

Engineering Composite Interfaces with Toughened T-Link® L-F620.

BONDING | INTERLEAF TOUGHENING | COMPOSITE RESIN INTERLEAF

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ABSTRACT

Toughened T-Link® Film L-F620 is a dry thermoplastic film that can be used as a structural bonding layer between prepared substrates, as an interleaf within epoxy carbon-fiber laminates, or as a thermoplastic resin matrix in composite applications. This paper organizes the available testing results around a potential function: engineering the interface without replacing the primary laminate reinforcement or epoxy matrix.

In bonding evaluations, prepared 17-4 stainless-steel and Ti-6Al-4V joints reached 33 MPa apparent lap-shear stress with cohesive failure. A Toray Cetex TC1225 LMPAEK-to-17-4 joint reached 19 MPa and a Toray Cetex TC1225 to Ti-6Al-4V joint reached 11.5 MPa; both were limited by composite substrate failure. Separate temperature-screening work with Toray TC380 showed that process temperature and substrate response remain important parts of bondline design.

As a laminate interleaf, 1 mil Toughened T-Link® Film L-F620 placed at all 31 interfaces in a 32-ply quasi-isotropic Mitsubishi NCT301 TR50S panel produced 66% higher compression-after-impact strength than the prepreg-only control under the reported conditions. Representative ultrasonic damage areas were approximately 69% smaller at two nominal impact levels, even though the L-F620 specimens received higher measured impact energies. A single center interleaf in ASTM D5528-13 testing increased mean Mode I initiation G_{Ic} from 303 to 1433 J/m² and propagation G_{Ic} from 284 to 1499 J/m², with substantial propagation scatter. Short-beam testing showed a more progressive response with a slight reduction in normalized strength.

The evidence supports L-F620 as a configurable material for bonding and full-area interleaving. The representative dry-glass-fiber cross-section establishes an initial wet-out feasibility condition for using L-F620 as a composite resin matrix, but dedicated laminate-level processing and mechanical testing are still required. Targeted interleaf placement is also a logical engineering strategy, although it is not independently validated by the all-interface results presented here.

All reported performance is specific to the materials, geometries, interface counts and processing conditions described in this paper. The results are not design allowables or universal product specifications.

A COMMON INTERFACE PROBLEM

Bonded joints and laminated composites are usually discussed as separate design problems. Mechanically, however, both are governed by what happens in a thin interfacial region. In a joint, that region must transfer load between substrates while resisting peel, shear and environmental exposure. In a laminate, it must prevent small matrix cracks from becoming unstable delaminations that reduce residual strength after impact.

Toughened T-Link Film L-F620 creates a useful bridge between those scales. As a bondline, the film provides a controlled thermoplastic layer between prepared surfaces. As an interleaf, the same material is placed between selected plies so that deformation and crack propagation encounter a tougher local phase. Targeted placement is the design extension: rather than using film everywhere, the engineer selects the interfaces or zones where additional energy absorption is expected to generate the most structural value.

ONE MATERIAL PLATFORM ACROSS FOUR PLACEMENT SCALES

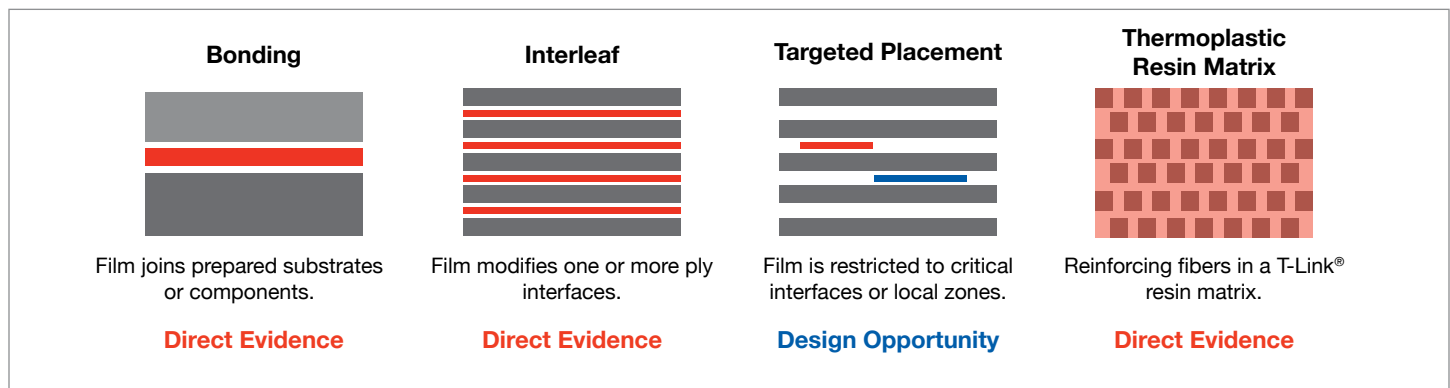


Figure 1. Bonding and interleaving are demonstrated uses. Targeted placement is an optimization strategy that requires validation.

The product platform is available in film, pellet, micropellet, monofilament and coated yarn forms. The present paper focuses on the film because it provides a defined, dry layer that can span a joint overlap or a laminate interface. Continuous-area coverage is especially relevant to prepreg processing because the toughening phase can be introduced without reformulating the complete epoxy matrix.

