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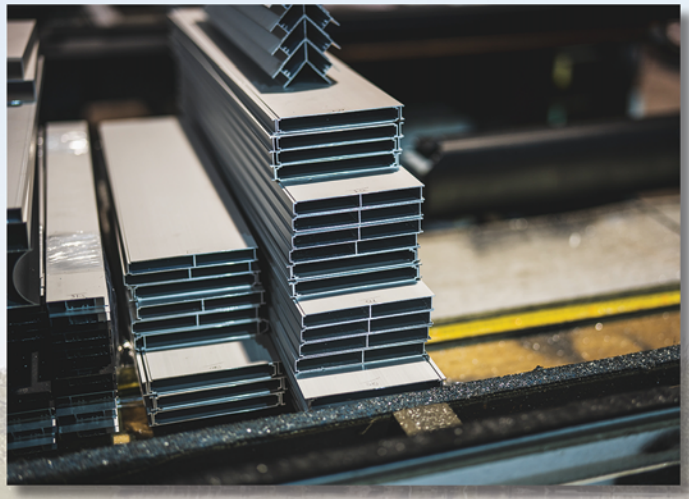
Adhesive Guide for Bonding Aluminum in OEM Assembly Applications



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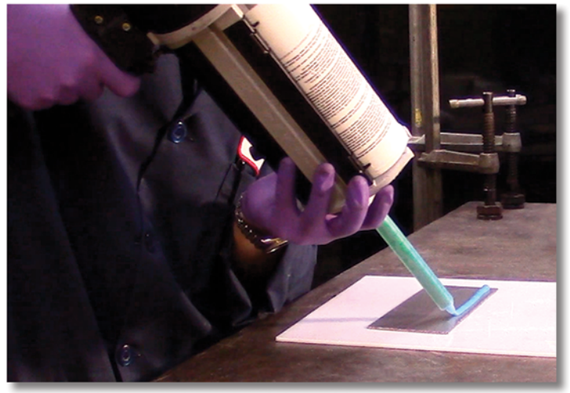

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1. Plexus Adhesives for Metal Bonding

This guide is intended as a resource to help manufacturers implement Plexus structural adhesives in their designs and assembly. This guide is intended to provide fundamental and important considerations in aluminum bonding. For specifics, please reach out to the sales and engineering teams at Plexus for additional answers and insights. Contact us at: itwperformancepolymers.com/contact-technical-service.

Plexus structural MMA adhesives have a long history of providing durable structural bonds to aluminum and other metals. These advanced adhesives have been qualified under rigorous automotive & transportation specifications & performance requirements and have a long history of success in the field.

1.1 Why Partner with Plexus?

Plexus adhesive systems include a range of advanced structural & semi-structural adhesives that help improve manufacturing and assembly techniques & processes. We believe our continued success is not only due to our unique formulations but also the importance we place on building solid & lasting relationships with our customers and recognizing the need to fully understand all aspects of their bonding requirements. The benefit is a philosophy of customer-backed innovation, creating solutions to meet our customers' specific needs.

Our wide range of advanced adhesive products are suitable for bonding the vast majority of composites, thermoplastics, metals and dissimilar substrates. The end result is a durable bond that is capable of withstanding harsh environmental & service conditions with minimal or no surface preparation. Our commitment to quality is embedded in every adhesive system we produce, providing our customers with confidence in reliability & consistency of our products.

Value Add Services to the Customer

- Expert Consultants – providing technical information and details to help solve engineering and processing issues at the manufacturing locations.
- Technical Support from idea to production – helping bring new product or design ideas to commercialization and provide after-sales support.
- Local Resources – Local sales managers that provide fast, professional expertise, supported by a wide distributor network with local inventory.
- Guaranteed quality certified ISO 9001.

Technical Support

- Technical Service Engineers to help test various adhesive systems.
- Equipped technical service lab to provide technical reports, application, and product testing.

1.2 Key Products and When to Use Them

Plexus offers a variety of adhesives, including, but not limited to the below selection, for bonding aluminum:

Product	Description	Working Time min.	Fixture Time min.	Tensile Strength psi (MPa)	Tensile Elongation %	Maximum Gap Fill in. (mm)	Part A Viscosity, cP * 10^3	Part B Viscosity, cP * 10^3
MA205HV	Primerless to Aluminum Ultrafast Fixture Time	3 - 5	7 - 9	2,000 - 2,500 (13.8 - 17.2)	20 - 50	0.25 (6.4)	100 - 130	15 - 50
MA830	Primerless to Aluminum, High Strength	4 - 6	15 - 25	3,200 - 3,800 (22.0 - 26.2)	30 - 60	0.5 (12.7)	80 - 120	35 - 80
MA832	Primerless to Aluminum, High Strength	12 - 16	55 - 60	2,700 - 3,000 (18.6 - 20.7)	30 - 60	0.5 (12.7)	80 - 130	35 - 80
MA8105	Next Generation Multi-Material Bonder, Low Odor	3 - 6	12 - 16	3,000 - 3,500 (21.4 - 24.1)	20 - 40	0.5 (12.7)	70 - 140	50 - 120
MA8110	Next Generation Multi-Material Bonder, Low Odor	8 - 12	35 - 50	3,100 - 3,600 (21.4 - 24.8)	40 - 70	0.5 (12.7)	40 - 70	40 - 70
MA8120	Next Generation Multi-Material Bonder, Low Odor	18 - 22	75 - 90	2,500 - 3,000 (17.2 - 20.7)	50 - 80	0.5 (12.7)	40 - 80	80 - 120
MA530	Highly Thixotropic, High Toughness	30 - 40	90 - 160	2,500 - 3,500 (17.2 - 24.1)	90 - 160	0.7 (18)	130 - 180	160 - 215
MA2230	Low Shrink, Highly Thixotropic, High Toughness	25 - 35	70 - 90	2,000 - 2,800 (13.4 - 19.3)	>60	1.5 (38)	180 - 220	35 - 70
MA2245	Low Shrink, Highly Thixotropic, High Toughness	40 - 45	100 - 130	2,000 - 2,800 (13.4 - 19.3)	>60	1.5 (38)	180 - 220	35 - 70
MA2290	Low Shrink, Highly Thixotropic, High Toughness	80 - 110	170 - 215	2,000 - 2,800 (13.4- 19.3)	>60	1.5 (38)	180 - 280	35 - 70

When selecting a Plexus structural adhesive, we must make sure the adhesive fully bonds with and is compatible with the substrates. The next factor to consider is "open-time," or the time needed to dispense the adhesive, and put the two parts together. Other considerations in selecting a suitable adhesive include the gap-filling capability and cross bonding compatibility with other materials.

The sales and engineering teams at Plexus are available to help narrow down the adhesive selection and provide additional insight. Please contact us at: itwperformancepolymers.com/contact-technical-service.

