Removal and Replacement of Failed Bonded Nutplates Utilizing Nonmetallic Torlon® Adhesive Cutters

SAMPE

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Integrity ★ Service ★ Excellence

Introduction

Adhesively bonded nutplates in manufacture of composite aerospace structures increasing (tens of thousands for some aircraft)

Utilized when two sided access not possible and/or maintenance access panels

- reducing # of holes
- reducing stress concentrations
- reducing installation & production costs
- reducing weight and rework

Operational units – nutplates that tend to fail are those used to secure panels and covers as they are frequently accessed (removed and reinstalled)

Failed Nutplates

Nutplates fail for a variety of reasons

- poor surface prep

- wrong grip length fastener (too long) when engaged pushing nutplate off structure

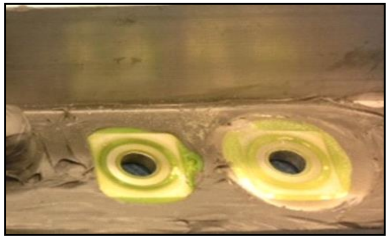
- fastener locked up in nut element (i.e. not turning) due to excessive heat from fastener during installation

- Improper fastener torque sequencing for panel installation

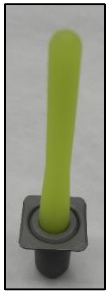
Following aircraft specific T.O. – takes from 24 to 72 hrs to effect a repair

Replacement of Failed Nutplate

- Removal of residual sealant/adhesive



- Failed nutplate location properly prep'd for bonding



- Preparing faying surface of nutplate

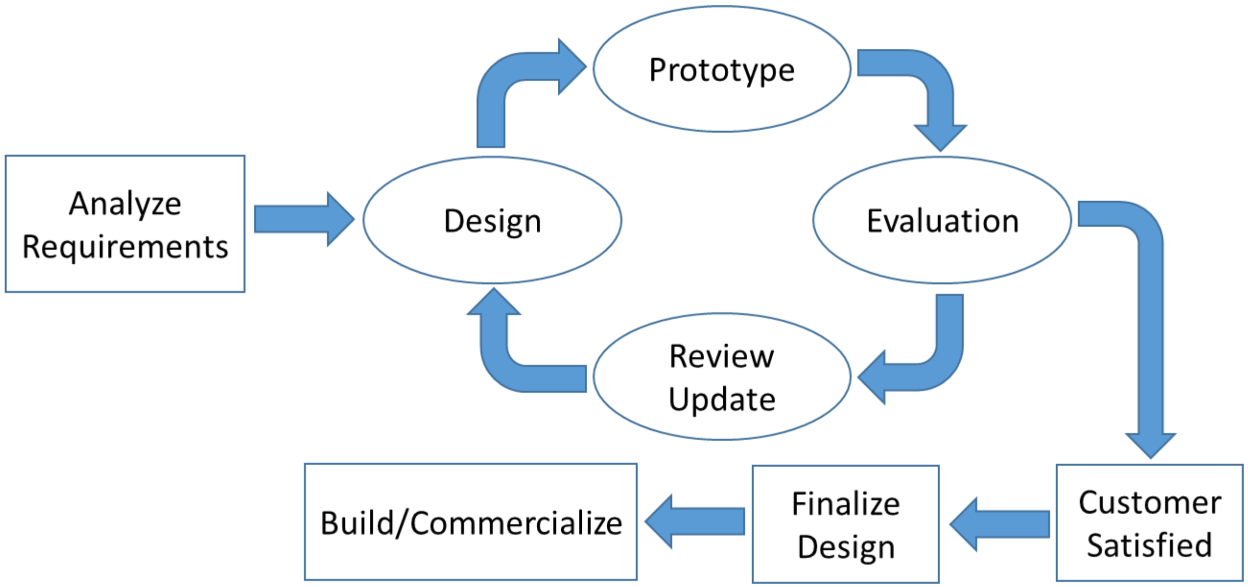
- Verifying faying surfaces readiness/acceptability for bonding

- Reinstalling nutplate with 2-part adhesive

All steps in removal & replacement of a failed nutplate are important to returning aircraft to operational status - AFRL working with OEM to address
Focus of this effort: reducing time to remove residual sealant/adhesive from hrs to min