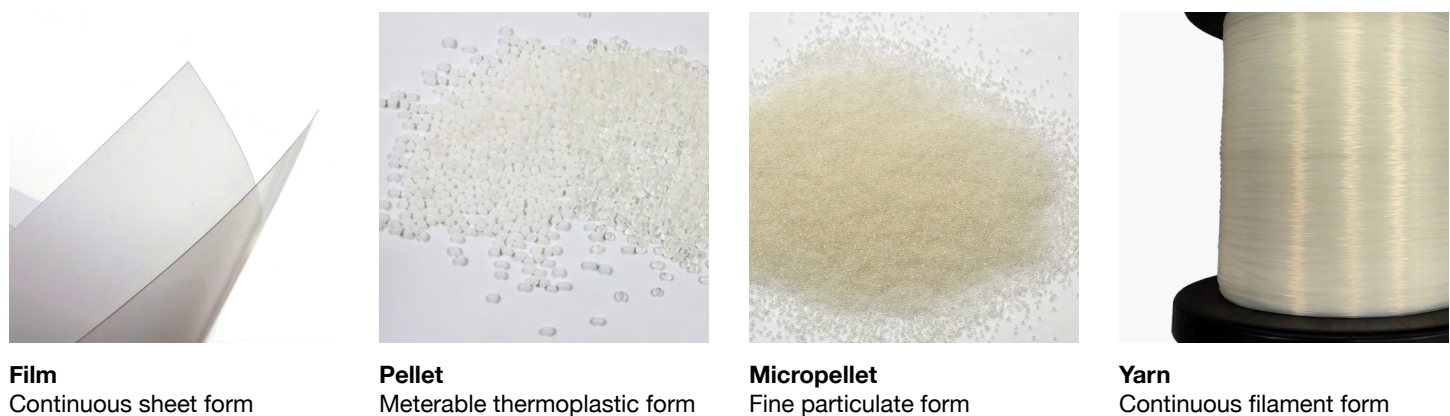


Figure 2. Material Forms

FUNCTION ONE: STRUCTURAL BONDING

Used between substrates, Toughened T-Link Film L-F620 behaves as a thermoplastic adhesive film.

The controlled layer offers practical advantages for layup and handling, but joint performance still depends on substrate chemistry, surface preparation, overlap geometry, bondline thickness, processing temperature and the stiffness mismatch between adherends. Apparent lap-shear stress is therefore a configuration result rather than a transferable material constant.

The substrate-failure observations in the Toray Cetex TC1225 LMPAEK-to-metal and Mitsubishi NCT301 TR50S-to-metal joints are important. They indicate that, in those tested configurations, the measured apparent joint strength was limited by the composite adherend rather than a clean separation at the film interface. They do not establish a universal lower bound because changing the composite thickness, overlap, test geometry or surface preparation can shift the governing failure mode.

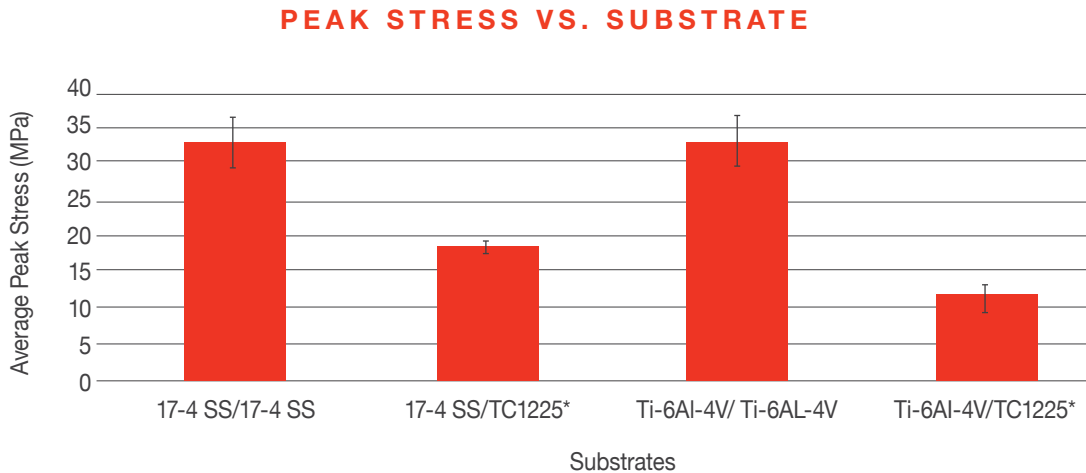


Figure 3. Toray TC1225 to 17-4 SS & Ti-6Al-4V bonding specimens and post-test substrate damage highlighted on the product webpage.

Test Conditions:

- 1" x 1" x 5 mil Toughened T-Link® Film L-F620
- All substrates grit blasted and solvent rinsed
- Conditioned for 20 minutes at 360°F [182°C]
- ASTM D5868
- 17-4 stainless steel [substrate thickness 3.2 mm]
- Ti-6Al-4V-[substrate thickness 1.5 mm]
- Toray TC1225 [45/0/-45/90] 3x [substrate thickness 2.3 mm]
- These conditions belong with the numerical results whenever they are communicated.

*Substrate failure

BONDLINE EVIDENCE ACROSS SUBSTRATE CLASSES

Substrate	Peak Stress (MPa)	Failure Mode	Bondline (mm)
17-4 SS/17-4 SS	32.7	Cohesive	0.06
17-4 SS/TC1225	18.7	Substrate failure (TC1225)	0.03
Ti-6Al-4V/Ti-6Al-4V	32.8	Cohesive	0.06
Ti-6Al-4V/TC1225	11.5	Substrate failure (TC1225)	0.05

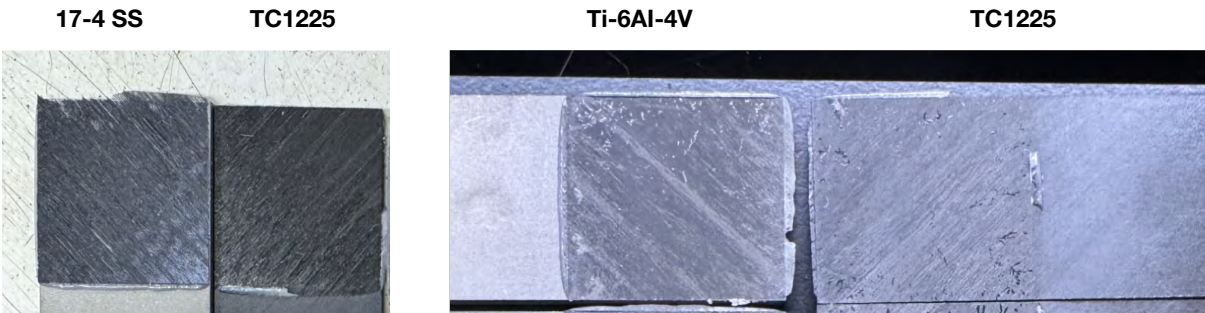
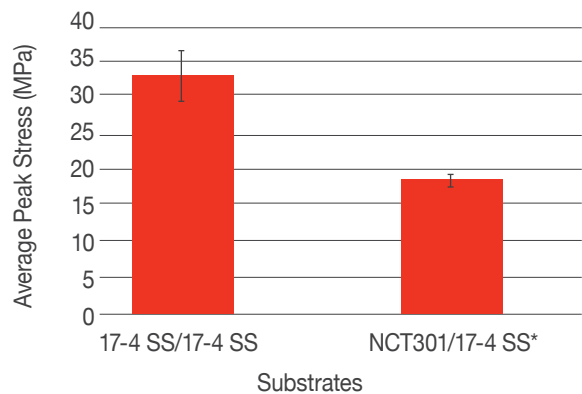


Figure 4. Representative post-test bonding evidence across metal and composite substrate classes.