2. The Plexus Adhesive Difference

Manufacturers return to Plexus time and again to help speed up production and create more robust, durable, and longer-lasting parts. Plexus products stand out from the competition in several crucial ways, notably:

Save Time & Money

Improve Durability

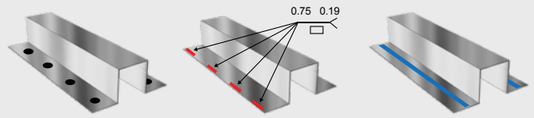
Ease of Use

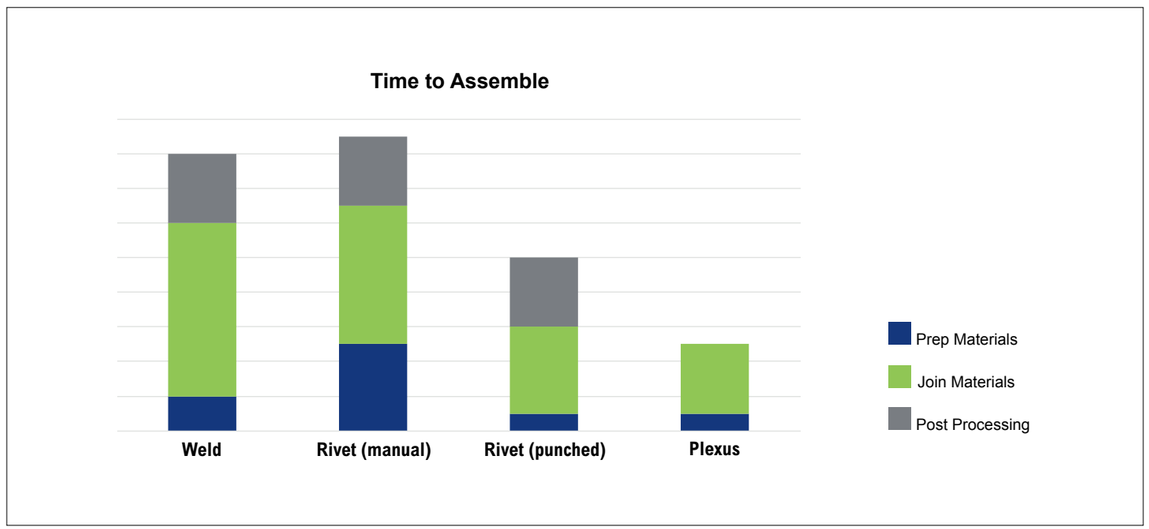
2.1 Reducing the Cost to Assemble

Plexus adhesives are used to lower cost of assemblies by combining fast dispensing and “snap-cure” strength development. Plexus adhesives are among the most cost-effective joining methods considering the joint strength versus cost per joined unit surface area. Reducing the number of manufacturing steps also contributes to significant cost savings.

Riveting is a multi-step process that often requires additional sealing steps. By switching to Plexus adhesives, you eliminate drilling holes and subsequent sealing steps.

Stitch welding also often requires secondary sealing, and a majority of welding requires secondary grinding to create a smooth, clean surface.





2.2 Improved Durability

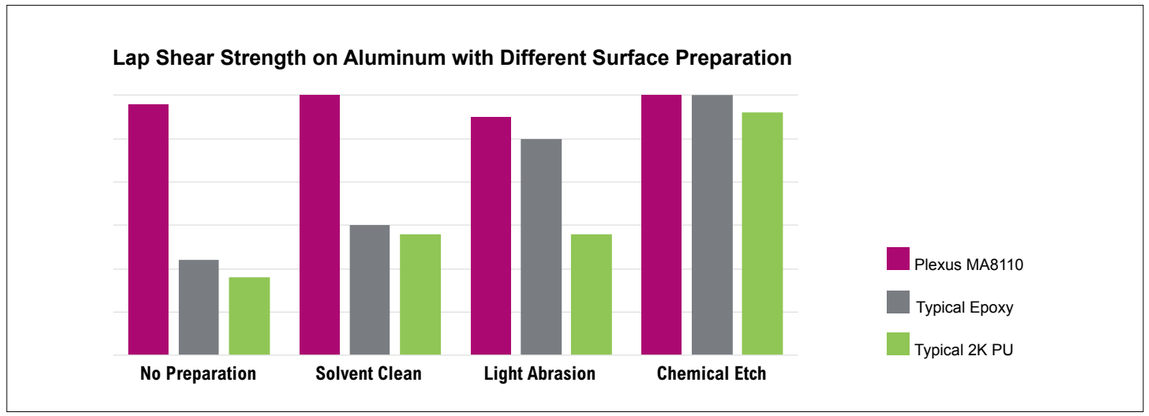
Plexus adhesives are highly toughened systems that provide both high strength & elongation. These properties distribute stress, absorb impacts, and enhance fatigue resistance. When combined with continuous joining and sufficient surface area, the results are macrostructures with outstanding durability.

Plexus adhesives used in transportation applications have survived millions of miles on the road. Similar durability has been achieved in the fiberglass boat industry, with many boats that are 20-plus years old still in service. The added benefit of being able to join & seal in one step means no holes are required, nor are there heat-affected zones caused by welding, thereby reducing the potential for leaks.

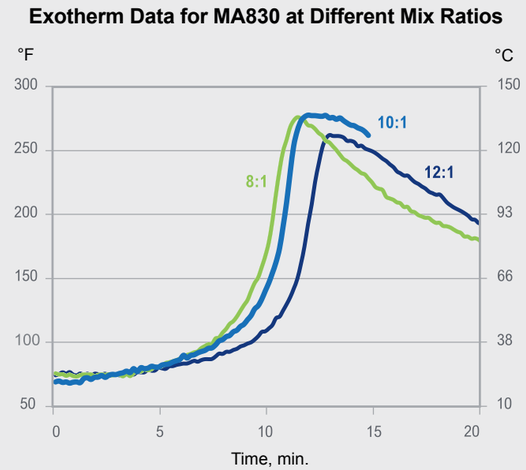
2.3 Ease of Use

Though all adhesives require a clean, stable surface for good adhesion, Plexus adhesives achieve robust adhesion over a broader range of surface conditions than other adhesive chemistries. For example, Plexus adhesives reduce labor costs by limiting the time spent on surface preparation.

Many Plexus products offer primerless adhesion to aluminum, meaning they bond “as-is” on lightly oxidized aluminum (but may require some abrasion on heavily oxidized aluminum – see surface preparation section for more information). The graph below shows Plexus MA8110 compared to other chemistries on aluminum with different surface preparations:



Plexus adhesives will also cure fully even when mixed off-ratio – which is very different from 2-part urethane or epoxy technology. Most Plexus adhesives are non-sag and dispense quickly on vertical surfaces without issues. Specific Plexus formulas have better non-sag properties, but all formulas have excellent shear-thinning properties that make them easy to dispense, mix, and apply.



2.4 Advantages and Disadvantages of Plexus Structural Adhesives

2.4.1 Advantages

Improved Stress Distribution
Plexus adhesives are highly toughened, providing excellent stress distribution over long continuous connections.

Mixed Material Joining
Plexus adhesives can bond dissimilar materials without primers – including aluminum, coated steel, composites, and most amorphous thermoplastics. The high elongation offered by Plexus adhesives can handle the difference in thermal expansion from dissimilar materials.

Gap Filling
Dimensional tolerances can change and the distance between parts can vary. Plexus adhesives are thixotropic and non-sag, meaning they will fill in the gaps between parts and remain in place during curing.

Fast Application Speeds
Structural adhesives can be dispensed and applied faster than a weld or rivet.

Clean Aesthetics
No holes are required in substrates. Weld marks are not generated using Plexus adhesives.

Join & Seal In One Step
Structural adhesives create structural bonds that are watertight. By distributing stress, assemblies are less prone to stress cracking, leading to a reduction in leak potential.

Single-Sided Access
Some weld areas or rivet locations can be challenging to access. Adhesives can be applied to one side of an assembly having the other surface joined later. Single-sided access is a major benefit to assembly lines.

Excellent Fatigue Properties
Plexus adhesives are highly toughened systems that utilize core-shell technology. Core-shell technology significantly reduces crack propagation, resulting in significant improvements to fatigue behavior. Depending on the gauge and grade of aluminum, the metal will fail in fatigue before the Plexus adhesive.

2.4.2 Disadvantages

Sensitive To Peel Forces
All adhesives have limited peel strength. Designs should consider this and minimize peel forces on the joints, by shifting forces into compression and shear loadings.

Dependent On Surface Cleanliness
Although structural adhesives provide excellent primerless adhesion and can cut through light contamination, the best practice is to remove surface contamination. We recommend abrading heavily oxidized aluminum and following up with a solvent wipe before bonding.

