



*Integrity ★ Service ★ Excellence*

# EnduroSharp™ Nonmetallic (Torlon®) Aircraft Maintenance Tools

## SAMPE

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# Current Removal Tools



- Many nonmetallic scrapers are available and approved or used for a variety of material removal applications
- Effectiveness of existing nonmetallic tools varies, depending on the application, but the tools are generally inefficient & short-lived
  - Typically incapable of shearing material; removal by brute force
  - Edges dull quickly and cannot be readily restored
- Metallic & improvised tools (usually unapproved) can be more efficient for material removal but pose great risk to underlying structure



**Selection of Fielded Nonmetallic Tools**



**Typical Metallic Tools**



**Modified Acid Brush  
Used to Remove  
Sealant**



# New Torlon<sup>®</sup> Nonmetallic Tools



- Under contract with the Air Force Research Laboratory's Materials Integrity Branch (AFRL/RXSA), the University of Dayton Research Institute (UDRI) developed improved material removal tools & accessories
- Transitioning developed tools to multiple weapons systems for material removal applications on composite components
- Injection molded from Torlon<sup>®</sup> 5030 - Solvay's polyamide-imide (PAI) resin
  - 30% glass reinforced plastic
- Commercially available from Performance Plastics, LTD (Cincinnati, OH)
  - EnduroSharp<sup>™</sup> trade name

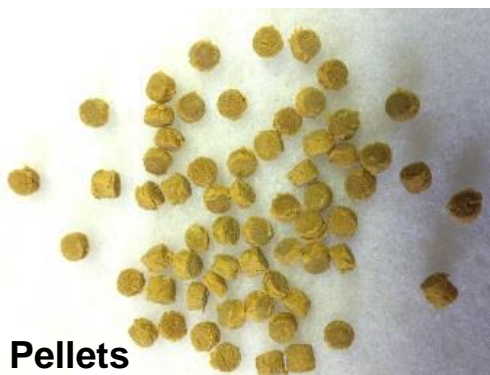


**AFRL Torlon Tools and Accessories**

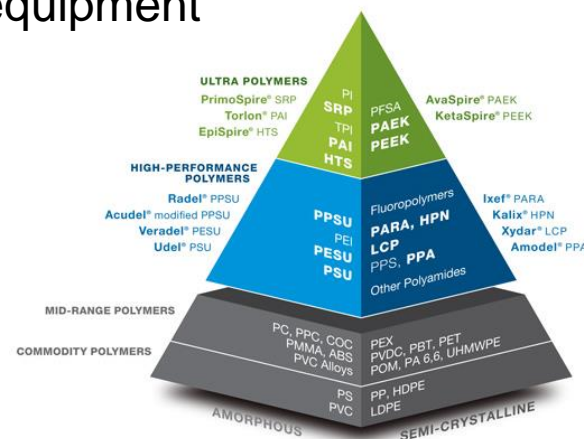


# Torlon® Thermoplastic

- Torlon® is Solvay’s polyamide-imide (PAI) resin
  - High-end niche material processing at  $\approx 371\text{ }^{\circ}\text{C}$  ( $700^{\circ}\text{F}$ )
  - 21-day extended cure at  $260^{\circ}\text{C}$  ( $500^{\circ}\text{F}$ ) after molding (crosslinks resin)
  - Behaves like a thermoset (does not soften but degrades at  $260^{\circ}\text{C}$  ( $500^{\circ}\text{F}$ ))
  - Relatively high strength and stiffness
  - Solvent resistant
- Few injection molders in the world
  - Hard to process (softens but does not flow freely at  $371^{\circ}\text{C}$  ( $700^{\circ}\text{F}$ ))
  - Requires more expensive injection molding equipment



Torlon® 5030 Pellets

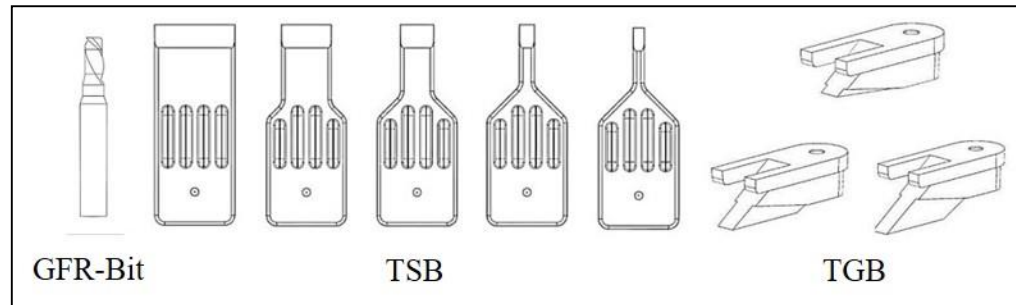


Polymer Pyramid - Solvay





# Torlon<sup>®</sup> Nonmetallic Tool Development



- Torlon nonmetallic tools addressed in this presentation:
  - Gap Filler Removal Bit (GFR-Bit)
    - 4 configurations (modeled after metallic counterparts)
    - 16 candidate materials (resin/fiber combinations)
    - Diameter (4.4 mm (0.162")) sized to remove filler from a common gap width
  - Torlon Scraper Blade (TSB)
    - 5 widths
    - 25°/25° angle - double sided (asymmetrical 1/3 to 2/3) cutting edge
  - Torlon Gap Blades (TGB)
    - 5 widths, 3 depths
    - 3 cutting edges

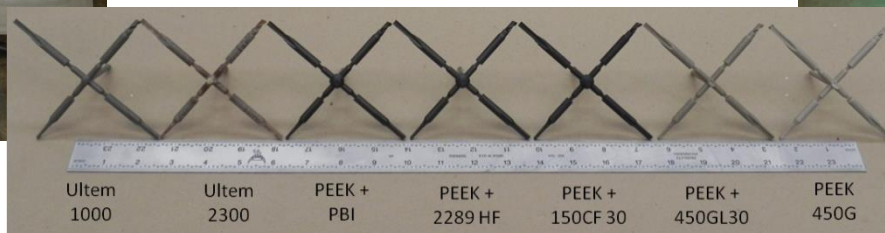


# Torlon Gap Filler Removal (GFR) Bit

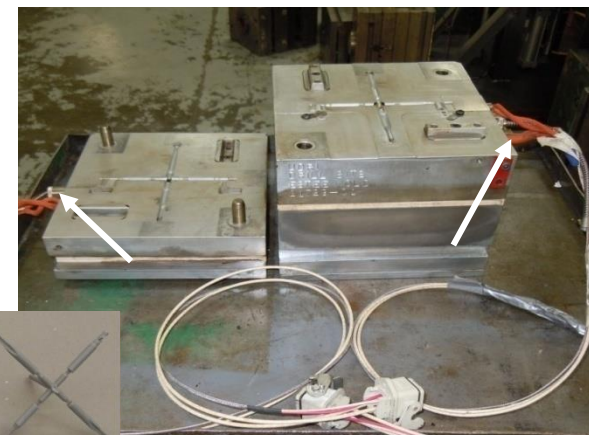


**Hand loaded (2)  
insert locations**

- A36 Steel
- Chrome-plated mold surface
- 2 Straight-fluted cavities
- 2 Spiral fluted cavities