Cohesive failure in the metal-to-metal specimens and composite substrate failure in the hybrid joints point to different limiting mechanisms. That is exactly what a technical screening program should reveal: the bondline is not evaluated in isolation, but as one part of a load path that includes adherends, preparation and geometry.



Substrate	Peak Stress (MPa)	Failure Mode	Bondline (mm)
17-4 SS/17-4 SS	32.8	Cohesive	0.06
17-4 SS/NCT301 TR50S	16.5	Substrate failure (NCT301 TR50S)	0.05

Test Conditions:

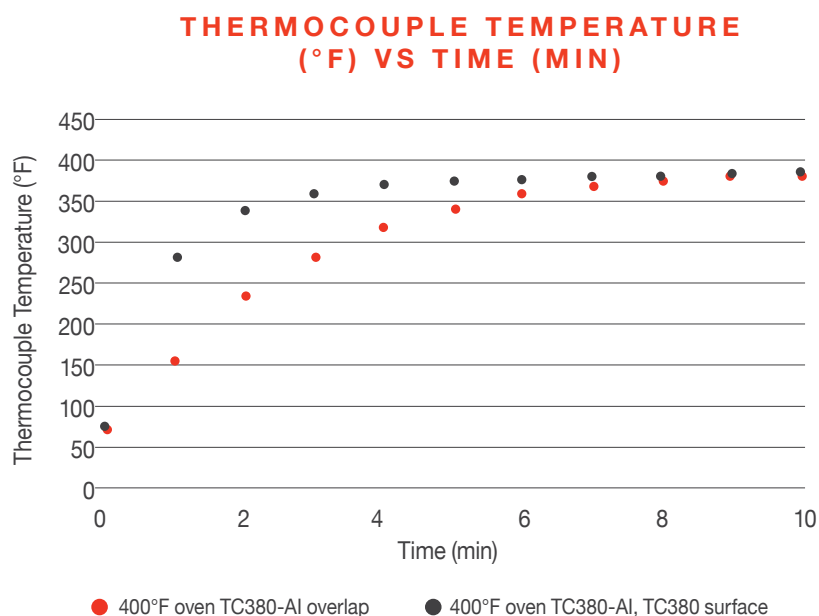
- 1"x1"x 5 mil Toughened T-Link® Film L-F620
- 17-4 stainless steel [substrate thickness: 3.2 mm]
- Mitsubishi NCT301 TR50S – quasi-isotropic laminate [substrate thickness: 3.5 mm]
- All substrates grit blasted, solvent rinsed, and plasma treated
- Conditioned at 360°F [182°C] for 20 minutes

*Substrate failure



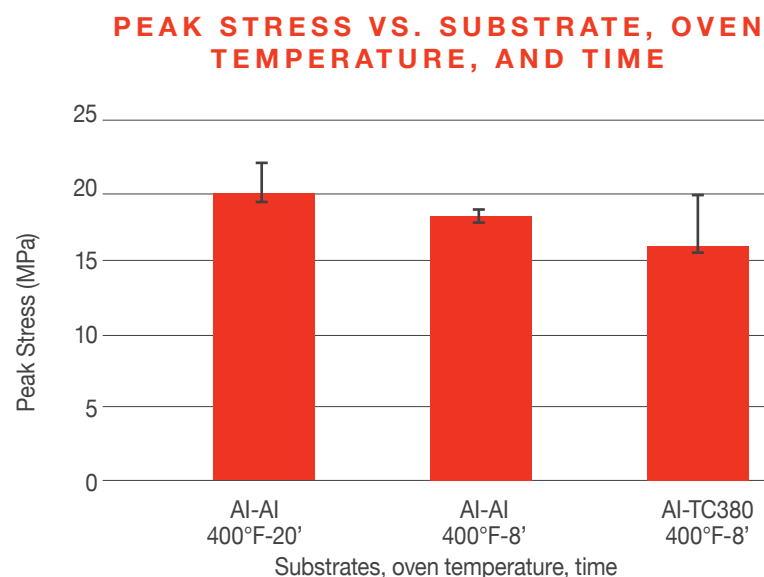
Processing temperature as a joint-design variable

A separate screening study used Toray TC380 composite bonded to metal while monitoring process temperature. The source work makes two points clear. First, the film must experience enough temperature and time to consolidate against the prepared surface. Second, the allowable process window may be limited by the composite substrate and by the practical heating method. The plotted response should be read as process-development evidence, not as a generalized cure schedule.



Method: Substrate temperature of Toray TC380 substrate monitored in oven at 400°F [204°C].

Figure 5. Toray TC380 bonding setup and temperature-screening.



Test Conditions:

- Aluminum 6061 [substrate thickness 3 mm]
- Toray TC380 [substrate thickness 1.4 mm]
- All substrates grit blasted and plasma treated
- 1" x 1" x 5mil Toughened T-Link® Film L-F620
- Conditioned at 400°F [204°C] for indicated time

Results:

Al-TC380 lap shear composite substrate failure.

Conditioning	Substrate	Peak Stress (MPa)	Failure Mode	Bondline (mm)
400°F-20'	Al-Al	20.1	Substrate yield	0.03
400°F-8'	Al-Al	18.3	Substrate yield	0.06
400°F-8'	Al-TC380	16.3	Substrate failure (TC380)	0.04

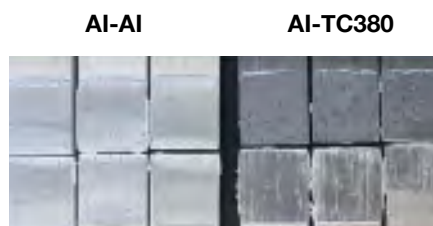


Figure 6. Torey TC380 apparent lap-shear response and representative post-test specimens.