Often Requires Fixtures During Curing
Parts need to be fixtured in place as the adhesive cures, in contrast to the instant fixture a weld or rivet provides. The need for clamping requires a shift in workflow, that when properly implemented, usually leads to overall time savings.

Limited High Temp Properties
Adhesives are primarily organic polymers, which soften when heat is applied. This property can limit their usage in specific applications that are exposed to continuous high heat (>250°F, 120°C).

Difficult To Disassemble
Structural adhesives are incredibly strong & tough, meaning they can be challenging to disassemble when fully cured. Though bonded assemblies may need repair much less frequently than other joining methods, systems that need routine disassembly may require other joining techniques.

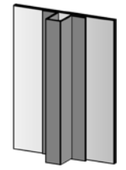
Fast application with Plexus adhesives


Welding requires specialized equipment and skill set

3. Potential Applications

3.1 Reinforcement Bonding

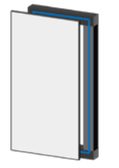
Many manufacturing methods benefit from bonding on stiffeners or ribs with Plexus adhesives. Plexus bonds a wide range of materials with little to no surface preparation. The final assembly benefits from the stress distribution, high strength and elongation that Plexus provides.



Plexus Benefits
- Clean Aesthetics
- Excellent Stress Distribution
- Fast Dispense and Joining Speeds
- Improved Durability

3.2 Panel Bonding

Many markets produce products by joining panels to frames. Design engineers like that Plexus joins material substrates. Manufacturing enjoys how easy, non-sag and fast Plexus is to use. The end results are strong, robust structures.



Plexus Benefits
- Clean Aesthetics
- Reduce Chance of Leaks
- Mixed Material Joining
- Improved Durability

3.3 Rivet Replacement

Plexus has successfully replaced rivets and other mechanical fasteners in a wide range of applications. Plexus adhesives result in uniform stress distribution. In addition, bonding with Plexus reduces a multi-step assembly process (hole, place, pop, seal) to a single step (bond with Plexus).

Plexus Benefits
- Improved Durability
- Faster Throughput
- Better Worker Safety
- Lowered Cost of Assembly

3.4 Weld Replacement

Plexus has successfully replaced welding for multiple applications. Companies see a huge reduction in time and labor costs, while maintaining strength. Plexus provides distinct advantages when welding thin metal to thick metal, as there is not weld marks, warping or heat-affected zone (HAZ).

Plexus Benefits
- Lower Cost of Assembly
- Enhance Design Flexibility
- Not HAZ or Heat Distortion
- Eliminate Weld Marks

4. Design Recommendations

Every project is unique in its complexity and requirement. This section provides basic information about designing assemblies to be bonded with Plexus adhesives. The sales and engineering teams at Plexus are available to discuss your project needs. Please reach out to us at itwperformancepolymers.com/contact-technical-service to discuss your aluminum bonding project.

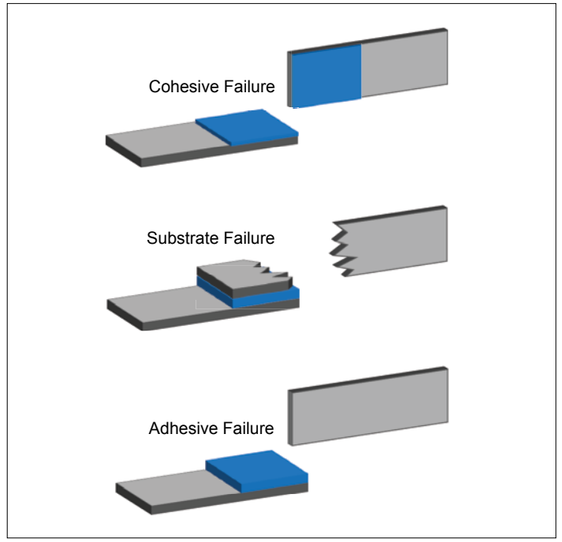
4.1 Failure Modes

As part of your joint design consideration, it is important to understand the failure modes of joints of adhesively bonded aluminum.

Cohesive Failure
In this mode, the adhesive remains bonded to both substrates and the failure occurs within the body of the adhesive itself. Cohesive failure is desirable because it implies that the bond to the substrate is stronger than the internal cohesive strength of the adhesive itself, and that it is possible to more accurately predict the stress needed to cause the joint to fail.

Substrate Failure
Substrate failure happens when the material being bonded fails, and neither the adhesive itself, nor the bond between the substrate and the adhesive is affected. Substrate failure can happen when using thin-gauge aluminum or bonding aluminum to other weaker substrates like thermoplastics or fiberglass.

Adhesive Failure
Adhesive failure occurs when the bond between the adhesive and one or both substrate materials is broken, or as shown the adhesive comes cleanly off one substrate. When a test results in adhesive failure, an alternative adhesive or surface treatment may change the failure mode.

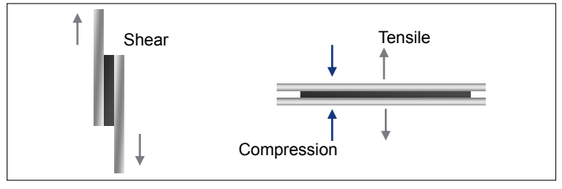


4.2 Types of Stress

Shear
Load is applied to the plane of the joint, allowing the adhesive to distribute stress across the surface.

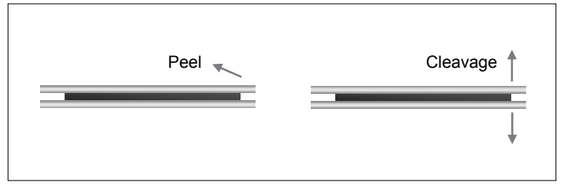
Compression
Load is applied perpendicularly into the adhesive joint.

Tensile
The load is applied perpendicularly away from the adhesive joint.



Peel
Peel occurs at the leading edge of a joint when at least one substrate is thin, or fixed, concentrating the stress linearly. Joint configurations should be designed to minimize peel stress. If peel stress cannot be avoided, a fastener at the leading edge can help reduce stress.

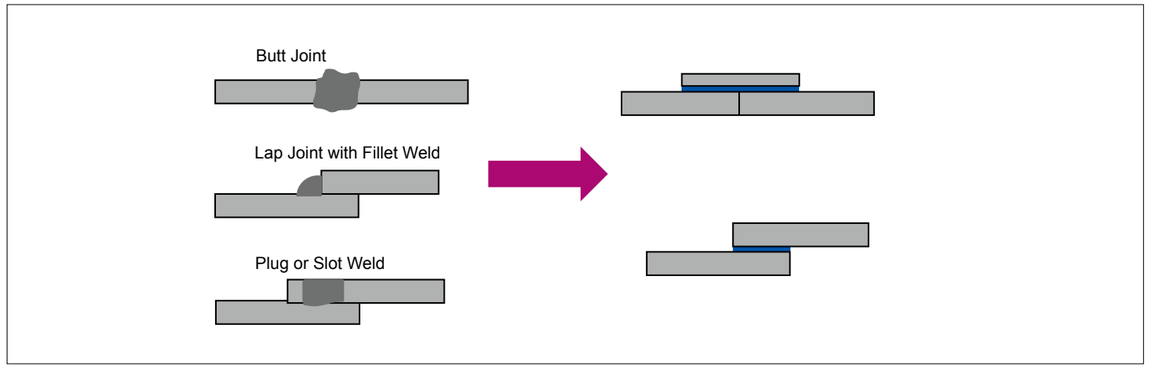
Cleavage Peel
Cleavage acts to separate the edge of two substrates and concentrates stress to a small area. Design engineers should take care to minimize cleavage stress. If cleavage stress cannot be avoided, a fastener at the leading edge can help reduce stress.

