted as through-thickness air evacuation channels for bubbles. Because air removal occurred *via* short and redundant through-thickness pathways (as opposed to edge breathing), porosity-free laminates were produced when edge-breathing was impaired or prevented. Such conditions often arise in production of large parts, as well as in in-field repairs.

Representative micrographs from polished sections of Panels D (DVD) and B (semi-preg) are shown in Figure 9.

Panels B and D exhibited porosity levels similar to the counterpart laminates cured on the tool plate (Panels A and C). Panel D showed 1.9% porosity, less than that of Panel C. While both Panels C and D exhibited similar levels of macroporosity, Panel D did not exhibit the same microporosity characteristics as Panel C (cured on the tool plate). The repair tool plate had distinguishing features, including scarfing along edges and a central observation window, which accommodated a much smaller repair patch. The shorter travel distance and potential for additional air pathways along the scarf edges, in contrast to sealed edge dams, explain the lower porosity compared to the Panel C (DVD). Panel B exhibited 0.1% porosity on average, usually with no apparent voids. Air bubbles present in the semi-preg were evacuated prior to full cure for both tool plate and repair tool laminates.

Panel performance

Porosity analysis provides one metric to compare the quality of repairs performed with the semi-preg vinyl hybrid system versus the DVD wet layup configuration. However, the performance of laminates produced with a new material system can be benchmarked to those produced with conventional epoxy, such as the one employed in Panels C and D. Figure 10 shows the glass transition temperature (T_g) and interlaminar shear strength (ILSS) for panels produced with semi-preg (Panel A) and those produced *via* DVD (Panel C), with error bars of one standard deviation.

Glass transition temperature is often used as an indicator of mechanical performance of a resin [34]. Note that the epoxy has a higher T_g than the vinyl hybrid (179.6 °C vs 160.1 °C), beyond the 95% significant level. Because the vinyl hybrid is a prototype formulation and not optimized, it is not surprising that the T_g for vinyl hybrid is slightly lower than the commercial epoxy. The ability to employ this resin would therefore depend on T_g tolerances in potential applications.

Interlaminar shear strength (ILSS) is also an important metric for mechanical performance. ILSS is a matrix-dominated metric, and is characterized by multi-axial loading, a condition most components experience in service. Porosity has a strong effect on ILSS and other matrix properties [35]. As expected after viewing the T_g results, the ILSS values for epoxy were greater than those of the vinyl hybrid (44.7 MPa vs 40.1 MPa). However, the difference was not statistically different at the 95% confidence level (unlike T_g values). Modifications to the resin formulations, both vinyl hybrid and epoxy, could increase performance levels to more closely approximate that of the wet layup epoxy.

4. Conclusions

A prominent concern for in-field repairs is the inconsistent quality of repaired panels, and current state-of-the-art repair methods simply compound the difficulties. In this study, a new prepreg material (semi-preg) is introduced to address these concerns, and is evaluated for suitability in soft patch scarf repairs. The semi-preg formatting of the material system yields porosity-free panels, even in the absence of edge breathing or DVD processing. The semi-preg format effectively eliminates the need for DVD processing by providing a multitude of short, redundant pathways for through-thickness air evacuation. These pathways also eliminates porosity when edge breathing is not possible, a condition consistent with scarf repairs. The material system also features a vinyl hybrid resin that does not require refrigerated storage and is well-suited to wet layup. These two features enable high-quality repairs with semi-pregs using a relatively simple bagging process. The semi-preg panels consistently yield void-free lminates, while wet-laid DVD panels show both micro- and macro-porosity.

A custom tool such as the one designed and deployed here, provides unique *in-situ* observations and critical insights into physical phenomena intrinsic to scarf repairs. Video footage and microscopy of polished sections demonstrates that through-thickness air egress in semi-preg laminates effectively eliminates porosity in repair processing conditions. Semi-preg formatting combined with a vinyl hybrid resin perform synergistically to address key challenges of in-field repair conditions. While the vinyl hybrid resin exhibits slightly lower strength than the control epoxy, the benefits of room temperature storage, reduced porosity, reduced manual labor for wet layup, and obviating DVD processing offer an attractive alternative for repairs. Nevertheless, in some repairs, a specific resin will often be required (other than vinyl hybrid) to match the parent material. In such cases, the semi-preg format can be employed with resins matched to the damaged structure (e.g. epoxies). However, semi-preg formats may have to be tailored to be the fabric type or prepreg layup. For example, thicker or more complex parts may require optimized resin distribution patterns or different cure cycles to ensure complete gas evacuation. The ability to conduct *in-situ* analysis through a scarfed repair tool will provide valuable guidance for optimizing semi-pregs for specific repair conditions. The tools and materials discussed here are well-suited to repairs, although the semi-preg format also is broadly applicable to OoA processing, potentially expanding the application space of composites.

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