FUNCTION TWO: LAMINATE INTERLEAF TOUGHENING

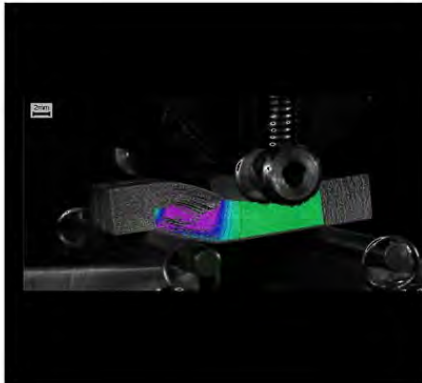
Placed between plies, Toughened T-Link Film L-F620 changes the local material architecture where interlaminar cracks initiate and grow. The thermoplastic phase can deform, bridge or redirect a crack and enlarge the energy-dissipating zone. The useful response depends on adhesion between the interleaf, epoxy matrix and reinforcement. If the interface is too weak, the film can act as a defect; if it is well integrated, it can force the crack through a more demanding path.

The short-beam program provides the first visible indication of this change in behavior. Digital image correlation images show a different strain-field evolution between the prepreg-only control and the panel containing L-F620 at every interface. The images are qualitative, but they support the load-displacement observations presented on the following page.

SHORT-BEAM DEFORMATION RESPONSE

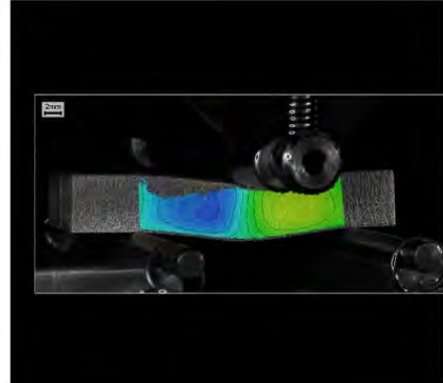
Prepreg control

Digital image correlation strain field



Prepreg plus L-F620

Digital image correlation strain field

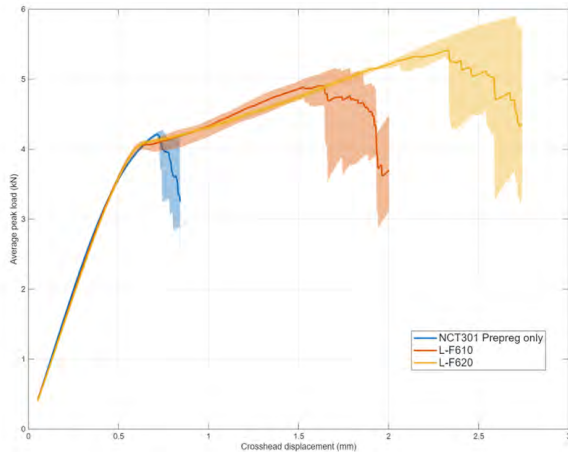


SHORT-BEAM RESPONSE REVEALS A STRENGTH-TOUGHNESS TRADE SPACE

SHORT-BEAM SHEAR EVIDENCE

Short-Beam Shear Evidence

Measured load response
Average short-beam curves



Short-Beam Shear Evidence

Normalized comparison
Stress and displacement interpretation

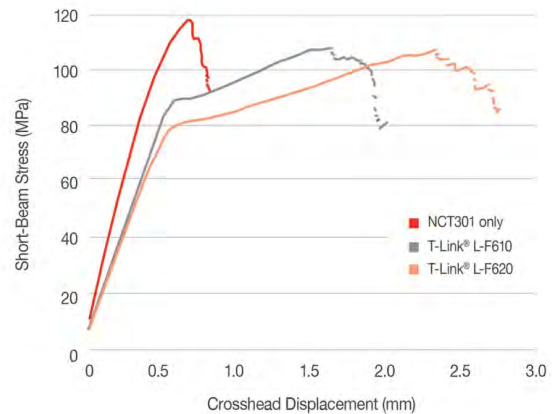


Figure 7. Short-beam response* for prepreg-only and fully interleaved panels.

The interleaved laminate maintained load over greater crosshead displacement than the prepreg-only control. The normalized presentation describes a large increase in strain with a slight decrease in strength. This is a useful technical result because it exposes the optimization problem rather than hiding it: the objective is not simply to maximize one coupon value, but to balance peak strength, progressive deformation, mass, thickness and the governing structural failure mode.

The ASTM D2344 method is often used as an interlaminar screening test, but the short-span beam develops a complex combination of shear, bending and local contact stresses. The curves should therefore be interpreted as comparative structural response for these panels, not as a pure interface constitutive property.

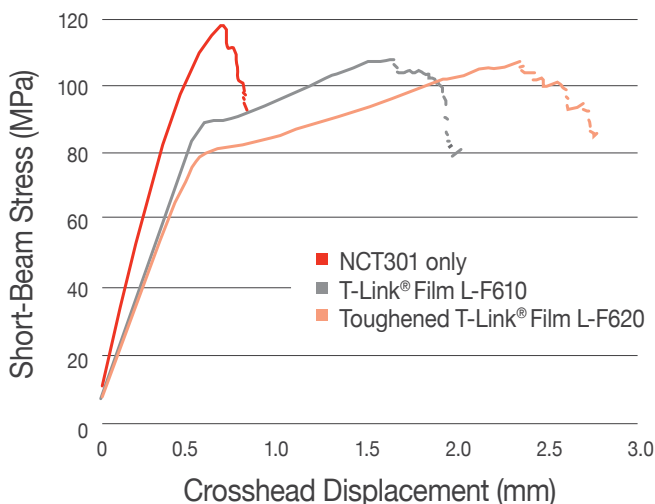


Figure 8. Summary of the short-beam result.

Next technical question. How does interleaf count and location affect progressive response, peak strength, mass and laminate thickness? The fully interleaved short-beam panel does not answer that question; it requires a dedicated study in which placement architecture is varied while the remaining laminate and processing conditions are controlled.

**Note : Interleaved laminates are composed of 30 layers of Mitsubishi NCT 301 TR50S G150 unidirectional prepreg with or without 29 layers of interleaved 1 mil T-Link. Panels were heat press cured at 135°C for 60 minutes at 100 psi. Samples were prepared according to ASTM D2344. Each line represents 5-6 samples from one panel. Range bands (Figure 7, left) reflect the range of samples from one panel. Results are corrected for machine compliance (Figure 8, left and right) and normalized for sample size (Figure 8, right).*

COMPRESSION AFTER IMPACT TEST ARCHITECTURE

Compression-after-impact testing evaluates the structural consequence of hidden impact damage. The reported panel used a unidirectional Mitsubishi NCT301 TR50S prepreg in a 32-ply quasi-isotropic layup with 1 mil L-F620 at all 31 interfaces. The laminate was debulked every five plies and at the end, then processed at 135°C for 75 minutes under 100 psi. Five specimens were taken from each control and interleaved panel.