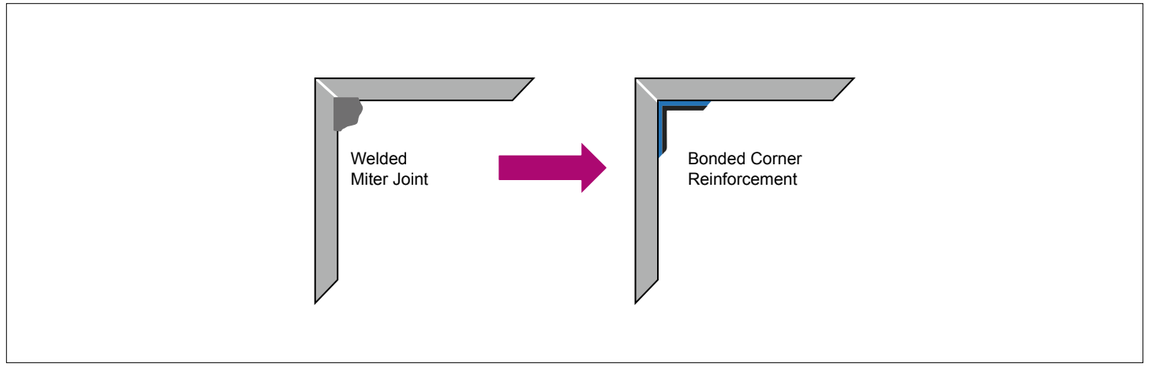


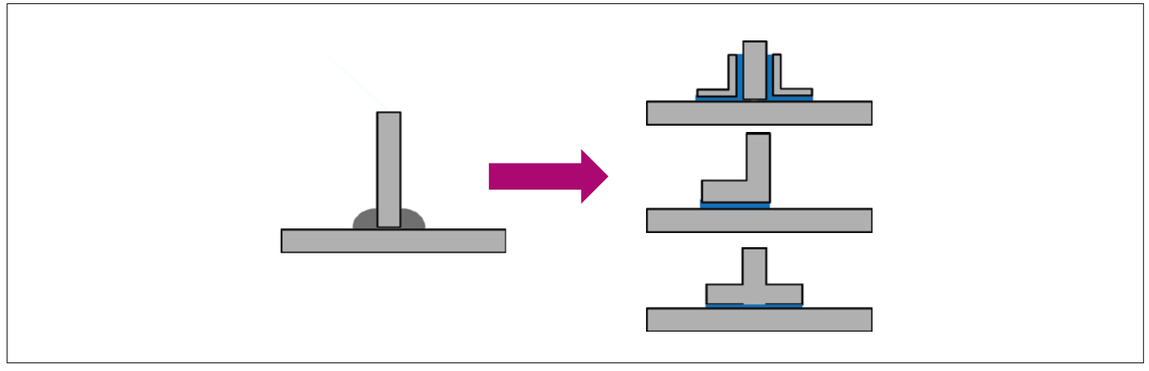
4.3 Converting MIG or TIG Welds to Adhesive Bonding

Joints designed with structural adhesives require overlap. However, metal inert gas (MIG) or tungsten inert gas (TIG) can get away with more limited contact points/areas.

Because of this, butt, mitre, and “T” joints must be modified for adhesive usage. Below are typical weld joints converted to adhesive-friendly configurations.







To determine the amount of adhesive required to replace a welded assembly, you need to know the weld shear strength and total weld length. Weld shear strength can be tested via tensile lap-shear or derived from a theoretical calculation. There are two main methods for calculating weld-strength:

Fillet Weld Strength
Weld wire manufacturers often provide a chart of shear strength per length of weld depending on the fillet size.

Metal Strength Heat Affected Zone (HAZ)
It is possible to calculate the shear strength per length needed to tear the metal, but it is important to use the metal's heat-affected zone strength, not the base metal properties.

An example theoretical calculation:

$$T_w = L_w \bullet t \bullet \sigma_{HAZ}$$

T_w = Weld joint strength
L_w = Total length of weld
t = Thickness of thinnest metal
σ_{HAZ} = HAZ Tensile shear strength of metal

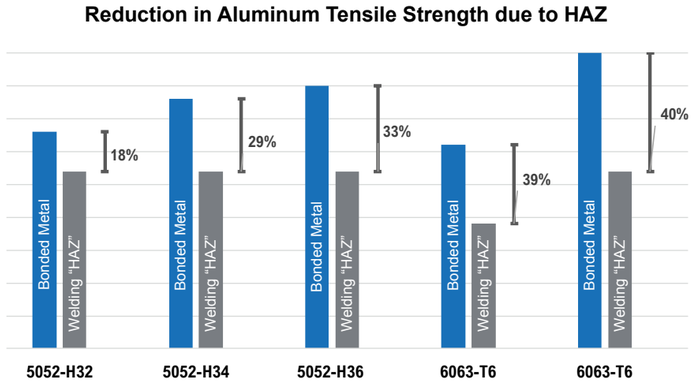
To calculate the overlap required, the following is commonly used:

$$\text{Adhesive Overlap} = T_w / (L_t \bullet \sigma_{ADH})$$

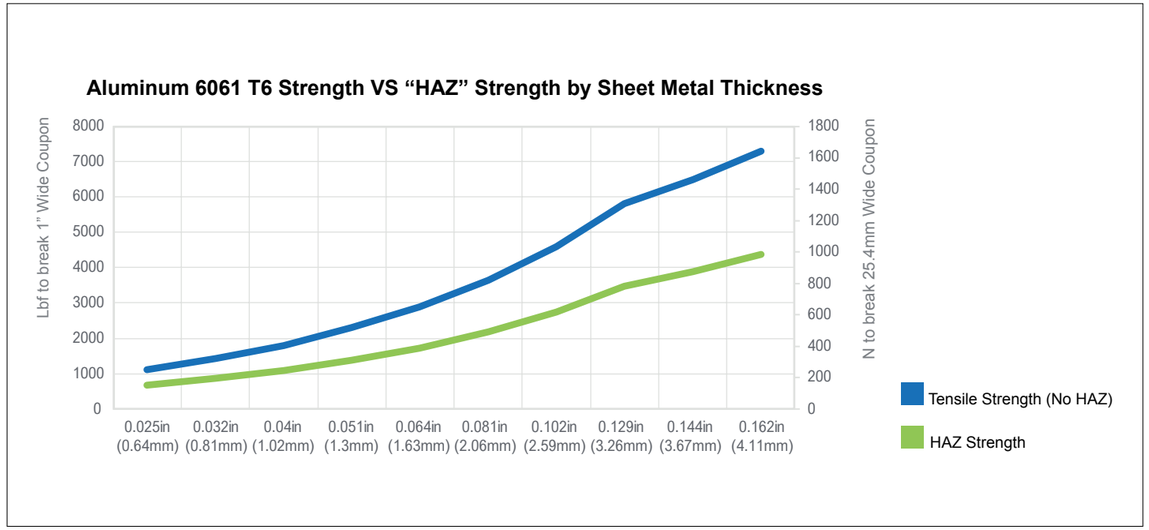
T_w = Weld Joint Strength
L_t = Total Length of Flange
σ_{ADH} = Tensile shear Strength of Adhesive

It is necessary to use the shear strength of the adhesive at the operating temperatures intended. All adhesives become weaker at higher temperatures. For example, if an assembly is exposed to 120°F (50°C), the lap-shear value of the adhesive at 120°F (50°C) should be used.

As mentioned above, an additional benefit of Plexus adhesives is the elimination of heat-affected zones (HAZ). Manufacturers often need to use thicker gauge aluminum to counter the reduction in strength caused by HAZ.