New Product Development Cycle

Iterative process followed to develop new removal tool
multiple efforts conducted in parallel to reduce time to deliver final product

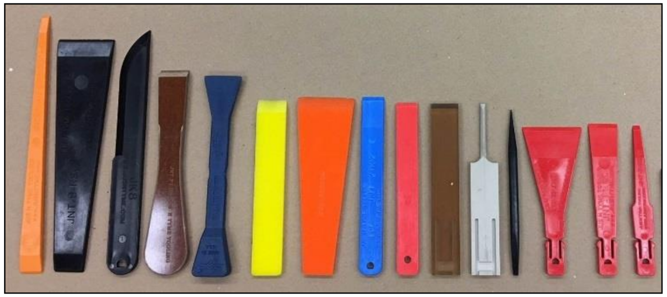


Key - Analyzing Requirements
Comprehensive understanding of end-user requirements (OEM and aircraft operational units)
Multiple site visits: discussions with OEM, Field Service Engineers, technicians & maintainers

Tool to be used in an operational environment
Needs to access most failed nutplate locations (target 90% or greater)
Rapidly prepare structure for a new nutplate w/o damaging underlying structure

Operational Units

Survey of Current Practices



Current T.O. authorized plastic removal tools

- did not adequately perform function
- time consuming

Led to (in some instances):

Use of non-authorized metallic removal tools

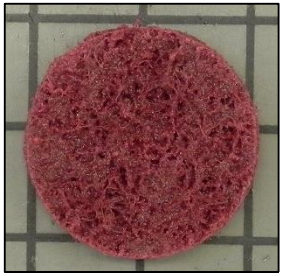
- removed sealant/adhesive quickly
- high potential to damage structure
  scratches and gouges – extensive rework

OEM Production

Survey of Current Practices

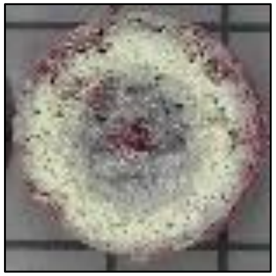
Early in the manufacturing process better access to aircraft structure
– subsystems & hardware not installed
Nutplate failures further down the manufacturing line or on the flight-line
- similar challenges to operational units (restricted access)


Andrews Tool


Norton Vortex
Medium Pad

Using a 3200 rpm pneumatic rotary tool with an abrasive pad to remove sealant/adhesive – heat generated causes sealant/adhesive to smear on faying surface and rapidly clogs pads

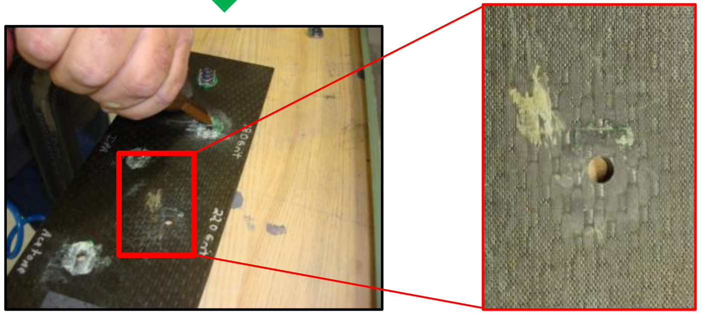
- 10 or more pads required to achieve clean surface
- access limited by throat depth
- cannot be used on composites



Design: Prototype Development

Determine if a Torlon scraper blade developed for another program is viable for this application

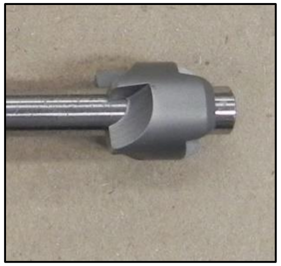
Attach 5030 glass-filled Torlon blade to a pneumatic driven tool to remove adhesive from a composite panel



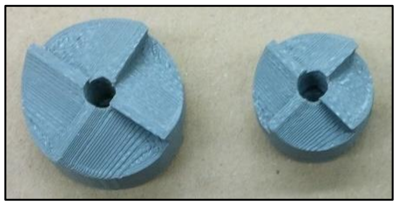
Easily removes adhesive with no visible damage to underlying structure

Field trials demonstrated inability to access many locations due to tools bulkiness - does not meet “accessibility” requirement