Layup $[0/+45/-45/90/0/+45/-45/90/90/-45/+45/0/90/-45/+45/0]_2s$

32-PLY BALANCED, SYMMETRIC QUASI-ISOTROPIC LAMINATE

Stack Shown Top to Bottom

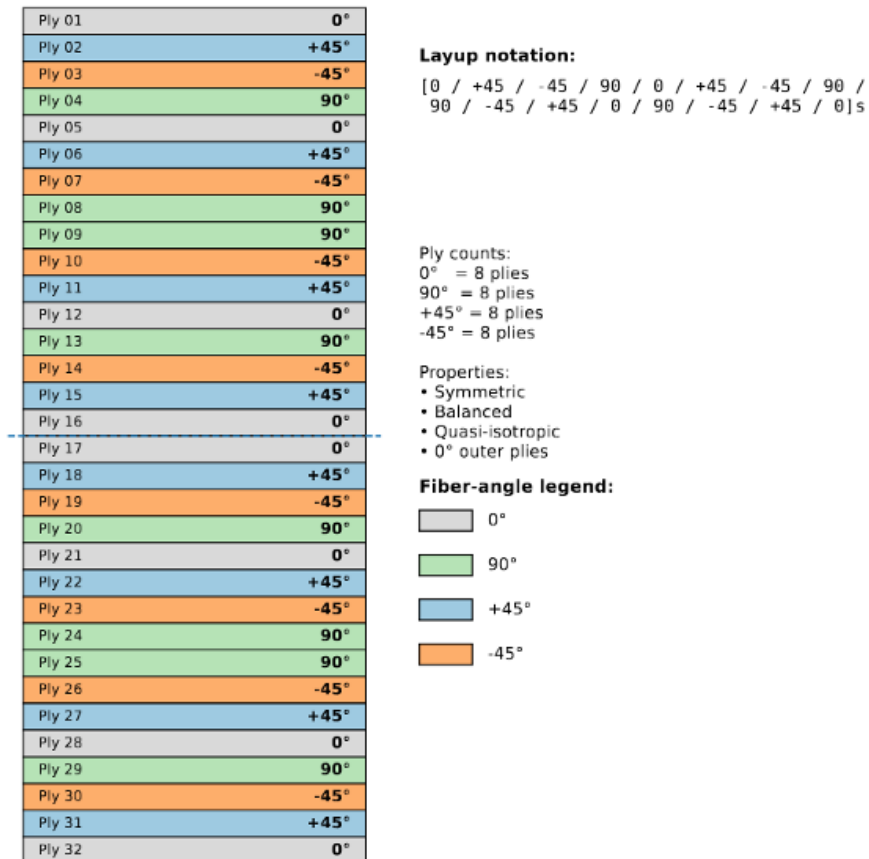


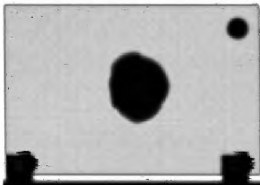
Figure 9. CAI panel construction.

IMPACT DAMAGE IS CONTAINED BEFORE RESIDUAL STRENGTH IS MEASURED

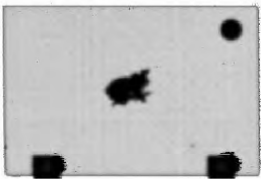
Representative ultrasonic images* were reported at nominal 1500 and 1700 in-lbf/in impact levels. At the lower nominal level, the measured impact energies were 283.68 in-lbf for the control and 326.76 in-lbf for the L-F620 specimen. Reported damage area decreased from 1.7324 to 0.5420 in². At the higher nominal level, the measured energies were 323.52 and 367.80 in-lbf, while damage area decreased from 2.6932 to 0.8156 in².

REPRESENTATIVE ULTRASONIC DAMAGE MAPS

Control at nominal 1500 in-lbf/in
283.68 in-lbf | 1.7324 in²



L-F620 at nominal 1500 in-lbf/in
326.76 in-lbf | 0.5420 in²



Control at nominal 1700 in-lbf/in
323.52 in-lbf | 2.6932 in²



L-F620 at nominal 1700 in-lbf/in
367.80 in-lbf | 0.8156 in²

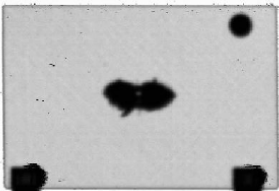


Figure 10. Representative post-impact damage map.
*Testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansa.

Nominal level	Configuration	Measured impact energy	Dent depth	Damage area
1500 in-lbf/in	Prepreg control	283.68 in-lbf	0.0195 in	1.7324 in ²
1500 in-lbf/in	Prepreg plus L-F620	326.76 in-lbf	0.0210 in	0.5420 in ²
1700 in-lbf/in	Prepreg control	323.52 in-lbf	0.0315 in	2.6932 in ²
1700 in-lbf/in	Prepreg plus L-F620	367.80 in-lbf	0.0245 in	0.8156 in ²

RESIDUAL COMPRESSION PROVIDES THE STRUCTURAL OUTCOME

The interleaved configuration produced 66% higher compression-after-impact strength than the prepreg-only control under the reported conditions. The significance of this result lies in the sequence of evidence: the ultrasonic maps show less extensive internal damage, and the subsequent compression test shows that the panel retains more load-carrying capability.