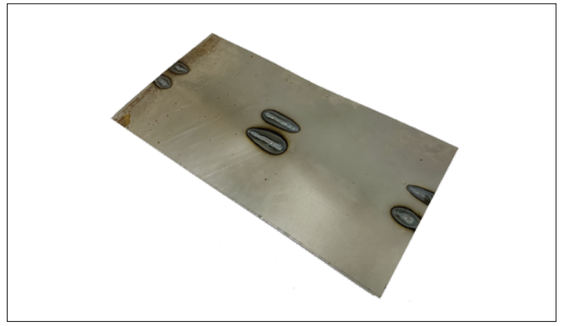
Lightweighting Potential
Structural adhesive bonding eliminates burn through potential and does not create HAZ. If there is sufficient surface area to use a Plexus adhesive, a large amount of aluminum can be down-gauged for significant mass & cost savings.



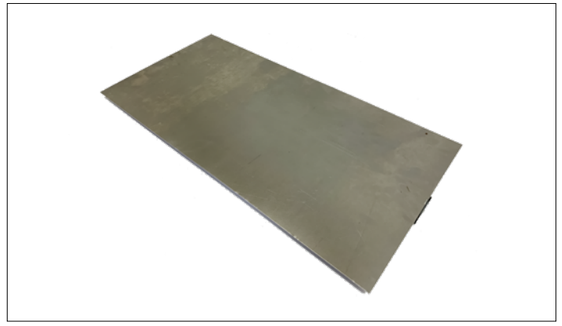
During durability tests, if the welded joint or the area around the weld is what fails, then switching to adhesive bonding, and down-gauging the metal is often an option. Look at the chart above, take the gauge of metal that is being welded and then match the equivalent strength of the blue line. That will give an indication of the possible gauge reduction that can be achieved.

Process Consideration
Often, time is lost grinding out weld marks and/or adjusting warped metal due to the welding heat. Switching to Plexus structural adhesives can eliminate those steps. Eliminating these downstream steps should be taken into consideration when building out a process workflow.

Aesthetics: Welded Panel vs Bonded Panel



Grinding required to eliminate weld marks for smooth finish



Clean finish with Plexus bonded panel

4.4 Converting Riveted Joints to Adhesive Bonding

Compared to welding, converting from rivets to Plexus adhesives is more straightforward. Most blind rivets come with documented shear strength. The vast majority of Plexus products are significantly stronger than the rivet shear strength and connect more surface area, more efficiently distributing stress and enhancing assembly durability and performance.

Rivets are point loads and require holes in the aluminum. These point loads cause stress cracks and increase the potential for leaking. Plexus adhesives help eliminate all of these.

4.5 Hybrid Joining Options

Hybrid joining techniques are often a combination of adhesive bonding with some other joining method for fast fixturing. For example, when an assembly cannot use fixtures, apply a bead of Plexus adhesive and then place a rivet at either end to hold the assembly in place as the adhesive cures. Tack welds are sometimes used, but care must be taken to keep the adhesive bead sufficiently away from the weld area to reduce flammability risks.

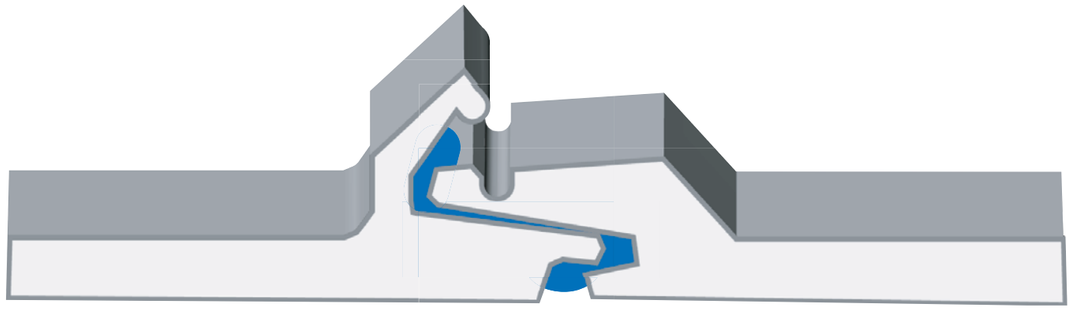
4.6 Aluminum Extrusion Designs

There are many creative design options for aluminum extrusions. In particular, designs that incorporate locking hooks that can be hammered or rolled into place provide a mechanical fixture as the adhesive is curing. (See figure below from Sapa's Bonding Aluminum Guide)

Other extrusion designs can show additional benefits such as:

- Self-aligning or self-fixturing.
- Adhesive "traps" that collect excess adhesive squeeze out.
- Channels or offsets that allow for injection or adhesive placement.

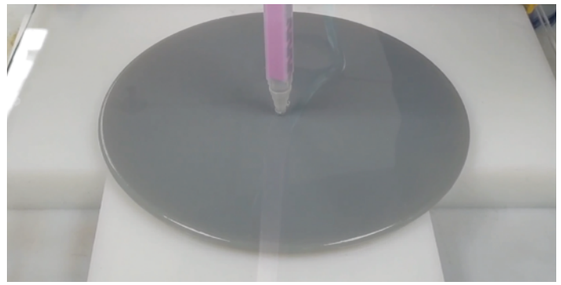
Feather and groove extrusion with locking. Lock hook is hammered or rolled into place while adhesive cures.



4.7 Injection-Style Joining

Plexus adhesives are often used successfully in injection applications, where they are pumped into one or more injection points to fill an engineered gap. It is essential to have exhaust ports to allow displaced air out and see that the adhesive fills the area. Setting the correct interval from around 0.04 – 0.08" (1-2mm) is crucial to allow good flow.

Injection-style bonding is beneficial when used as a hybrid bonding technique (see above section 4.5). Here channels can be riveted or welded to fix them in place and Plexus adhesives can be injected quickly into the gap.



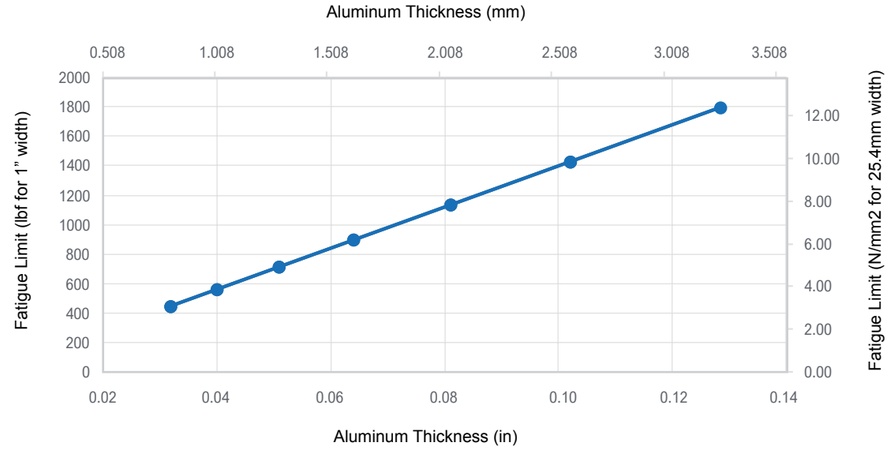
Example of Plexus injected between clear plastic

4.8 Fatigue

Unlike steel, aluminum does not have an endurance limit. However, it does have a fatigue limit. Fatigue limits for aluminum are typically a percentage of tensile strength. Specific grades of aluminum have higher limits, such as 5052 with a fatigue limit of 47%. Other grades don't perform as well, like 6061-T6, with a fatigue limit of 31%.

Plexus adhesives tend to have a fatigue limit around 50% of their ultimate shear strength. This fatigue limit is significantly higher than rivets, which create point loads. They also tend to have better fatigue resistance than welding since welding can weaken the metal in heat-affected zones.

