

Composite Repair for the Neophyte (Dummy)

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Outline

- Introduction
 - Recommended PPE (Safety glasses, Dust Mask Disposable Gloves)
 - Tools of the Trade
- Repair Planning
 - Laminate Pedigree
 - Resin Type
 - Cloth Type
 - Repair Type: down hand, wet bag, vacuum infusion
- Part Preparation
 - Clean part to be repaired removing all oils and dirt
 - Remove old paint and/or past repairs
 - Preparation of defective location

Outline Cont.

- Composite Repair
 - Selection of resin
 - Selection of composite cloth
 - Proper dimensional coverage
 - Determining the number of layers
 - Application of repair (applying cloth and resin)
 - Technique for applying resin and cloth
- Final Repair Steps and Finishing
 - Common finishing preparation methods
 - Final topcoat

Recommended PPE

- ✓ Eye Protection - use a least ANSI approved glasses. The missing cut off wheel piece in the photo nicked the side of my nose and I have since purchased a face shield.
- ✓ Hearing Protection - a least 23 dB of attenuation. The 'band' style I prefer as it allows you to wear safety glasses comfortably.
- ✓ Skin Protection - gloves preferred as the ointments don't protect enough, especially when working with solvents.
- ✓ Respiratory Protection - recommend the 3M double elastic style or cartridge mask.
- ✓ Tyvek sleeves - I highly recommend these as they are great when laminating (no skin reaction) and sanding (no itch).

Tools of the Trade

- Basic Hand Sander, 1"-2" wide chip paint brushes and small plastic cups & mixing sticks
- Fabric Cutting Tools
 - Wheel cutters
 - These are excellent but need to use a good surface to cut on so that the blade lasts.
 - Use Masonite, plywood or urethane mat at sewing sources
 - I have used particle board but it leaves little wood chips in your fabric and you are annoyed picking them out
- Rags (bond breaker)
 - Cloth rags are not used no matter how often they are washed or washed with TSP
 - Preferred are the Scott Blue Shop Towel or similar
- Gloves
 - Nitrile
 - These are great if one has a reaction to latex, however they are not resistant to ketone solvents (acetone or MEK)
 - Latex
 - Resistant to strong solvents but may cause skin reaction
 - Skin reaction solution is to wear nitrile under the latex gloves when cleaning up with acetone or MEK

Tools Cont.

- Scissors
 - These should be good industrial grade which will save time and hand fatigue
- Razor blades
 - If the preference is still to use a single edge blade then cut using a straight edge and keep the blade at a shallow angle
- Straight edge
 - Preference is an aluminum straight edge. May want to add a non-slip surface on the back.
 - May also use a drywall square as it is convenient to make quick square cuts using the edge of the table or bench
- Hip square
- Table Top for Cutting Surface
 - A large table with a Masonite top works well. Do not use particle board or under lament for the cutting surface as it eventually results in little wood chips in the fabric

Repair Planning

- Laminate Pedigree
 - This is important for the repair of primary structure such as composite fuselage and flying surfaces
 - Not a concern with secondary structure such as cowlings, wing tips or wheel pants
- Fiber Type
 - Glass or Carbon Fiber
- Resin Type
 - Polyester, vinyl ester or epoxy
 - Note: carbon fiber demands epoxy resin on primary structure!
 - This is due to interlaminar strength properties

Damage Assessment

- At times there may be less damage on initial inspection.
 - Many coats of cracked paint can be deceiving
- If part is removable then an added inspection of the inside surface will likely reveal the true story.
- If the inside surface is not accessible, such as a flying surface or airframe, then use the tap test as the initial inspection tool.
 - The availability of UT equipment would be found in a fully equipped repair shop.
- The assessment of the extent of the damage then initiates the approach to the repair.

Surface Preparation

- Clean part to be repaired removing all oils and dirt
 - Degrease with Simple Green and ample water
- Remove old paint and/or past repairs
 - Paint removal done with abrasives
 - 3M has a Rol-Loc bristle disc able to remove the paint without damage to composite substrate if handle correctly
 - DA sander may be used in larger flat areas
- Determine the extent of damage
 - Tap test
 - Use a coin to tap out the damage and mark with a Sharpie
 - Explore the amount of damage as one grinds out the damage site
- Preparation of defective location
 - Grind off all delaminated composite into the undamaged areas

Composite Repair

- Selection of resin and fiber type
 - Based on original pedigree
 - Based on structure (primary or secondary)
- Proper dimensional coverage
 - Area of repair to extend beyond damage
 - Commonly a 7:1 or 11:1 scarf taper and repair for primary structure
- Determining the number of layers
 - Based on original pedigree for primary structure
 - Adequate to restore repair to original thickness for secondary structure
- Application of repair (applying cloth and resin)
- Techniques for applying resin and cloth

Selection of Resins

(Available from Aircraft Spruce and Wicks)

- Gougeon Brothers Inc. (GBI) ProSet Epoxy 125/135 resin
 - Hardeners: LAM-226 (med), LAM-229 (slow), LAM-237 (extra slow)
- Hexion MGS L285 resin
 - 285F (fast), 287S (slow) hardeners
- PTM&W Aeropoxy PR2032 resin
 - PH3660 (fast), PH3665 (slow) hardeners
- With all three of these resins room temperature curing results in good properties; curing at elevated temperatures, or post curing, will result in the highest achievable strength and Tg.
- GBI is the only manufacturer that claims that hardeners may be blended to adjust cure times. MGS is clear that one cannot mix components of the 285 and 335 resins together. PTM&W is silent
- We do not recommend the use of the Endurance Technologies E-Z Poxy!
 - Contains carcinogenic constituents and unreactive diluents