**Molded GFR-Bits**



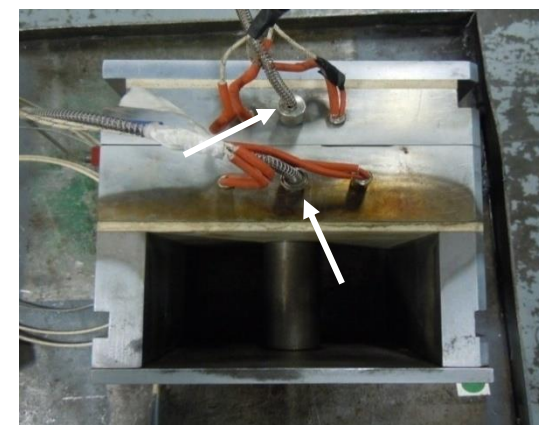
**4-300 watt heaters  
(2 per half)**



**Mated mold**



**Injection machine**

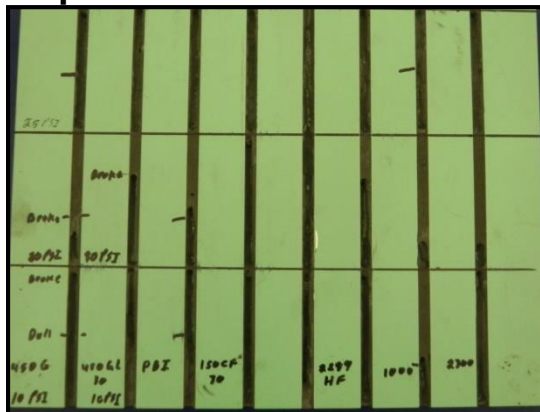


**Thermocouples**



# Torlon Gap Filler Removal (GFR) Bit

Gap Filler Removal Test Panel



Sample Tested GFR-Bits



- Single fluted spiral bit design chosen as optimal design
- Evaluations conducted at multiple psi setting
- 6,000 - 7,000 rpm required for maximum material removal efficiency and bit life
- Dotco<sup>®</sup> 12,000 rpm, 90-degree hand-held grinder with air pressure reduced to 241-310 kPa (35-45 psi)
- Lower-speed (rpm) grinders not available
  - Higher-speed grinders lose significant torque when adjusted to 6,000 rpm
  - Tachometer used to confirm air adjusted to obtain desired speed



# Torlon Gap Filler Removal (GFR) Bit



Material Group	Bit Material	Material Removed (New Filler)	Time	Bit Initial Weight (Grams)	Bit Post Weight (Grams)	Material Loss (Grams)	Percent Loss
LNP	EC008PXQ	30.48 cm x 6.35 mm x 4.5 mm (12.0 in x 0.250 in x 0.180 in)	00:03:34	1.4414	1.4247	0.0167	1.16
Ultem	2300	30.48 cm x 6.35 mm x 4.5 mm (12.0 in x 0.250 in x 0.180 in)	00:03:01	1.5012	1.4931	0.0081	0.54
Peek	150CA30	30.48 cm x 6.35 mm x 4.5 mm (12.0 in x 0.250 in x 0.180 in)	00:02:42	1.3471	1.3406	0.0065	0.48
	450GL	30.48 cm x 6.35 mm x 4.5 mm (12.0 in x 0.250 in x 0.180 in)	00:02:57	1.4011	1.3976	0.0035	0.25
	2289HF	30.48 cm x 6.35 mm x 4.5 mm (12.0 in x 0.250 in x 0.180 in)	00:02:15	1.4400	1.4283	0.0117	0.81

- Post test images and results of down selected materials
  - Selected materials still lacked desired durability and performance
- Manufactured bits from Torlon material (filled and unfilled)



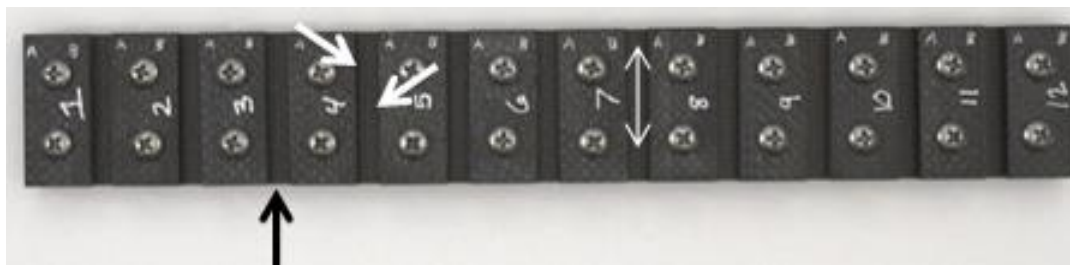
Material Group	Bit Material	Material Removed (New Filler)	Time	Bit Initial Weight (Grams)	Bit Post Weight (Grams)	Material Loss (Grams)	Percent Loss
Torlon	4275	25.5 cm x 6.35 mm x 4.57 mm (12.0 in x 0.250 in x 0.180 in)	00:02:26	1.501	1.4862	0.0148	0.99
	4301	16.5 cm x 6.35 mm x 4.57 mm (6.5 in x .250 in x 0.180 in)	00:00:58	1.4621	1.4568	0.0053	0.36
	5030	25.5 cm x 6.35 mm x 4.57 mm (12.0 in 0.250 in x 0.180 in)	00:01:12	1.6385	1.6128	0.0257	1.57

- Post test images and results of Torlon materials
- **Torlon 5030 selected at final material**