Design: Prototype



Familiarity with general mechanics' tools
- Take concept of reverse counterbore tool used for metals and modify for current effort – fabricate from plastic



1st iteration – 3D printed cutters

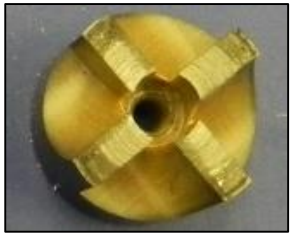
Test concept – 3D printed 2 most prevalent sizes for nutplates - assessed form and fit

Transition into fabricating/machining from Torlon 5030 to fit both Andrews Tool and drill motor

Prototype Evolution

Trials of Torlon 5030 machined cutters

Effectively and quickly removed (in a min or less) remnant adhesive on aluminum substructure when attached to a 1400 rpm drill motor

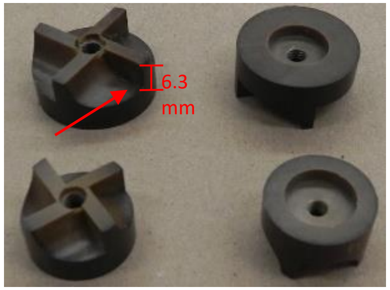


Thin blades – 1.91mm (0.075”)
Blade draft – 3.8mm (0.15”) deep

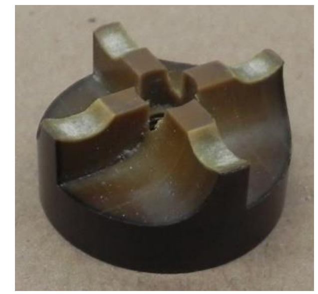
Blade edges worn away due to combination of adhesive’s hardness and rotational speed of drill motor

New design for cutters needed

Updated/Improved Cutter Design



Blade width increased to 2.84mm (0.1120")
Draft increased to 6.35mm (0.25")



Evaluation – reran same test (w/ 1400 rpm drill motor)
Notching of cutter blades observed where edges come in contact with adhesive

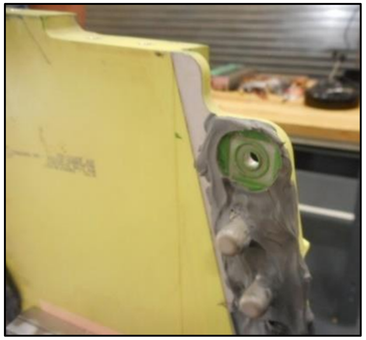
Focusing in on lower-speed models of tools
Andrews Tool company provided 3200, 1000, and 500 rpm tools for evaluation

@ 3200 rpm – notching
@ 1000 rpm – slight notching
@ 500 rpm – no observed damage/wear to cutter

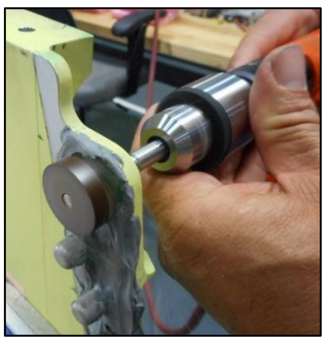
Selected 500 rpm Andrews Tool & 600 rpm DOTCO Drill

Demonstration to Customer

Demonstration of new Torlon cutter design with 600 rpm drill motor to OEM & FSEs

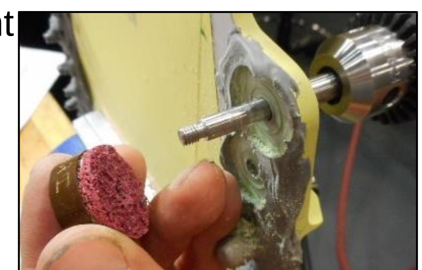


Representative aircraft structure
Failed nutplate location with
sealant and adhesive



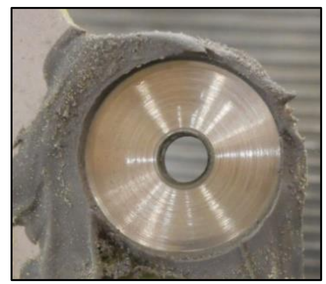
DOTCO pneumatic drill
with Torlon cutter