Fatigue Limit per Inch (25.4mm) Depending on Metal Thickness of Aluminum 6061 T6



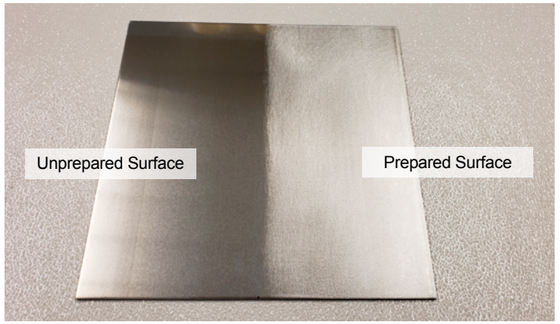
5. Assembling & Manufacturing with Plexus Adhesives

5.1 Surface Preparation

All structural adhesives stick to the outer surface of the two materials they are joining. Surface preparation or proper wetting out is critical for any successful bonding application. Many Plexus adhesives are designed for primerless adhesion to aluminum and can cut through some mill or stamping oil. It is always best practice to ensure a reliable surface to bond to. For fresh aluminum with minimal oxidation, use a clean rag and solvent to clean the surface.

In the event the aluminum is heavily oxidized or the final part is expected to be exposed to long term environmental conditions, surface preparation or removal of the oxide layer is important. Regardless of the process followed, it is good practice to measure the surface energy before and after to validate surface optimization. Advanced (and expensive) surface conditioning such as acid etching is often not required with Plexus MMA adhesives.

Lightly Abrading Aluminum to Prepare for Bonding



Aluminum "as is" and scuffed

Close up of "as is" and scuffed aluminum

Anodization is another way to treat aluminum for long-term durability. This treatment stabilizes the oxidative layer on the aluminum and Plexus in general bonds very well to this surface. There are multiple variations of anodization, so we recommend testing the exact version of anodized aluminum to verify a robust adhesive bond.

5.2 Dispensing

Plexus MMA adhesives are two part systems, where the mixing of Part A with Part B starts the chemical reaction. Mixing through a mixing tip (or static mixer) is the best practice. After mixing, the adhesive has an "open time" – the time to place the adhesive and join the two parts. Open time is affected by temperature, with warm temperatures resulting in shorter open-times, and cold temperatures in longer open-times.

Dispense rates vary depending on adhesive, the dispenser used, and mix tip configuration. In general, Plexus MMA adhesives dispense very quickly. Most versions are non-sag, meaning they do not slide down on vertical surfaces.

5.3 Clamping

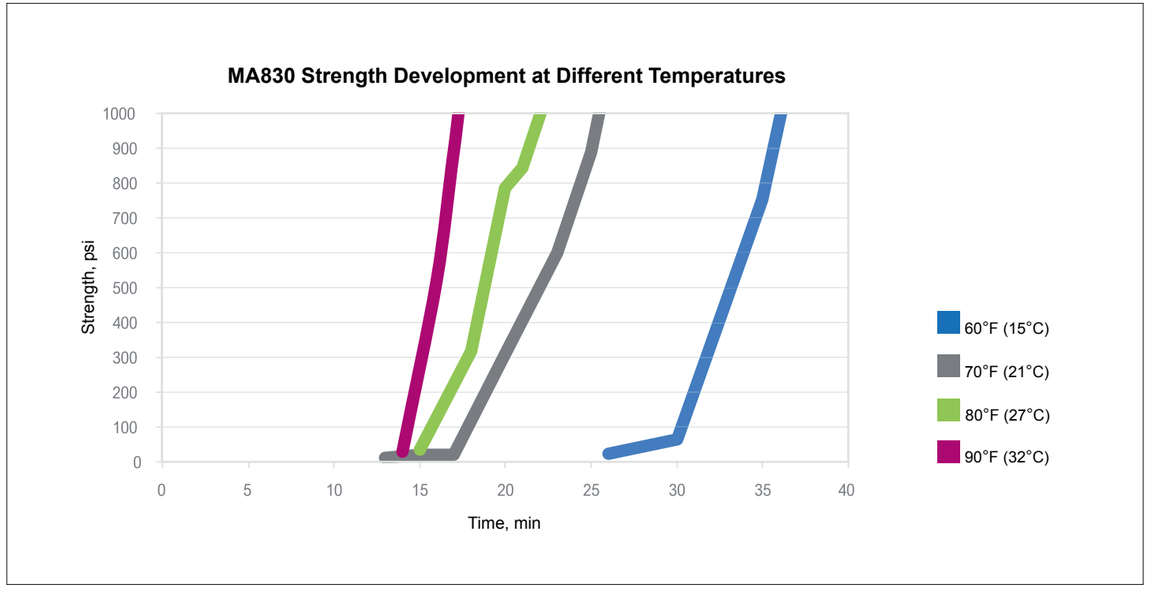
After dispensing Plexus MMA adhesives and joining the two parts together, the assembly must be clamped until the adhesive sufficiently cures. The amount of strength required depends on the application, size/mass of the parts, and what happens next in the assembly process. Some light parts only require a few psi (MPa) of strength, whereas large assemblies might need a great deal of force.

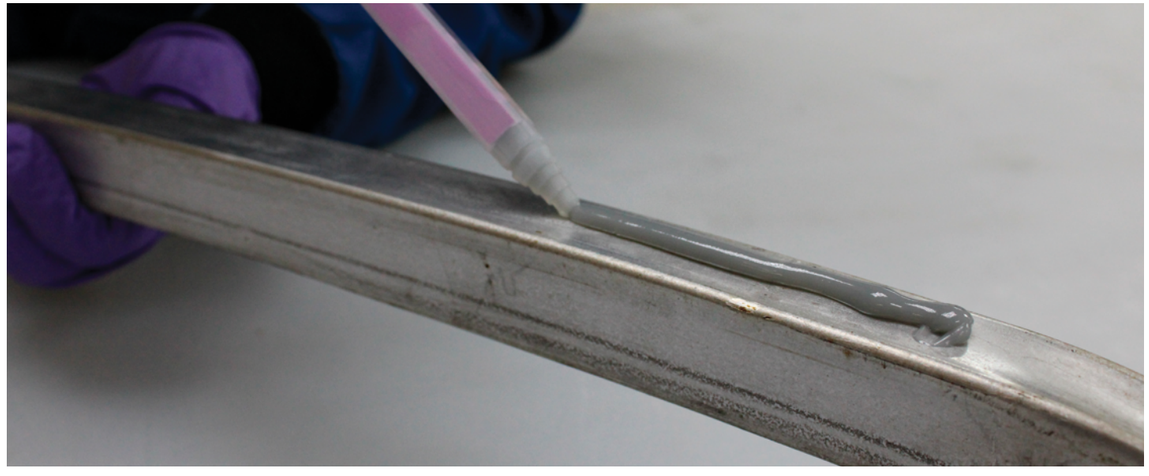
There are multiple methods for clamping parts as the adhesive cures. C-clamps or custom-built clamp systems are common methods for holding assemblies in place. As mentioned above, hybrid joining with fasteners used as a clamp are another method. Ideally, close to uniform pressure helps wet out the adhesive to a predetermined bond line thickness.

5.4 Curing

Plexus MMA adhesives cure via a free radical reaction, building strength quickly at room temperature. Cure rates are affected by ambient temperature but not humidity. Heat accelerates curing, but there is a maximum threshold for heating MMA adhesives (typically around 150°F or 65°C). A complete cure can take a day to a week at room temperature, but only a portion of the full cure is required to finish the assembly for most applications.

Additionally, they can tweak reactivity by changing the mix ratio. Most formulas can handle ±20% off-ratio, with some 1:1 Plexus formulas that can take greater off-ratios. Please consult with the technical service team at ITW Performance Polymers (itwperformancepolymers.com/contact-technical-service) to help answer any additional questions regarding curing.