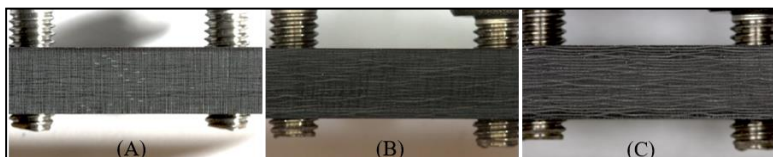




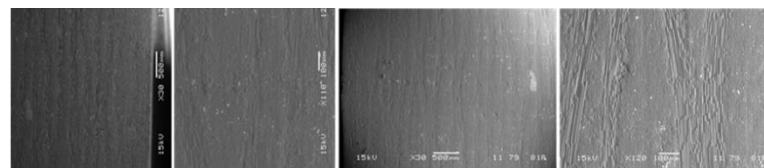
# Torlon Gap Filler Removal (GFR) Bit



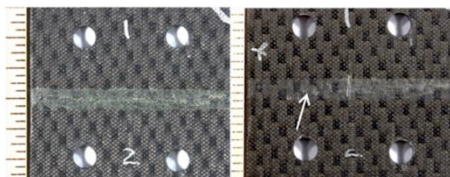
Damage Evaluation Test Gap Panel Configuration



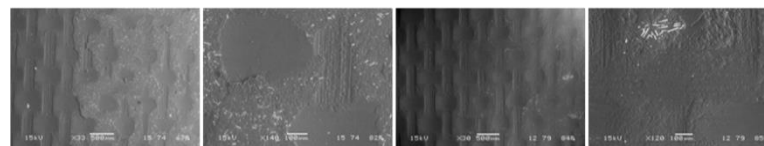
Test Panel Gap side Walls



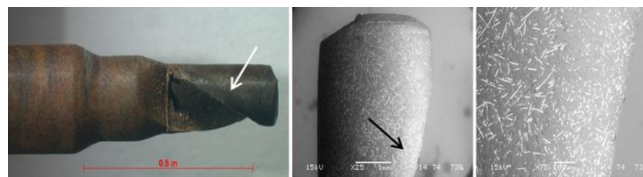
Test Panel Gap side Walls (Magnified)



Test Panel Gap Bottom



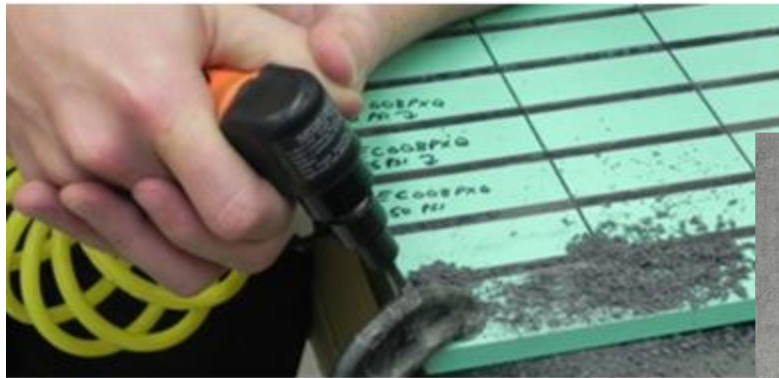
Test Panel Gap Bottom (Magnified)



Torlon 5030 GFR-Bit after Evaluation



# Torlon Gap Filler Removal (GFR) Bit



**GFR-Bit Operated at 6,000 rpm**



**GFR-Bits**



**Gap Filler Removed**

- Removes “flexibilized” epoxy resin gap filler material
- Not suitable for removal of extremely soft or highly elastic materials



# GFR Bit Performance



- Removes minimum of 3 feet of flexibilized epoxy resin gap filler
  - Operated at 6,000 - 7,000 rpm and using proper technique
  - Demonstrated on both composite and metallic structure (primed & unprimed)
  - No damage to underlying primer, composite structure, or metallic structure
- Removes epoxy resin fastener fill from a minimum of 45 fastener heads
  - Operated at 6,000 - 7,000 rpm
  - Demonstrated on both steel and titanium fasteners
  - No damage to fasteners or surrounding composite structure



# Torlon Scraper Blades (TSBs)



**Available Torlon Scraper Blades**

- More durable nonmetallic blade designed to remove elastomeric coatings, preformed protective boots, tapes, sealants, adhesive residue, and gap filler materials
  - Five widths available (4.3 mm (0.170”), 5.8 mm (0.230”), 12.7 mm (0.500”), 19 mm (0.750”), and 30.5 mm (1.20”))
  - Heat resistant to 500°F & resistant to standard aircraft fluids/solvents
- Improvements over existing nonmetallic scrapers
  - Decreased material removal times
  - Blade stays better engaged in material due to Torlon stiffness & edge design
  - Holds cutting edge longer, easier to sharpen, machinable to reconfigure



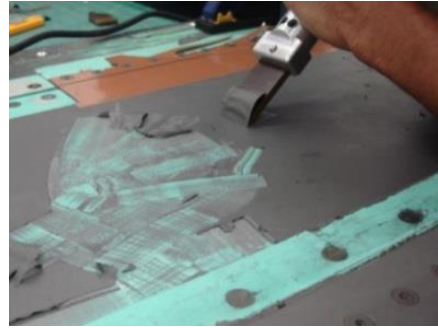
# TSB Handle and Pneumatic Tool



- TSBs used with Standard and pocket blade holders or COTS pneumatic tool
  - Quick disconnect for blade exchange
  - TSB head attachment fits COTS pneumatic tool without tool modification
  - Sharpen and maintain proper asymmetrical cutting edge with unique sharpening fixture

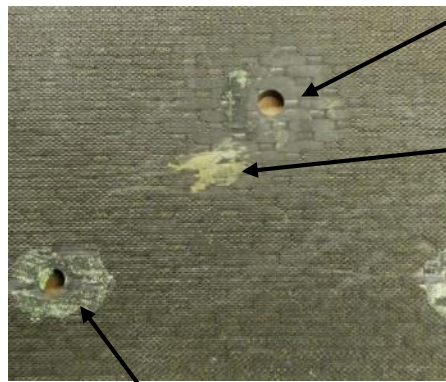


# TSB Evaluation & Performance



Removing Coating Material (with & without heat assistance)

Boot/Tape Removal

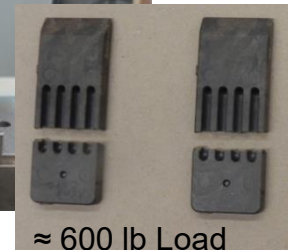


Residual Epoxy Adhesive Removed

While trying to damage composite, TSB degraded leaving Torlon remnants on composite panel without damaging composite

Residual Epoxy Adhesive

Thickness variation & porosity concentration



≈ 600 lb Load

- Material removal capability assessed in field and lab; shown to require less effort & speeds removal vs other plastic blades
- TSB quality, strength & impact on substrate materials evaluated in lab