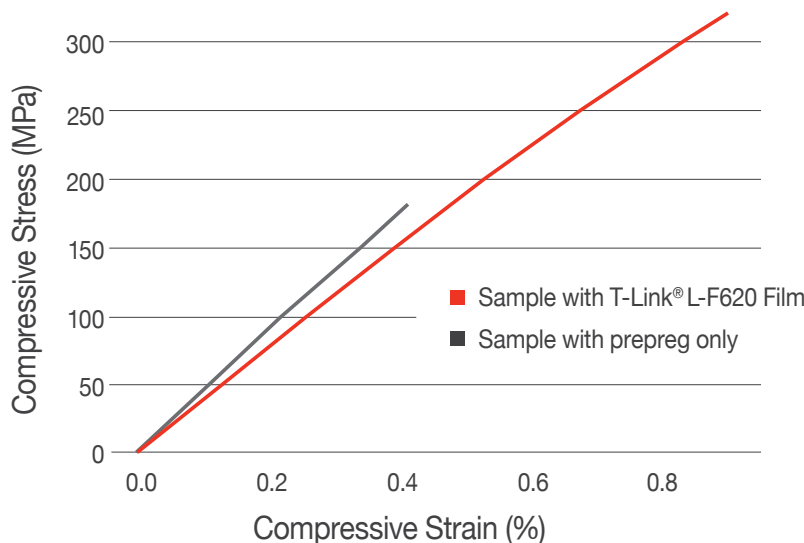
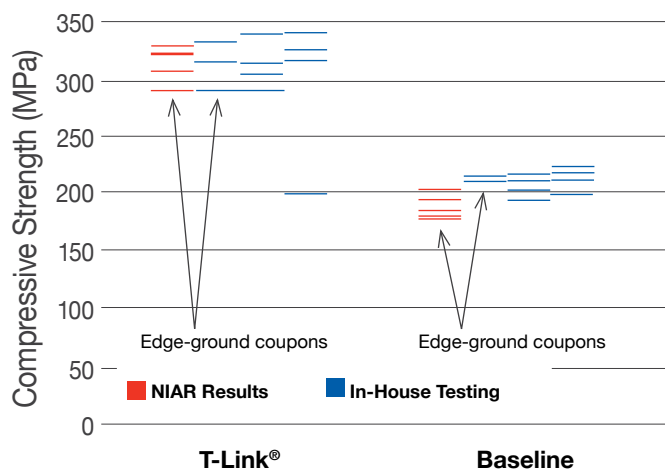


Figure 11. Representative CAI response Compression-after-impact strength. Impact was 1500 in-lbf/in.

COMPRESSION-AFTER-IMPACT RESULTS

Overall comparison CAI Result Overview



Panel Comparison Control and interleaved placements

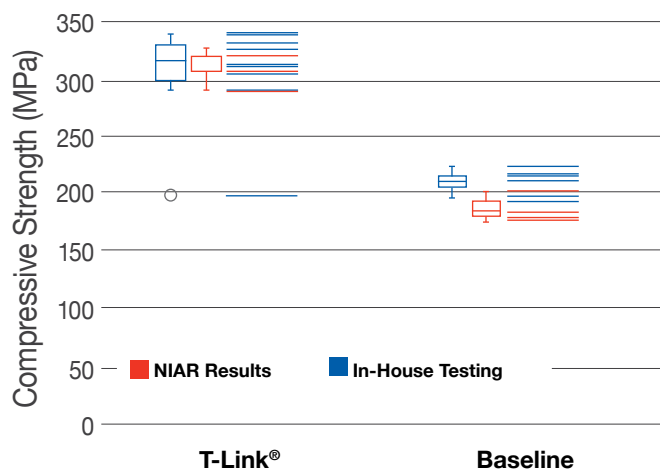


Figure 12. CAI comparison including the reported 66% improvement. Impact was 1500 in-lbf/in.

MODE I FRACTURE TOUGHNESS ISOLATES
CRACK-GROWTH RESISTANCE

ASTM D5528-13 double-cantilever-beam testing* used a 28-ply Mitsubishi NCT301 TR50S unidirectional panel with one 1 mil L-F620 film at the center interface and a 0.5 mil PTFE starter film. The results demonstrate a significant increase in the fracture toughness with the interleaf film. However, the large standard deviations and the following sample photos reveal crack migration from the interleaf into the fiber matrix layer.

MODE 1 FRACTURE TOUGHNESS ISOLATES CRACK-GROWTH RESISTANCE

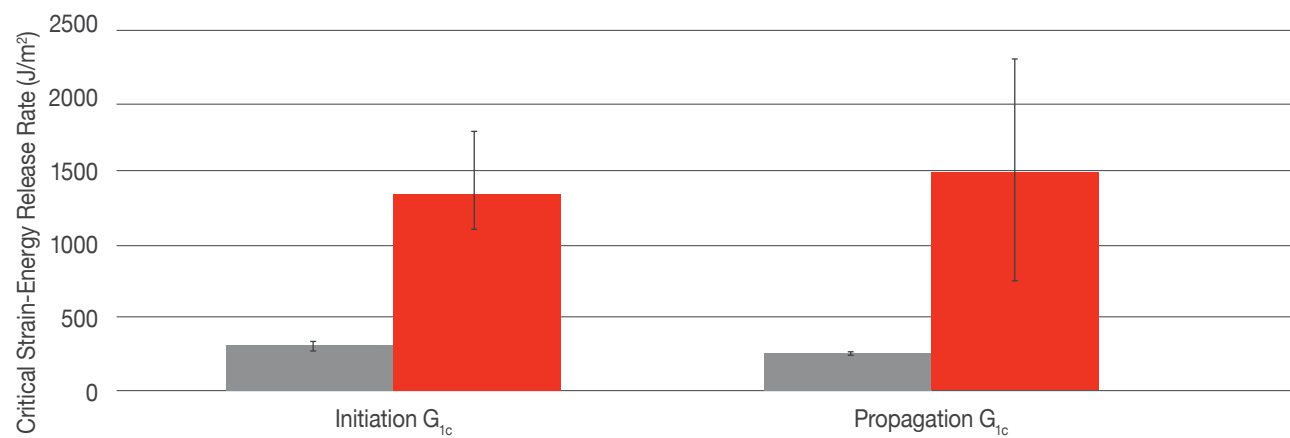
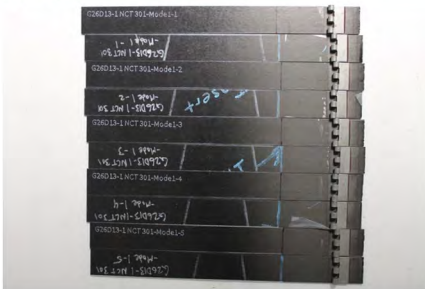


Figure 13. Mode I critical strain-energy release rate.
*Testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansa.