After one min – sealant removed and only a “ghosting” of adhesive remaining



Abrasive pad for
final preparation

Surface ready
for bonding



In less < 2 min gone from failed nutplate to structure ready for bonding
- Following T.O. procedure would have taken 10’s of min

Customer Evaluation

Beta kits of Torlon cutters, mandrels, and Andrews Tool Adapter

Sent to Operational units for several months of Evaluation/Field Trials
- very positive feedback – significantly reduced time for preparing structure for bonding
- found/discovered new requirements
    - additional size cutter desired – 33mm (1.3”) diameter for hard to access locations
    - difficult to remove Torlon cutters from tools
        - redesigned cutter to have a flat zone on its backside - engage with a wrench

Prototyped a wrench – field trials discovered another requirement
- wrench needs to engage with Andrews Tool adapter

Created new prototype – field trial – customer approved new design

Worked with Custom Tool Stamping Vendor to produce for kit deployment

Torlon Cutter
Final Design – Build/Commercialize

Customer satisfied with Torlon cutter design now necessary to move to mass production

Optimal manufacturing method is injection molding
- reduces cost by a factor of ten
- more readily available

UDRI worked with AFC Tool Company – design of cutters for injection molding

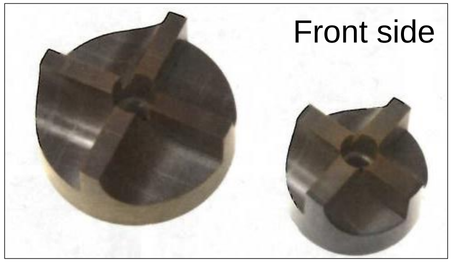
and

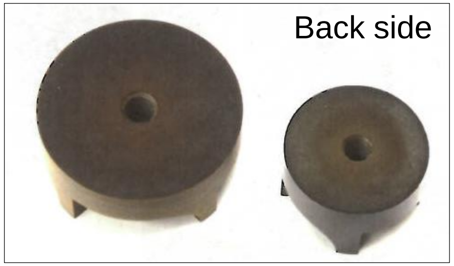
Performance Plastics Ltd (PPL) for fabrication of injection mold tool & injection molding cutters

Torlon Cutters
Validation of Injection Molded Cutters

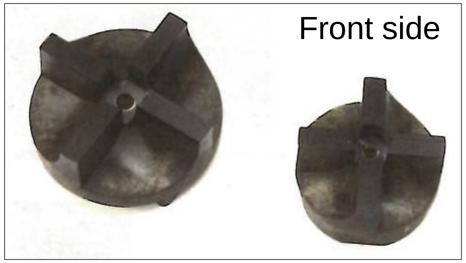
Final Article Evaluation

Machined Cutters





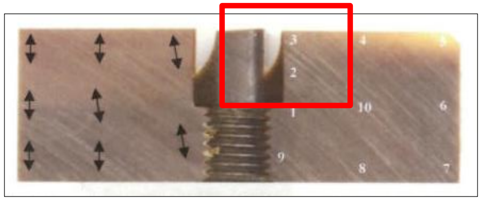
Injection Molded Cutters

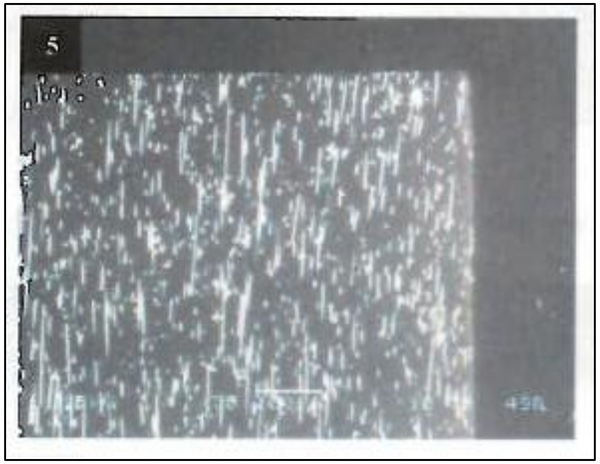


Section lines shown for photographic study

Torlon Cutters
Validation of Injection Molded Cutters

Representative cross-section through thickness of a cutter





Cutters from machined rod stock
Fibers aligned perpendicular to cutters edge

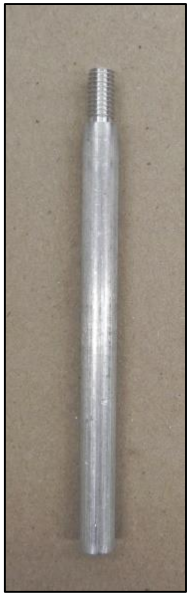
Focusing on cutter's edge saw only 2% increase in fiber density for injection molded cutter