# TSB Evaluation & Performance



## TSB Unprimed and Primed Test Panel

Panel ID	Specimen ID	Blade Style	Part Number	PSI	Blade Angle to Surface	Number of Passes	Elapsed Time (Seconds)	Test Area Length (Millimeters (inches))	Force (Kilograms (pounds))
<b>Primed and Unprimed Test Panel</b>									
UPC-1	UPC-1-1 thru 5	TSB	TSB-(170-1200)	90	25°	6	15.85	31.8 x 8.9 (1.25 x 3.5)	4.8-6.0 (10.6-3.4)
UPC-1	UPC-1-6 thru 12	TSB	TSB-(170-1200)	90	45°	6	17.42	31.8 x 8.9 (1.25 x 3.5)	5.08-6.6 (11.2-14.6)
PC-1	UPC-1-1 thru 5	TSB	TSB-(170-1200)	90	25°	6	11.93	31.8 x 8.9 (1.25 x 3.5)	4.8-6.0 (10.6-3.4)
PC-2	UPC-1-6 thru 12	TSB	TSB-(170-1200)	90	45°	6	12.59	31.8 x 8.9 (1.25 x 3.5)	5.08-6.6 (11.2-14.6)

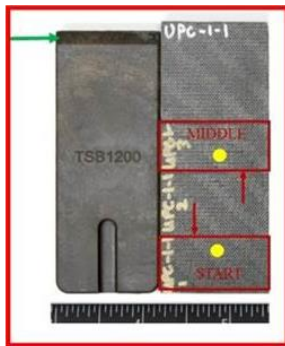
## TSB Test Metrics

88ABW-2018-2529



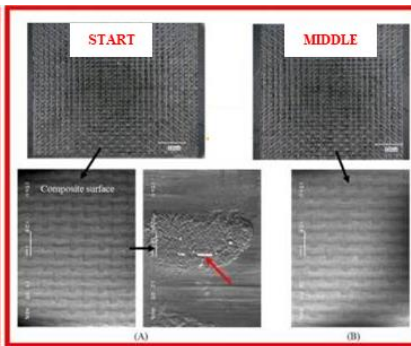


# TSB Evaluation & Performance



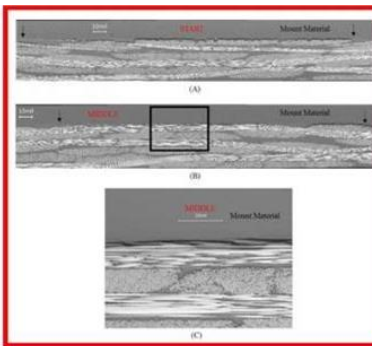
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



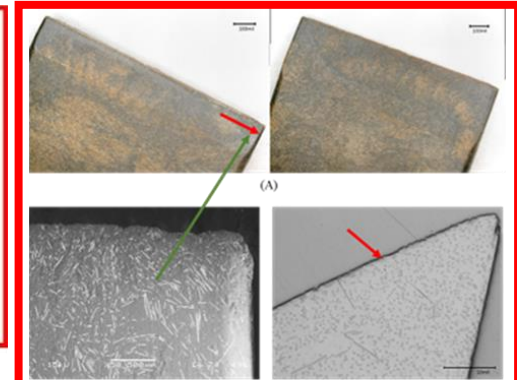
(2)

Scale bar: (A & B, top photos) 2.54 mm (100 mil),  
(A & B, bottom photos) 1.0 mm (0.039 in) & 100 micron



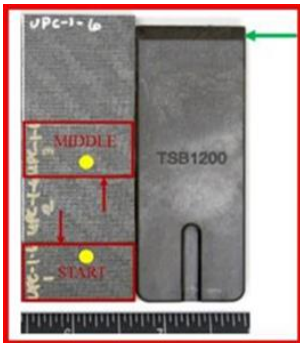
(3)

Scale bar:  
0.254 mm (10 mil)



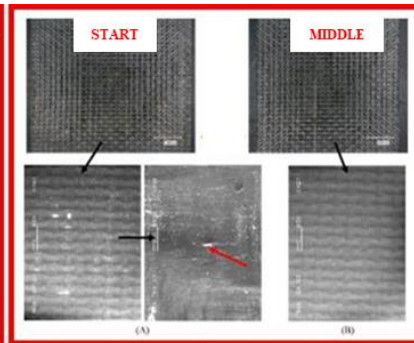
Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.254 mm (10 mil)

## TSB-1200 @ 25° Tool Angle on Unprimed Test Panel



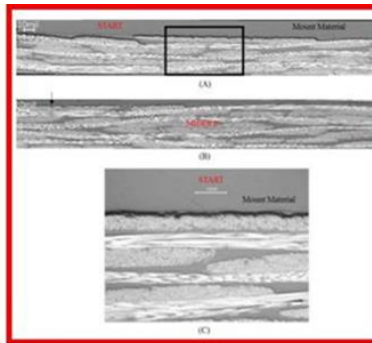
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



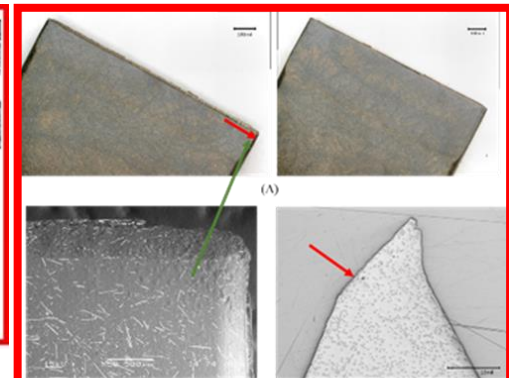
(2)

Scale bar: (A & B, top photos) 2.54 mm (100 mil),  
(A & B, bottom photos) 1.0 mm (0.039 in) & 100 micron



(3)

Scale bar:  
0.254 mm (10 mil)