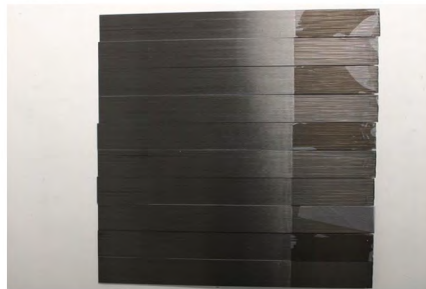
Metric	Prepreg Control	Prepreg Plus L-F620	Derived Multiple
Initiation G_{Ic}	303 ± 20 J/m²	1433 ± 278 J/m²	4.7
Propagation G_{Ic}	284 ± 11 J/m²	1499 ± 794 J/m²	5.3

DOUBLE-CANTILEVER-BEAM SPECIMENS AND FRACTURE SURFACES

Control Specimen
Prepreg-Only DCB



Control Fracture Surface
Prepreg-Only DCB



L-F620 Specimen
Interleaved DCB



L-F620 Fracture Surface
Interleaved DCB



L-F620 Specimen Detail
Interleaved DCB



L-F620 Surface Detail
Interleaved DCB

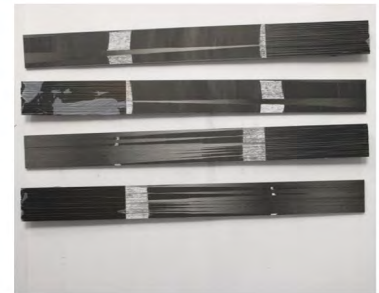


Figure 14. DCB specimens and fracture-surface evidence used to interpret the Mode I response.

PLACEMENT BECOMES THE NEXT COMPOSITE DESIGN QUESTION

The preceding data demonstrate that L-F620 is a tough thermoplastic adhesive film that can increase ductility, resistance to interlaminar crack growth and post-impact performance in the tested composite configurations. Each test used a placement architecture selected for its specific purpose: the Mode I specimen positioned one L-F620 film at the prescribed crack plane, whereas the short-beam and compression-after-impact panels evaluated fully interleaved laminates. These configurations demonstrate material behavior; they do not establish an optimum interface count or placement strategy.

The results instead lead to the next engineering question: where, and in what quantity, should L-F620 be incorporated to deliver the required structural benefit while managing mass, thickness and processing complexity? Optimal placement should be treated as an application-specific design objective governed by the load path, expected damage mechanisms, geometry, manufacturing constraints and service environment.

Candidate location*	Why it may be valuable	Minimum validation
Ply drops and thickness transitions	Interlaminar stress concentrations can initiate local delamination	Matched coupons or subcomponents with representative taper and manufacturing sequence
Free edges and geometric discontinuities	Edge effects can amplify peel and interlaminar stresses	Open-edge or feature specimens with digital image correlation and damage mapping
Expected impact zones	Local toughening may contain damage before compression loading	Drop-weight impact and CAI with local-placement maps and matched measured energy
Bonded-joint runouts or co-cured transitions	The load path moves between bondline and laminate interfaces	Representative joint geometry with peel-sensitive and fatigue loading
Selected laminate mid-plane or interface families	Specific interfaces may dominate Mode I, Mode II or mixed-mode growth	DCB, ENF or mixed-mode testing for each placement architecture

***Note:** The locations are proposed as candidates for future investigation, not as validated or recommended placement positions.

FUNCTION THREE : THERMOPLASTIC COMPOSITE RESIN MATRIX

In the bonding and interleaf applications, L-F620 remains a discrete film positioned between substrates or prepreg plies. A third potential use is for L-F620 to become the thermoplastic resin matrix surrounding dry fiber reinforcement.

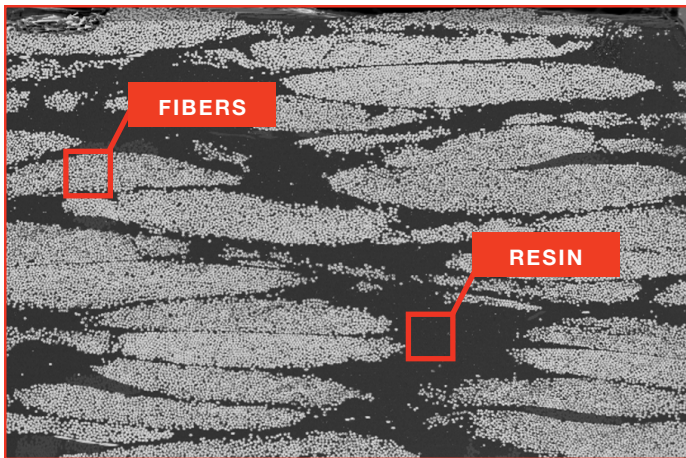
The CAMX presentation includes a representative cross-section described as S-2 glass composite wet-out using a 5 mil L-F620 film and 40 wt% reported resin content. In this specimen, L-F620 is functioning as the matrix rather than as an interleaf between already resin-bearing prepreg plies.

Because initially dry fibers must be impregnated rather than simply contacted by a film, this specimen represents an intentionally demanding—or extreme—proof of wet-out. Resin is visible around the reinforcement, and no obvious voids are visible within the inspected field.

The image provides qualitative evidence from one cross-section. It does not establish laminate-wide void content, impregnation uniformity, process repeatability or structural performance. The first development requirement for matrix use is therefore demonstrated locally: L-F620 can wet and surround dry reinforcement under the evaluated conditions.

Future testing should determine whether this result can be reproduced across complete laminates. A dedicated program should quantify fiber and resin content, porosity, impregnation uniformity, processing window and thickness stability before evaluating tensile, compressive, shear, interlaminar, impact, fatigue and environmental performance.

T-LINK® S-2 GLASS COMPOSITE WET OUT



- Ingredient in epoxy thermosets
- Thermoplastic adhesive
- Thermoset composite interleaf resin
- Thermoplastic composite resin matrix

Figure 15: Initial resin-matrix feasibility evidence showing representative L-F620 wet-out of dry S-2 glass-fiber reinforcement.