Injection molded cutters
Fibers have more random orientation

Injection molded cutters subjected to hands-on evaluation

- multiple trials on test articles
- easily & efficiently removed adhesive w/o damaging structure
- performed slightly better than machined versions

Mandrel Prototype Development



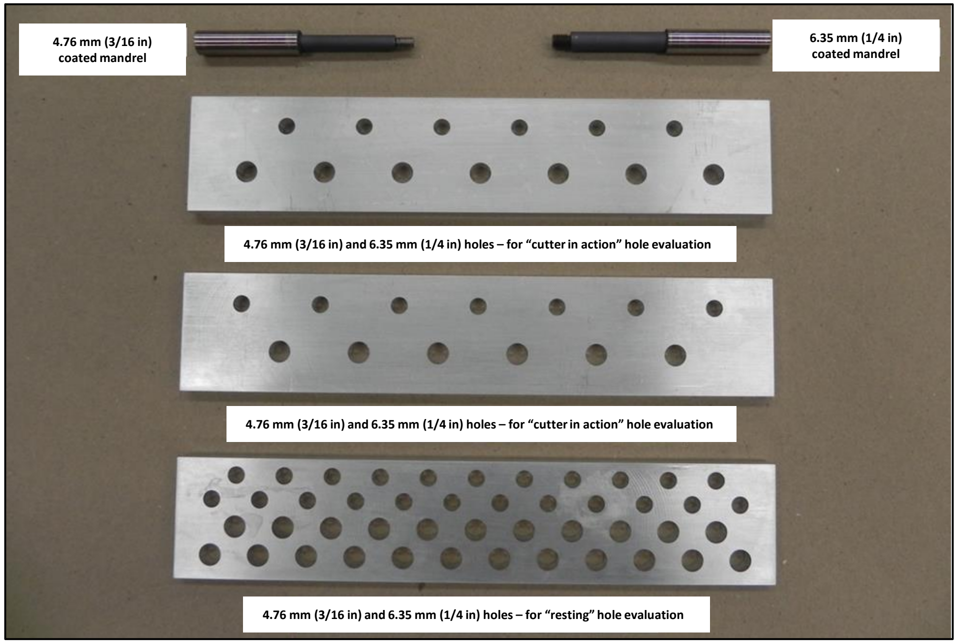
1st iteration
6061 Al standard mandrel
galling observed –
potential damage to hole

2nd iteration
4140 steel – shoulder added due to concern with FOD
Several months in humid environment – pitting corrosion
OEM concerned could cause damage to hole

3rd iteration
17-4 PH SS
H-1000 condition
Similar UTS but much higher corrosion resistance
No observed corrosion after months of testing

Mandrel Evaluation

Two set of 4.76mm (3/16") and 6.35mm (1/4") dia 17-4 PH SS mandrels produced
one set coated with molybdenum disulfide dry film lube
Spun in holes associated with nutplate fasteners of 5.46mm (0.215") and 6.99mm (0.275") dia
Simulated aircraft structure - 2124-T8151 aluminum

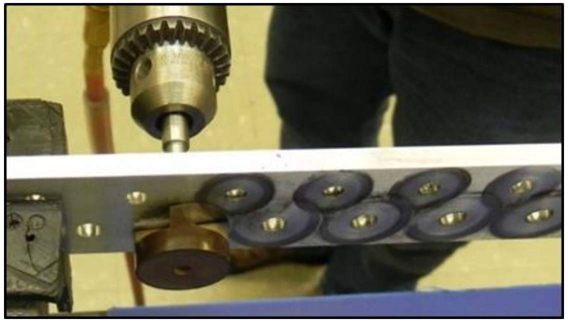


Test panels prior to mandrel evaluation

mandrel "resting" in the hole

Two conditions

mandrel simulating "cutter in action"