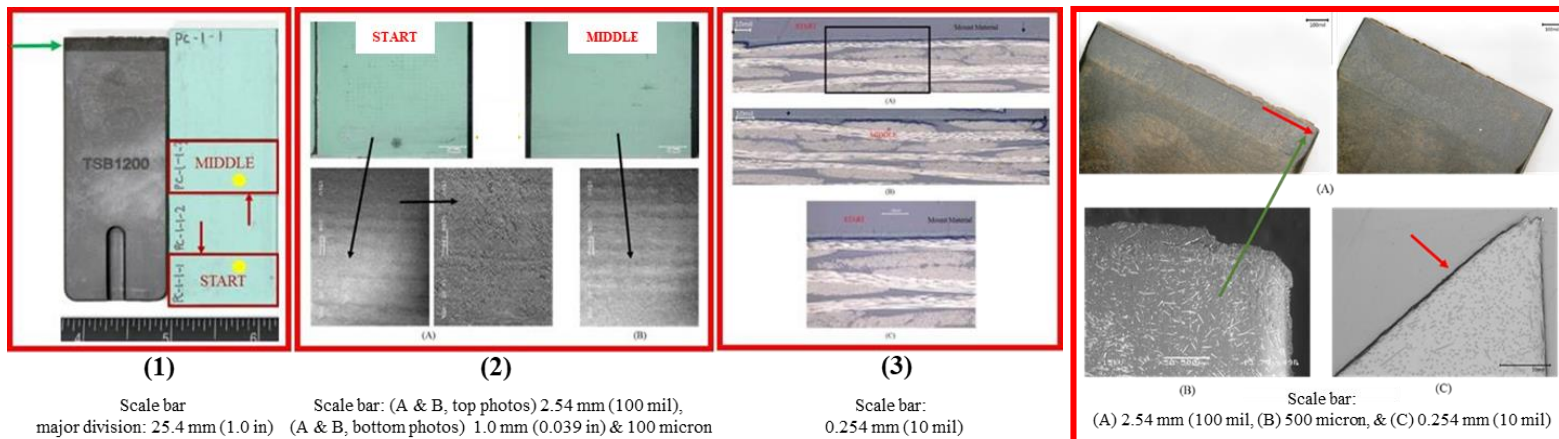
Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.254 mm (10 mil)

## TSB-1200 @ 45° Tool Angle on Primed Test Panel

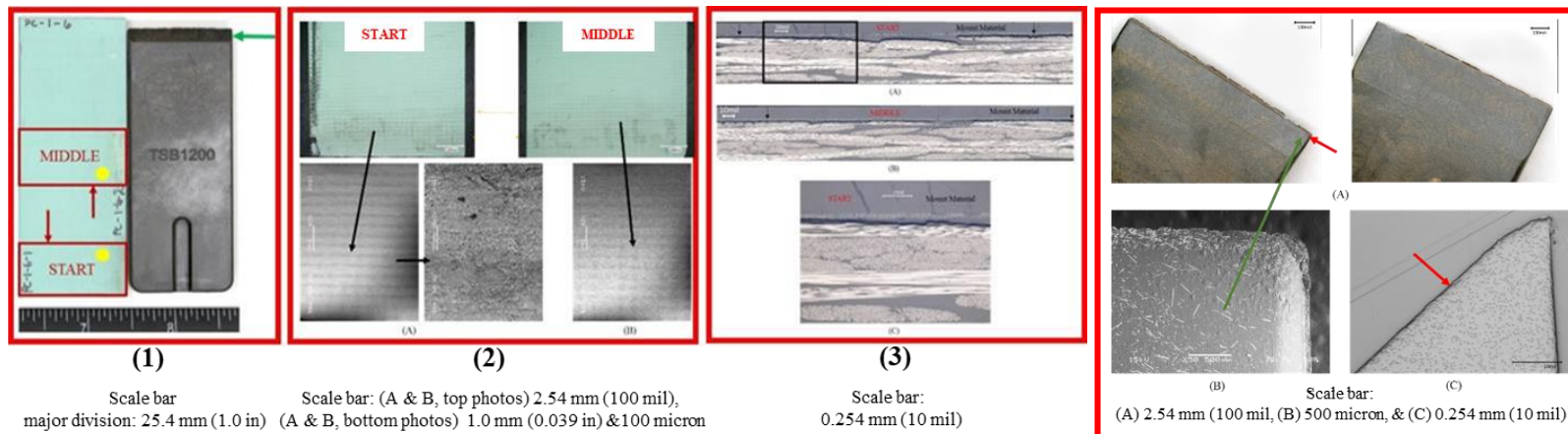




# TSB Evaluation & Performance



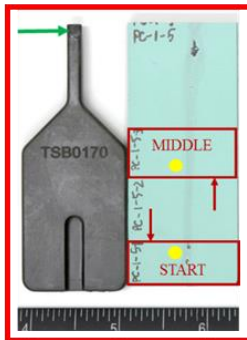
## TSB-1200 @ 25° Tool Angle on Primed Test Panel



## TSB-1200 @ 45° Tool Angle on Primed Test Panel

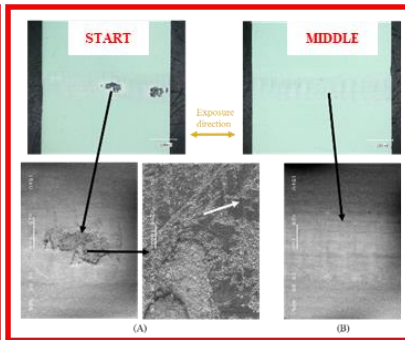


# TSB Evaluation & Performance



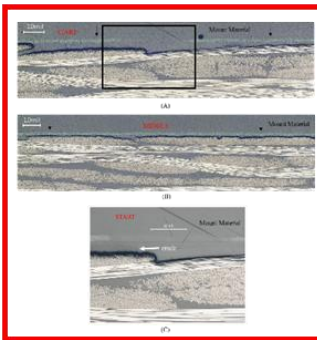
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



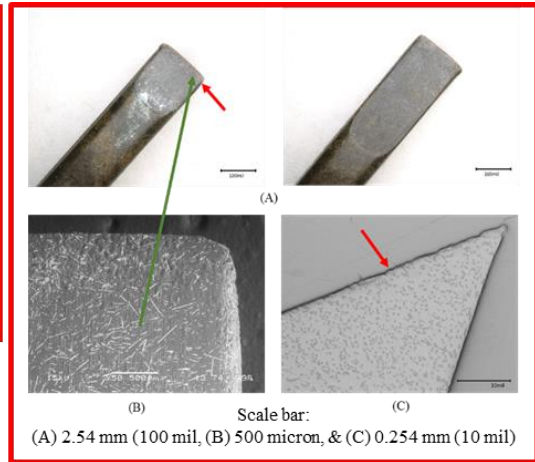
(2)

Scale bar: (A & B, top photos) 2.54 mm (100 mil),  
(A & B, bottom photos) 1.0 mm (0.039 in) & 100 micron



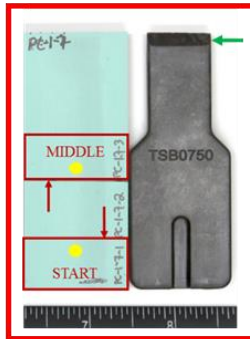
(3)

Scale bar:  
0.254 mm (10 mil)