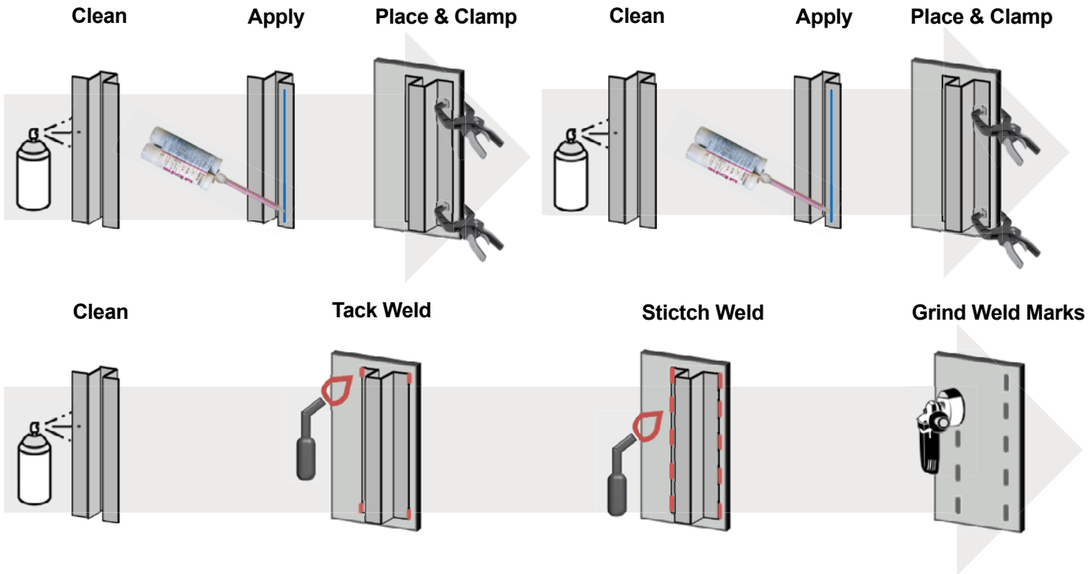




5.5 Changes in Assembly Workflow

Using a structural adhesive may be new to many. Understanding how they function and their benefits are important in order to assure an optimized new work flow process. Riveting and welding produce an instant fixture point. However, dispensing a Plexus adhesive can be applied 10-20X faster than welding. Aligning the work flow to account for the characteristics of the adhesive can result in higher and more efficient workflow. Adhesives can help create twice as many parts in the same time frame as welding.

Typical Workflow Differences Between Plexus (top) and Welding (bottom)



6. Testing and Verification

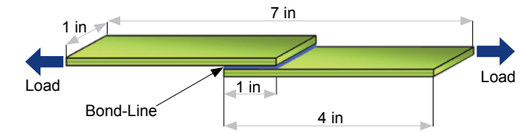
ITW Performance Polymers has regional testing laboratories for screening adhesive performance for different substrates. The lab tests uses small-scale coupons of substrates.

Larger scale prototypes are typically done at the manufacturer, based on the manufacturers' internal test methods.

6.1 Lap-shear

Adhesive lap-shear testing via ASTM D1002 highlights the strength of an adhesive bond under shear loading. This is an industry standard test that allows adhesives to be compared side-by-side and allows for analysis of bond failure modes. Bonded test coupons are loaded into a testing frame and pulled at a standard rate as shown below.

Schematic of a Lap-Shear coupon under load



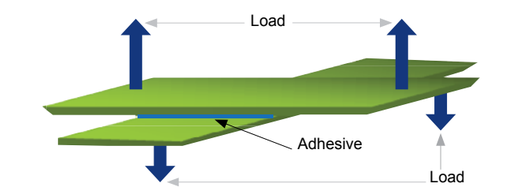
6.2 Environmental Exposure

ITW Performance Polymers Technical Services laboratory can perform various long-term environmental tests to help replicate real-world product performance. Capabilities include salt fog, humidity, and temperature testing; which can be designed to simulate exposure to the specific climate in which a product will be deployed. Contact us today at itwperformancepolymers.com/contact-technical-service.

6.3 Cross Peel

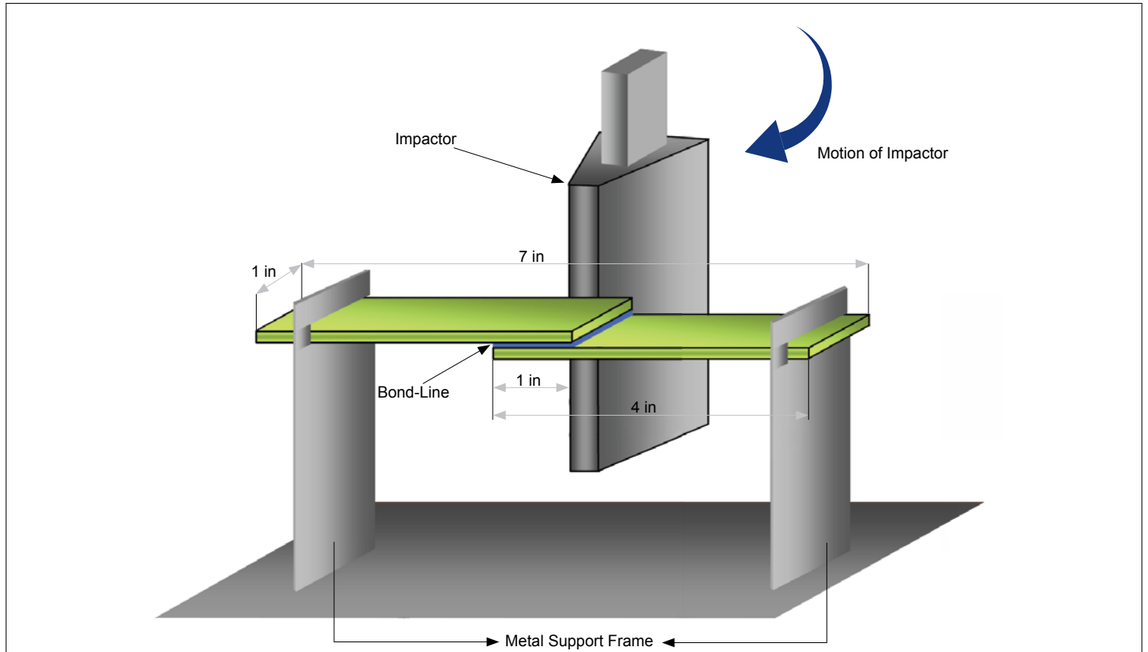
Adhesive Cross Peel testing via SAE J1553 evaluates the strength of an adhesive bond when loaded with a perpendicular peel force. Many real-world adhesive joints, including stringer-to-hull bonds, experience these kinds of peel forces. Cross Peel testing allows manufacturers to simulate real-world peel loadings on bonded parts and investigate potential failure modes.

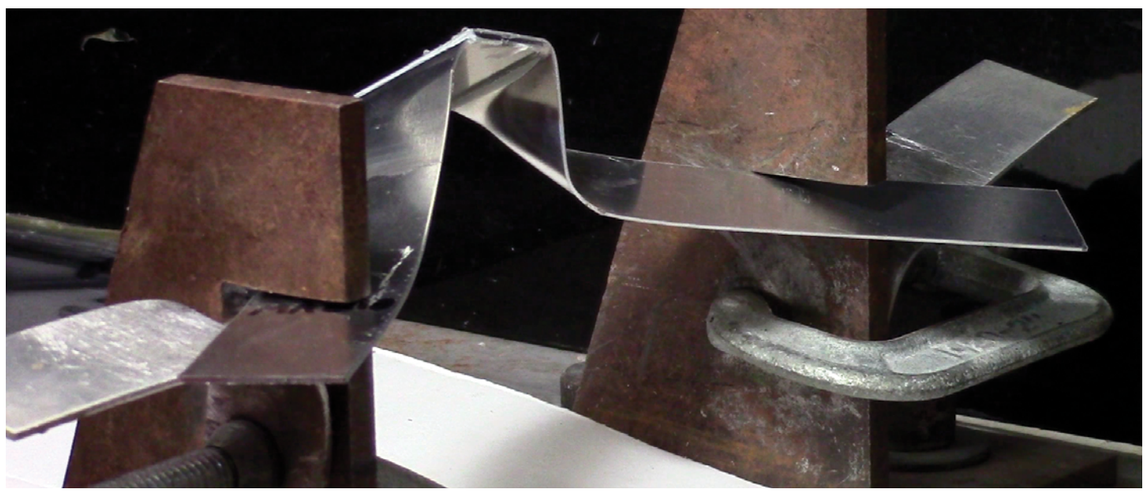
Schematic of a Cross-Peel sample under load



6.4 Impact Resistance

GM9751P Side Impact testing can be used to show the strength of an adhesive bond when an impact force is experienced. This is particularly helpful when attempting to determine bond strength and failure modes in the event of a collision or worst-case scenario.