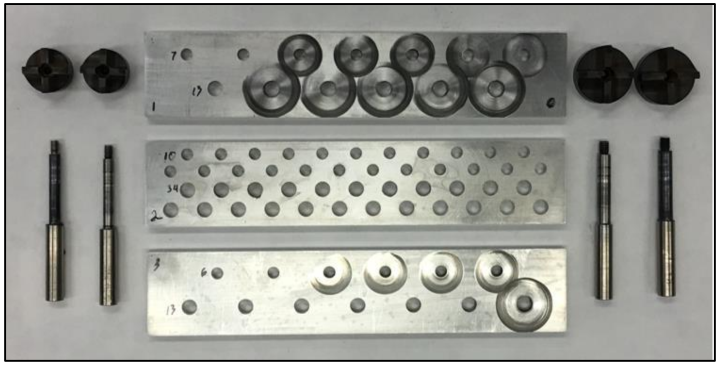
Mandrel Evaluation

Hole Assessment

In collaboration with OEM, two techniques employed to assess hole condition

3x Optical Microscope – topside hole

FaroArm - inside hole



Findings

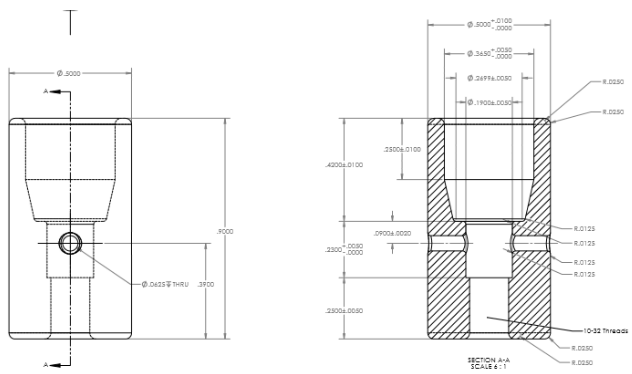
(within equipment error)

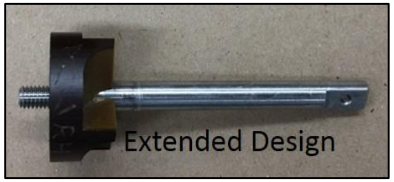
- No damage created with or without coating on mandrel
- No damage to backside of aluminum structure despite aggressiveness with cutters

Tetherable Mandrel Development

Feedback from maintainers' evaluation of Torlon Cutter beta kits indicated need for a swivel apparatus to attach to cutter side of mandrel

Incorporated a COTS Offshore Angle ball bearing swivel into a housing that threads onto the extended mandrel





Noble Tool Corporation manufactured two prototypes
- taken to operational units and evaluated on-aircraft
- very favorably received

Tetherable Mandrel Development

Units desired a multi-piece (segmented) tetherable mandrel of varying lengths

- allows easier access into confined areas
- defined length of each segment

Also desired smaller (shorter) swivel connectors

AFRL/UDRI contracted Noble Tool Corp to fabricate to the new specifications

Updated swivel connector

Segmented mandrels – different diameters

Segmented tetherable mandrel broken into a tether mounting hole (a), and a 12.7mm (0.5”) (b), a 63.5 (2.50”), a 38.1 (1.50”) segments

Segmented tetherable mandrels with Torlon cutters & tethers

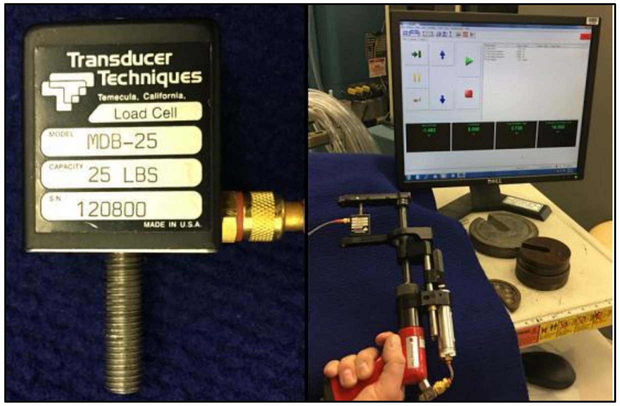
Andrews Tool Improvements

AFRL/UDRI discovered compressed air available for use varied across OEM & operational units
- differed from manufacturer's recommendation (lower)
- affected efficiency of Andrews tool