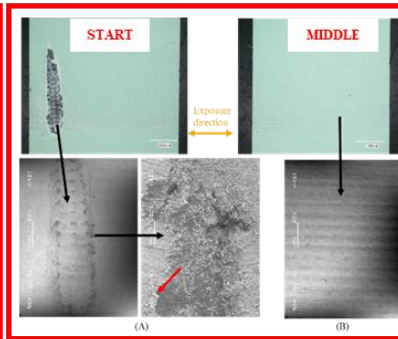
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.254 mm (10 mil)

## TSB-170 @ 25° Tool Angle on Primed Test Panel



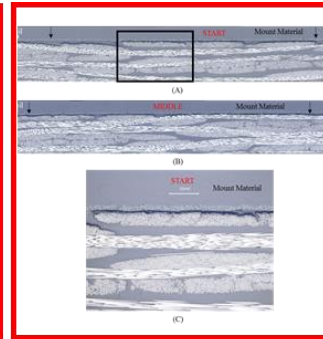
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



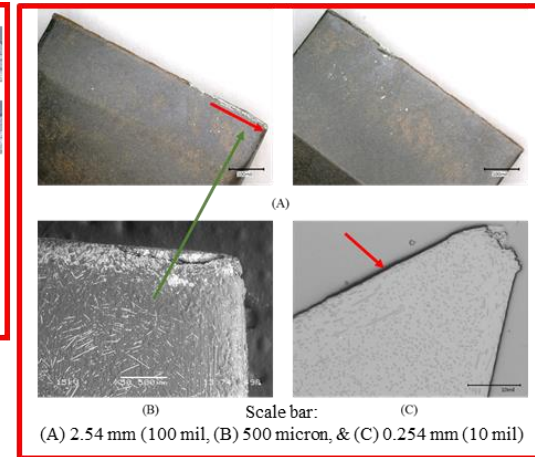
(2)

Scale bar: (A & B, top photos) 2.54 mm (100 mil),  
(A & B, bottom photos) 1.0 mm (0.039 in) & 100 micron



(3)

Scale bar:  
0.254 mm (10 mil)



(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.254 mm (10 mil)

## TSB-750 @ 45° Tool Angle on Primed Test Panel



# Torlon Gap Blades (TGBs)



**Concept & Prototype**



**GFR Blades and Adapters**

- Unique blades designed to remove gap filler materials
  - Shears material at bottom and sides of gap; less stress for operator
  - Five widths available (1.9 mm (0.075"), 2.5 mm (0.100"), 3.05 mm (0.125"), 4.3 mm (0.170"), and 5.8 mm (0.230"))
  - Three depths for each width (1.9 mm (0.075"), 4.1 mm (0.160"), and 6.35 mm (0.250"))
- Intended for incremental removal using the multiple-depth blades
  - Less effort for tougher materials & deeper gaps; enables partial depth removal



# TGB Adapter Handle & Pneumatic Tool



Location for Handle Detent Pin

Spring Inside

Adapter Detent Pin

Slot to Ease Blade Removal



“Pocket” Holder  
with Adapter & Blade

TGB adapter

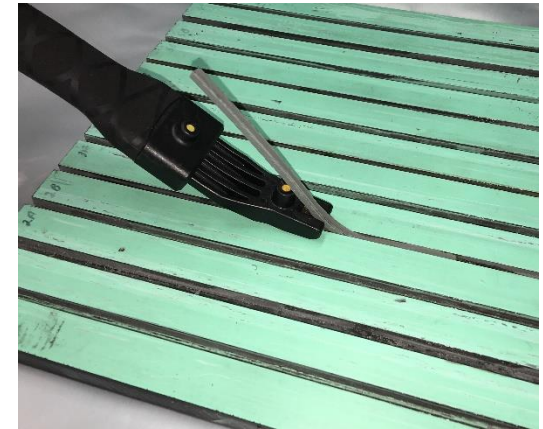
- TGBs used in adapter with standard & pocket handles or COTS pneumatic tool
  - Quick disconnect of adapter from handle or pneumatic tool
  - Quick disconnect for blade exchange while adapter remains on handle/tool
  - “Pocket” blade holder allows for work in restricted areas or with tight radii



Torlon gap blade in adapter on COTS handle and pneumatic tool



# TGB Evaluation & Performance



- TGBs reduce gap filler removal time when used with proper technique
  - Plunge through gap then level off to allow adapter to ride along surface
  - Use three blade depths incrementally (shallowest to deepest)
  - Blade can be narrower than gap and still be used efficiently to remove filler
- Blades break rather than penetrate/damage substrate if twisted in gap
- TGBs can be sharpened with abrasive paper



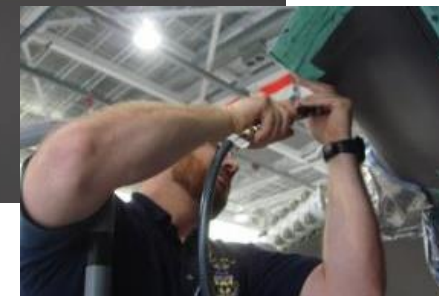
# TGB Evaluation & Performance



Lab Evaluation



Thickness variation & porosity concentration

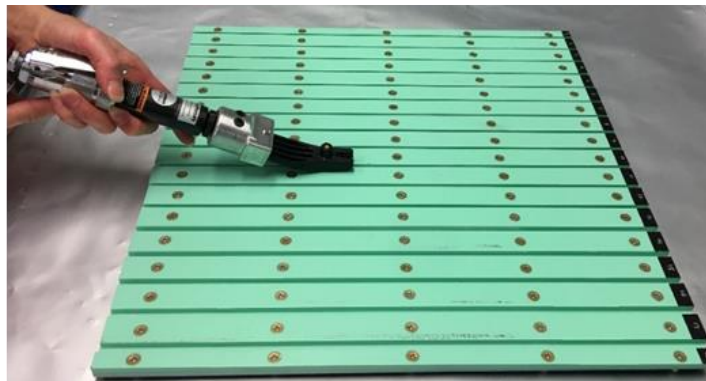
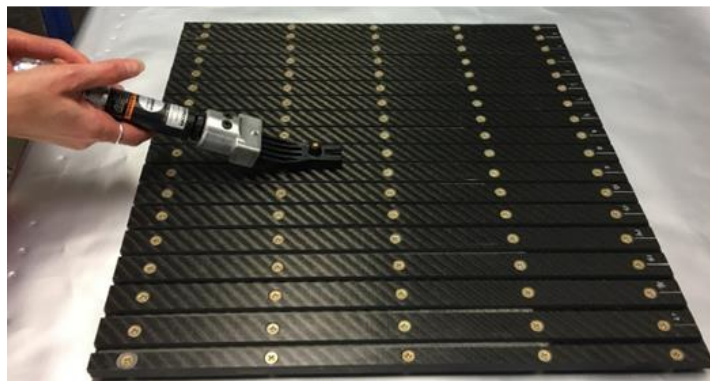