Impact testing of Plexus adhesives

7. Success Stories

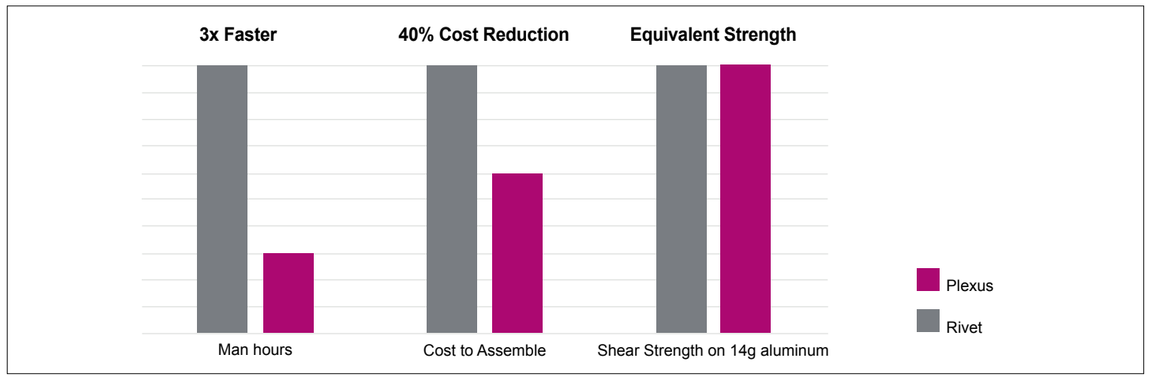
7.1 Marine Metal Door – Weld Replacement

A manufacturer of metal doors for a US Coast Guard tactical vessel had a difficult problem. They had more orders than workers to meet their customers demand of the metal doors. The operations manager worked with Plexus adhesives in the past and knew how successful and strong the adhesives were in the marine industry. He reached out to see if Plexus adhesives could replace the full perimeter weld to join the complex design and and time consuming welding process.

The Problem
Welding was the time constraint in door production.

The Solution
ITW Performance Polymers partnered with the manufacturer to demonstrate that the Plexus adhesive had the required strength to replace the welding.

The Results
When doing prototype doors, it was found that they could produce 3X as many doors bonding together compared to welding. This not only solved their productivity issues, but also led to significant cost savings.



7.2 Semi-Trailer – Rivet Replacement

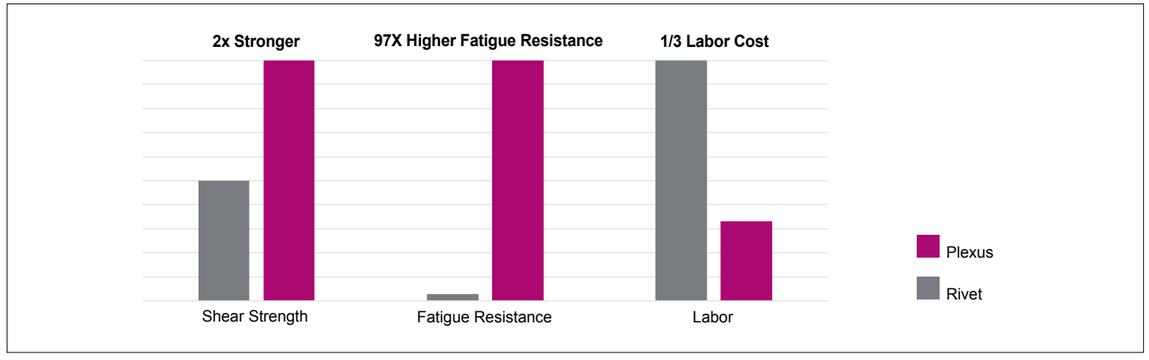
The benefits and advantages of bonding aluminum is not unique to Marine. Plexus structural adhesives have a long history of replacing rivets and welds in the extreme demanding environments of trucks and trailers. A great example is when a manufacturer of logistic track in the semi-trailer reached out to Plexus with a problem. They needed to distribute up to 30 tons on their logistic tracks and when they used rivets, it caused catastrophic failures once a dynamic load was applied.

Problem
Rivets created point loads of stress, which caused stress cracking and failures. The manufacturer's logistic track needed to distribute 30 tons of stress over length of the trailer and rivets were not strong enough.

Solution
Bonding the aluminum logistic tracks with long open time Plexus adhesives.

Results
The company recorded all distance traveled with bonded logistic tracks on their prototype trailers. When they reached 100 million kilometers without a single failure, they felt comfortable warrantying their product for the life of the trailer when installed with Plexus adhesives.

Logistic track bonded with Plexus adhesive



7.3 Metal Gate – Gauge Optimization

A Metal fabrication shop had a unique problem. They were looking at making a retractable gate with welded in stiffeners. The issue was welding a thin outer panel to thick stiffeners caused significant warping and scaring imprints on the finish side of the metal and gate.

To fix this they originally looked at increase the gauge of the outer panel, but this drastically increase mass making, which increased cost and the size of the motor required to retract the gate.

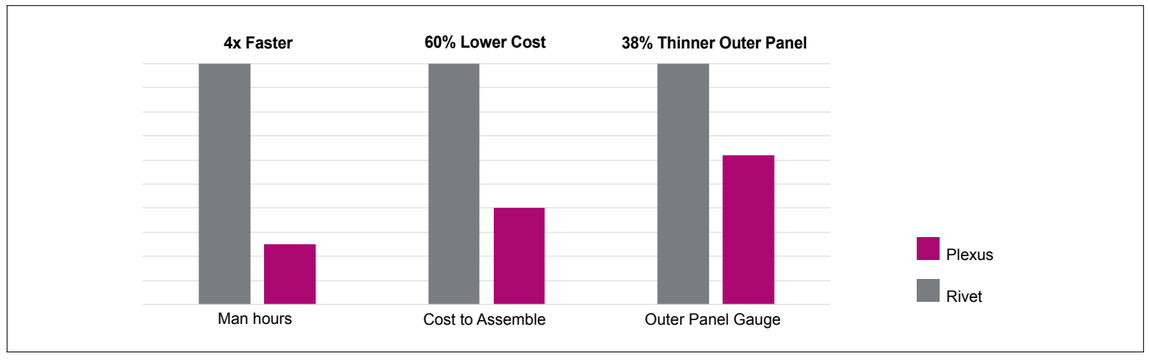
Problem
Welding thin gauge to thick gauge causes metal warping. Welding stiffeners required minimum sheet metal thickness to prevent Heat Distortion.

Solution
The customers initial fix was to increase the gauge of the outer panel. However, this increased the overall gate mass creating other issues such as increased costs and larger more expensive electric motors. This was not a suitable long term solution.

Plexus was ultimately tested and approved to replace the welding on the original design and substrate gauge. Bonding in the stiffeners with Plexus eliminated the warping and heat affected zones.

Results
The outer panel gauge was able to be reduced in thickness by 38%, which saved significant material costs and was able to "right size" the motor for additional cost savings.

Metal Reinforcements onto an outer panel



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