AFRL/UDRI conducted study to determine minimum compressed air pressure required to provide adequate clamping pressure
- sufficient to ensure cutting edge of Torlon cutters can remove adhesive
- if not sufficient too much adhesive remains – more abrasive pads required - increases time

In process of conducting study found inconsistences in tool operation
- worked with Andrews Tool Corp to address

Bottom-Line: With tool improvements found that 90 psi inlet pressure to the tool (98N or 22lbs-force) is required to operate Andrews Tool efficiently

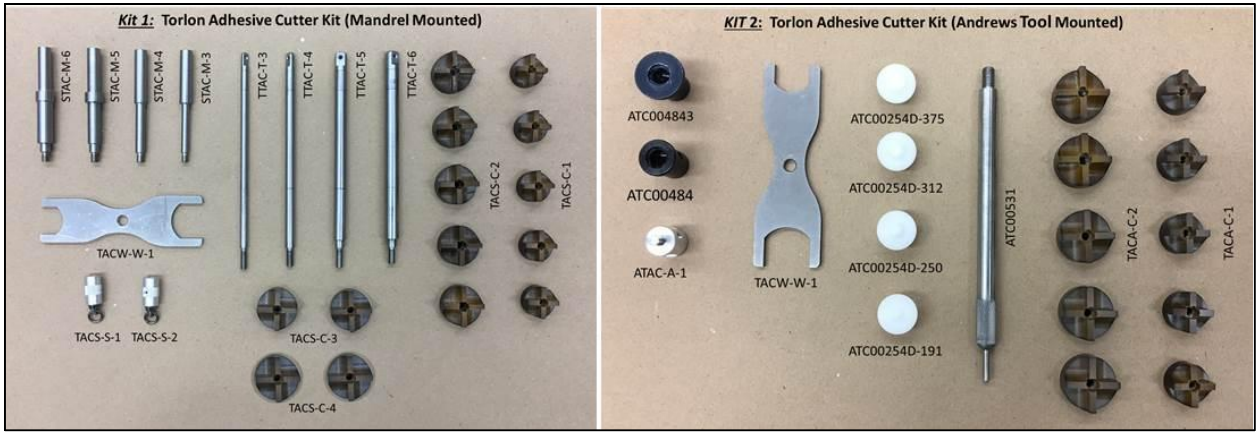


Andrews Tool clamping force evaluation

Surface Preparation Tool Force Readings (Andrews Tool Co)						
Pneumatic Tool Model # ATCP2L7-USPR500-88-R						
	Clamping Force Before Modification Newtons (lbs-force)	Clamping Force After Modification Newtons (lbs-force)	Clamping Force Before Modification Newtons (lbs-force)	Clamping Force After Modification Newtons (lbs-force)	Clamping Force Before Modification Newtons (lbs-force)	Clamping Force After Modification Newtons (lbs-force)
	621 kPa (90 psi)		687 kPa (100 psi)		758 kPa (110 psi)	
Avg of 20 cycles	85 (19)	98 (22)	107 (24)	116 (26)	116 (26)	129 (29)
Std Deviation	5.3 (1.2)	1.4 (0.32)	3.0 (0.68)	2.3 (0.51)	2.6 (0.59)	2.2 (0.50)
Note: inlet pressure verified using a Electromatic Checkline M 3i						

Case Design

Original concept grown from initial beta kit which only included cutters, four mandrels and Andrews Tool adapters to:
(based upon evaluation and user input which drove additional requirements)



To complete usefulness for Operational units, the Torlon cutters and their associated tools must be put into a case that is:

- durable
- allows for easy identification of kit tools and components
- conveniently organization for rapid kit inventory

Case Design

Prototype Torlon Adhesive Cutter Kit Configuration

Drill Motor

Andrews Tool Motor

Put into convenient package

Case Design

- Iterative process that followed the established New Product Development Cycle utilized to evolve non-metallic reverse counterbore Torlon Adhesive Cutters from concept to a commercialized product
- Key to successful development was close working relationship between AFRL/UDRI and targeted end-users (OEM and operational unit maintainers

Kit soon to be available

- will dramatically reduce time to remove remnant sealant/adhesive w/o damaging aircraft structure
- will result in reduction of maintenance manhours associated with repair/replacement of bonded nutplates
- will increase aircraft availability for Air Force and other services

Acknowledgements

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