Field demo's and User Performance Evaluation

- Material removal capability assessed in field and lab; shown to require less effort & speeds removal vs other plastic blades
- TGB quality, impact on substrate materials evaluated in lab



# TGB Evaluation & Performance



**TGB Unprimed and Primed Test Panel**

Panel ID	Gap ID	Blade Style	Part Number	Disc/Blade Thickness mm (in)	Blade Depth mm (in)	Gap Width mm (in)	Gap Depth mm (in)	kPa (psi)	Number of Passes	Elapsed Time (Seconds)	Gap Length cm (in)	Force kg (lbs)
<b>Unprimed and Primed Unfilled Gap Test Panel</b>												
UPUFGC-1	16	TGB	TGB-23-25	19.05 (0.075)	6.35 (0.250)	2.41 (0.095)	4.88 (0.192)	620.5 (90)	1	14.67	30.5 (12.0)	1.59-2.27 (3.5-5.0)
UPUFGC-1	17	TGB	TGB-23-25	19.05 (0.075)	6.35 (0.250)	2.41 (0.095)	4.88 (0.192)	620.5 (90)	6	28.22	30.5 (12.0)	1.59-2.27 (3.5-5.0)
PUFGC-1	16	TGB	TGB-23-25	5.85 (0.230)	6.35 (0.250)	6.35 (0.250)	4.88 (0.192)	620.5 (90)	1	11.23	30.5 (12.0)	1.59-2.27 (3.5-5.0)
PUFGC-1	17	TGB	TGB-23-25	5.85 (0.230)	6.35 (0.250)	6.35 (0.250)	4.88 (0.192)	620.5 (90)	6	25.33	30.5 (12.0)	1.59-2.27 (3.5-5.0)

**TGB Test Metrics**

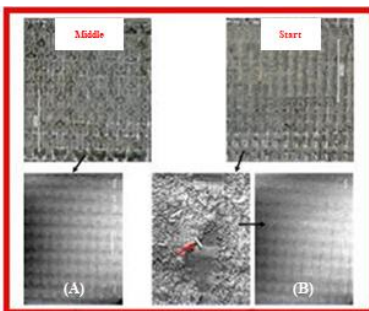


# TGB Evaluation & Performance



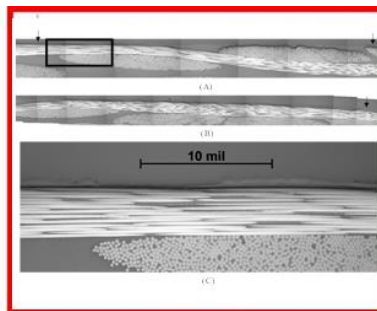
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



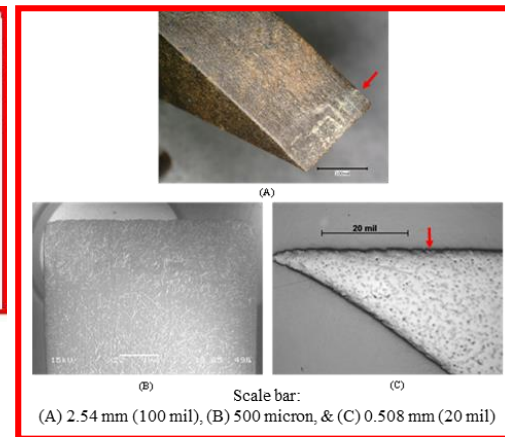
(2)

Scale bar:  
2.54 mm (100 mil), & 500 micron



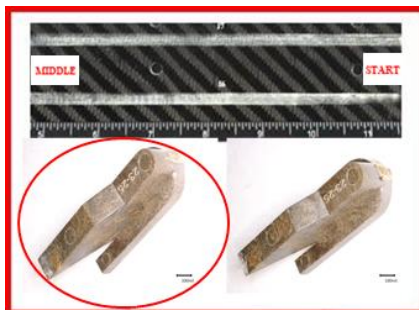
(3)

Scale bar:  
0.254 mm (10 mil)



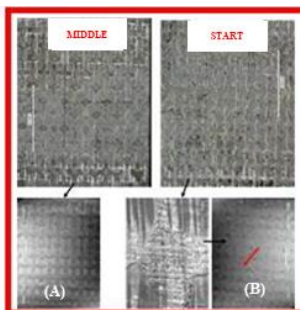
Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.508 mm (20 mil)

## TGB-23-25: Single Pass on Unprimed Test Panel



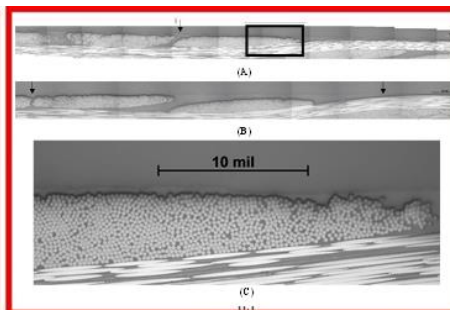
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



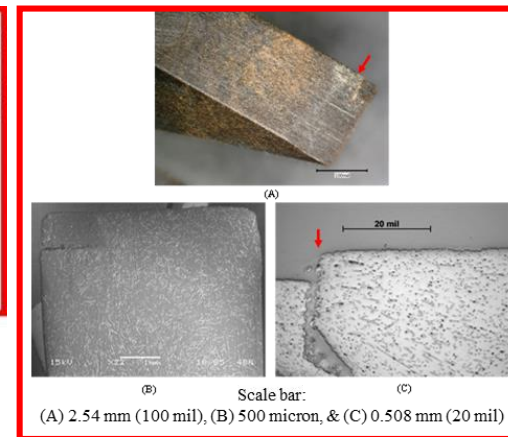
(2)

Scale bar:  
2.54 mm (100 mil), & 500 micron



(3)

Scale bar:  
0.254 mm (10 mil)



Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.508 mm (20 mil)

## TGB-23-25: Six Passes on Unprimed Test Panel



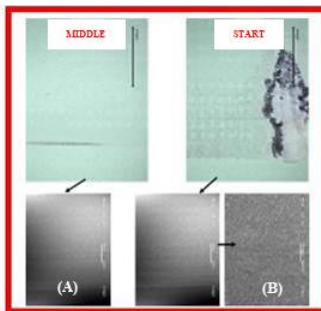


# TGB Evaluation & Performance



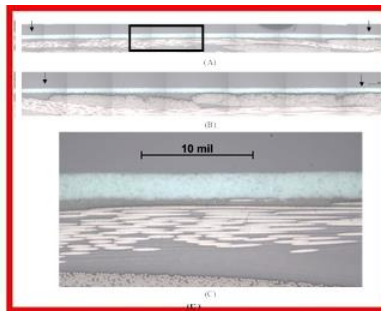
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