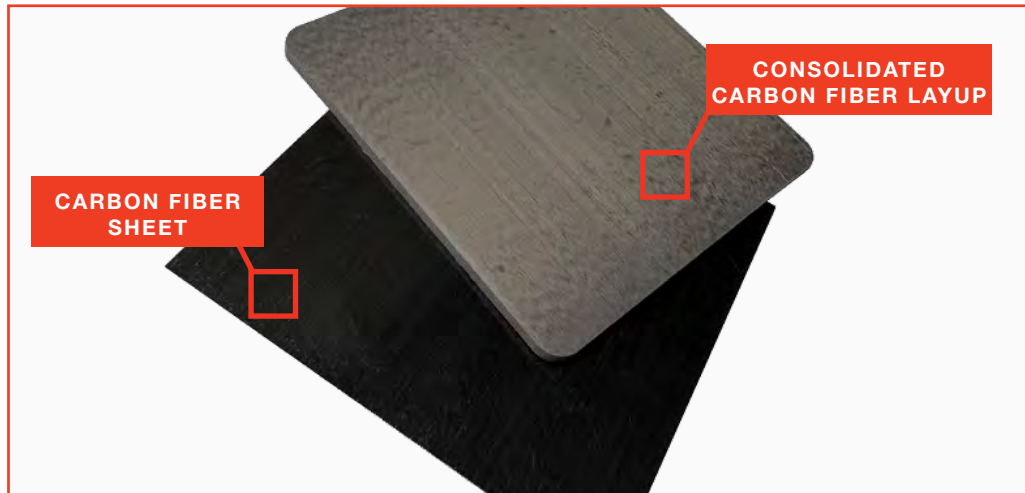
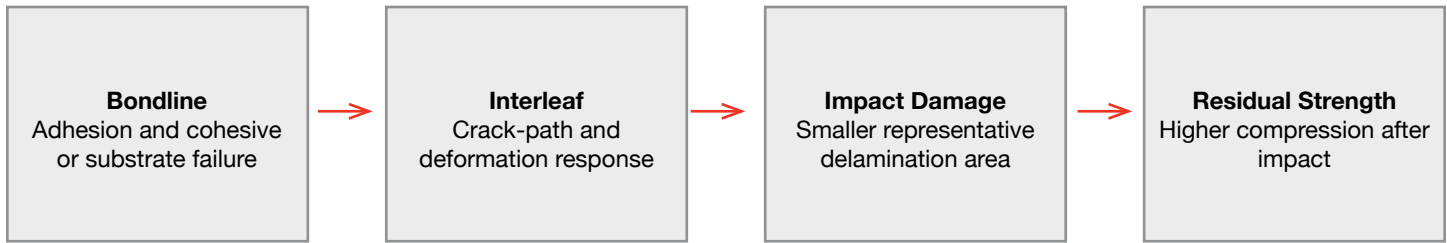


Figure 16: Consolidated carbon fiber layup and unidirectional carbon fiber sheet.

INTERFACE ENGINEERING CONNECTS THE EVIDENCE STREAMS



Bonding and interleaving are distinct applications of the same interface-focused material platform.

Figure 17: The evidence streams are consistent with an interface-engineering mechanism, while remaining specific to their individual test configurations.

The bonding data establish that the film can transfer load across prepared metal, thermoplastic-composite and thermoset-composite interfaces. The short-beam and Mode I results show that, within a laminate, the film changes deformation and crack-growth response. The ultrasonic maps show less extensive representative impact damage, and the CAI test connects that containment to a higher retained compressive capability.

This sequence is more informative than a collection of isolated percentages. It supports a coherent technical proposition: L-F620 is a thermoplastic material platform whose function depends on how it is placed and consolidated. Bonding and interleaving are mechanically tested uses, while the dry-fiber wet-out evidence opens a third development pathway in which L-F620 serves as the composite resin matrix.

CONCLUSIONS

- L-F620 has three potential uses: a thermoplastic adhesive bonding film, a thermoplastic composite interleaf film and a thermoplastic composite resin matrix. The first two are supported by mechanical testing presented in this paper; the third is supported by initial dry-fiber wet-out evidence and requires dedicated structural validation.
- Prepared 17-4 and Ti-6Al-4V metal joints reached 33 MPa apparent lap-shear stress with cohesive failure; hybrid Toray Cetex TC1225 LMPAEK-to-metal and Mitsubishi NCT301 TR50S -to-metal joints were limited by composite substrate failure at 19 and 16.9 MPa, respectively.
- A 32-ply Mitsubishi NCT301 TR50S laminate with 1 mil film at all 31 interfaces showed 66% higher CAI strength than the prepreg-only control under the reported conditions.
- Representative post-impact damage areas were approximately 69% smaller at two nominal levels, despite higher measured impact energies for the corresponding L-F620 specimens.
- One center interleaf increased mean Mode I initiation and propagation G_{Ic} by derived multiples of 4.7 and 5.3, while the high propagation scatter demonstrates the need to report variability and crack path.
- Short-beam evidence shows a more progressive response with a slight normalized-strength reduction, making interface count and placement an optimization problem rather than a one-direction performance claim.
- The single-interleaf Mode I specimen and the fully interleaved short-beam and CAI panels should not be interpreted as placement endpoints. They are separate test architectures designed to evaluate different aspects of material behavior. Determining where and how much L-F620 to use requires a dedicated placement study for the intended composite system and load case.
- The dry S-2 glass-fiber cross-section provides an intentionally demanding proof that L-F620 can wet and surround dry reinforcement within the inspected region. It should not be interpreted as laminate-wide consolidation or structural-performance evidence.

INSIGHTS FROM COMPOSITES INDUSTRY SURVEY

During National Composites Week, L&L Products asked the composites community where future performance improvements were most needed. Among the 12 respondents to the detailed website survey, eight selected interlaminar performance as a property they would significantly improve, while nine identified interlaminar materials and interfaces as an opportunity for innovation.

These findings are directional rather than statistically representative. They do not validate a particular product or material solution. They do, however, identify a recurring engineering question: if laminate performance is frequently limited by what happens between the layers, can that region be engineered without reformulating the entire composite system?

[READ THE SURVEY REPORT >](#)

CLOSING PERSPECTIVE

The technical value of Toughened T-Link is not that one film produces one universal number. Its value is that the same formable thermoplastic layer can be deployed at the interface scale that controls the structure—between components, between plies or eventually within selected high-risk zones. The scientific task is to preserve the failure-mechanism benefit while minimizing added material and process burden. That is a tractable, testable design problem.

For an application review, define the substrate or prepreg, target interface, film thickness, processing window, governing load case and environmental conditions before selecting the validation sequence.

ABOUT TOUGHENED T-LINK

Toughened T-Link® is a composite-performance solution built on the T-Link® platform. It combines thermoplastic processing, adhesive functionality and configurable interlaminar placement. Application development should begin with the target reinforcement, resin or prepreg, surface condition, processing cycle and governing structural requirement.

Technical information and application contact tlink.llproducts.com/toughened-composites/

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Don Paquet is a Senior Scientist at L&L Products with over thirty years' experience in the polymer industry. In this technical paper, he brings together research on materials science to demonstrate the efficacy of using Toughened T-Link® as a thermoplastic component in composite structures. The paper, presented at CAMX 2026, provides a baseline for the next set of engineering questions: where L-F620 should be placed, how much material is required and which validation methods are needed for a specific composite system.

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