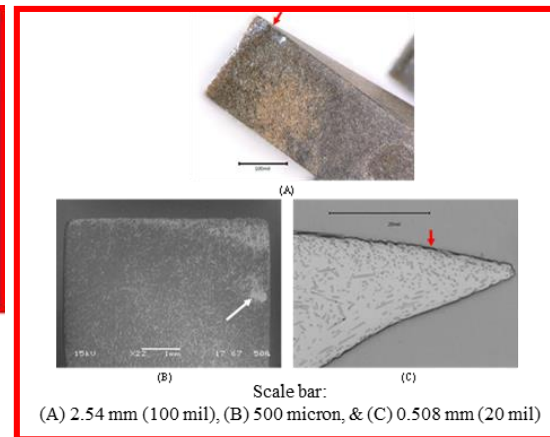
(2)

Scale bar:  
2.54 mm (100 mil), & 500 micron



(3)

Scale bar:  
0.254 mm (10 mil)



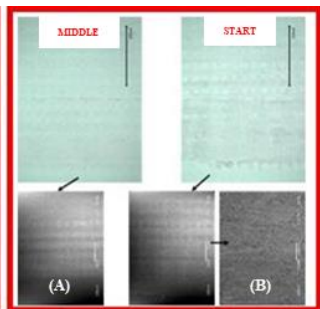
Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.508 mm (20 mil)

## TGB-23-25: Single Pass on Primed Test Panel



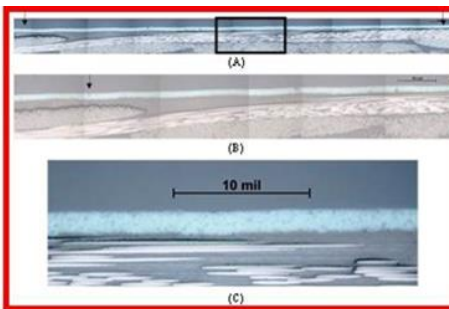
(1)

Scale bar  
major division: 25.4 mm (1.0 in)



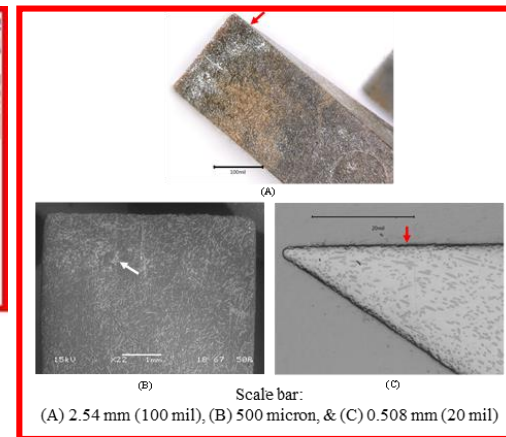
(2)

Scale bar:  
2.54 mm (100 mil), & 500 micron



(3)

Scale bar:  
0.254 mm (10 mil)



Scale bar:  
(A) 2.54 mm (100 mil), (B) 500 micron, & (C) 0.508 mm (20 mil)

## TGB-23-25: Six Passes on Primed Test Panel



# Commercial Availability



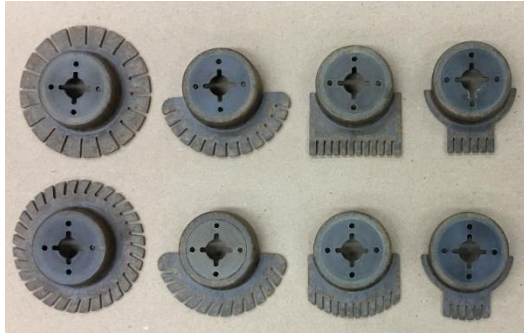
## ENDUROSHARP™ TORLON® NONMETALLIC TOOLS



- Performance Plastics, LTD (Cincinnati, OH) licensed by UDRI
  - EnduroSharp™ trade name; one-stop shop for Torlon tools & accessories



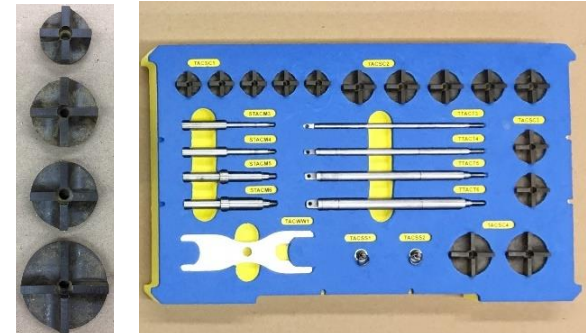
# Other Torlon Tools



**GFR Discs**



**Torlon Reamers**



**Torlon Cutters & Accessories**

- GFR Discs (used on oscillating tools)
  - Gap filler removal; scoring thick elastomeric coatings
- Torlon Reamers (adhesive, etc. removal from holes)
- Torlon Adhesive Cutters
  - Similar to metallic reverse counterbore cutters
  - Three sizes designed for removal of residual adhesive/sealant associated with bonded nutplates
  - Associated mandrels (including tethered); other accessories

**Torlon Adhesive cutter  
Removing Fastener Filler**



**GFR Disc Removing Gap Filler**



# Summary



- We are transitioning Torlon material removal tools developed in house
- EnduroSharp™ Torlon® blades and other tools commercially available from Performance Plastics, LTD in Cincinnati (individually & kits)
  - Includes accessories (handles, pneumatic tool, sharpening fixture)
- EnduroSharp tools offer improvements over other material removal options
  - Significantly less damage potential than often-used metallic tools
  - Faster material removal rates than other nonmetallic tools for most applications
  - Less operator effort required than for other nonmetallic tools
  - Maintain sharp edges; easier to sharpen than other nonmetallic tools
- In use or under evaluation by 11 weapons systems at >10 DoD locations
- Procured by ≈50 organizations (incl. aerospace OEMs & nonaerospace)



# Acknowledgements



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  - Eric Atkins (Lockheed Martin)
  - Jason Cary, Dave Nielson, & Brandon Smith (AFLCMC/WWUV)
  - Ryan Osysko, Kevin Davis, Al Fletcher, & Chad Hunter (AFRL/RXS)
  - SSgt Bryan Adkins OUSD (AT&L)