Final Repair Steps & Finishing

- Common finishing preparation methods
- Final topcoat

GBI ProSet

- Low viscosity for quick wet out of all organic and synthetic composite fabrics; especially effective with aramid (aka Kevlar®) and carbon fiber.
- Slow cure speed hardener provides 4 to 5 hours working time at 77° F (25° C). A typical laminate will be gelled in 6 to 7 hours.
- Optimized for hand wet out and machine impregnation in contact molding, vacuum bagging and light RTM (such as VARTM) applications.
- Room temperature cure properties suitable for many composite components and structures.
- Tg as high as 197° F (92° C) with proper post cure providing excellent temperature stability and great part cosmetics.
- Cost Effective - High Performance Epoxy formulation for composite manufacturing. In use by Scaled Composites.
- Reformulated in 2013 yielding enhanced mechanical properties and lower retail pricing.

Hexion MGS

- Laminating resin system approved by the German Federal Aviation Authority
- Best known and accepted in the light aircraft industry; these being European gliders and aircraft such as Diamond, Lancair, Cirrus, Cessna, Icon
- In the wind industry, the MGS line of Hexion resins is the global leader, with the slower blends.
- Even unfavorable low temperature and high humidity conditions in the work environment will not effect the quality of the product. The resins do not contain any unreactive diluants which with many systems result in de-gassing and bubbling of the painted finish. The MGS resins do NOT contain aromatic amines.

PTM&W AEROPOXY

- The resin system gives excellent wet-out of fiberglass, carbon and aramid fibers.
- Special additives have been incorporated into this system to promote chemical adhesion to fabrics made with these fibers.
 - **Note:** We have not seen the interlaminar mechanical data to agree with this statement
- The AEROPOXY systems will cure completely at room temperature, or can be given an elevated temperature cure.
- It satisfies all structural, pot life and wet-out characteristics according to tests by former Rutan Aircraft Factory.
- AEROPOXY contains no MDA and meets or exceeds current OSHA requirements for safe use. PTM&W AEROPOXY epoxy products are made from raw materials carefully chosen to minimize or even eliminate toxic chemicals, and therefore offer the user high performance products with minimum hazard potential when properly used.

About GBI WEST SYSTEM®

- WEST SYSTEM® is a reformulated laminating resin originally developed for wood cold molding.
- It is not recommended in aircraft structural applications as the average Tg is 130°F. One can achieve 142°F with 205 fast hardener and post curing.
- Most popular hardener is the 206 for longer working times. The Tg is 126°F at room temperature cure. However, one can achieve a 10° bump in Tg with a post cure.
- WEST System is excellent for use with micro filler. Further, it is readily available from local retailers.
- However, I do not recommend the use of GBI 410 Microlight filler as it is a plastic micro-sphere and not a glass micro-sphere. It has the potential to swell under certain surface heating conditions.
- WEST SYSTEM may be used for non-structural applications such as instrument panels and interior consoles.

What About the Properties?

- Neat (pure resin) mechanical properties are what we use to compare candidate resins
- For application in the military and aerospace industry the manufacturers' SPEC's are not trusted and each candidate material would go through parametric investigation
- American Standard for Testing of Materials (ASTM) publishes and manages the test standards
- Caution is used when accepting the manufacturers published properties as they can be embellished by post curing to the 'second heat' condition (onset of 2nd Tg by post curing)

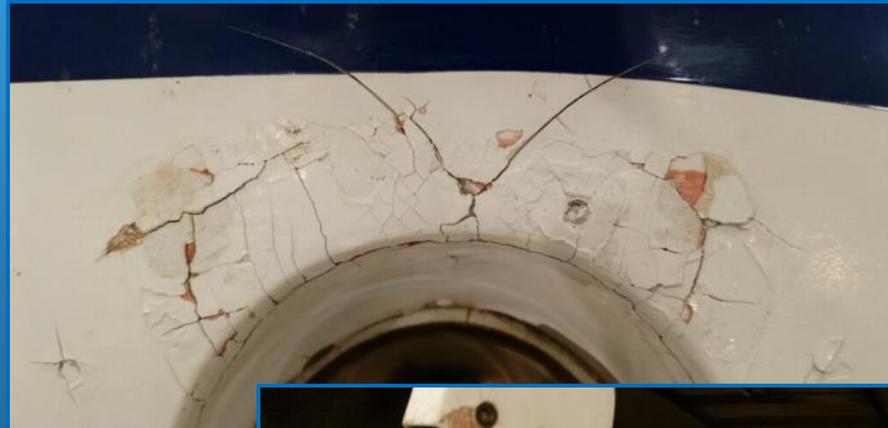
Property Comparison

EPOXY PROPERTIES (neat)	Test Method	Gougeon ProSet		MGS*	PTM&W	E-Z Poxy
		LAM 125/226	LAM 125/229	L285/287	PR2032/PH3660	EZ-10 / EZ-84
Mix Ratio: by Weight		100 : 29	100 : 29	100:40	100 : 27	100:44:00
by Volume				2:1	3:1	100:47:00
Hardness (Shore D)	ASTM D-2240	92	92	NA	86 - 88	
Compression Yield (psi)	ASTM D-695	16,800	16,200	17,400 - 20300	13,288	14,000
Tensile Strength (psi)	ASTM D-638	8,100	9,380	10,150 - 11,600	9,828	8,2300/10,000
Tensile Elongation (%)		2.1 - 7.2	3.5	5.0 - 6.5	1.9	3.5
Tensile Modulus (psi)		5.30E+05	5.56E+00	4.64E +05	4.18E+05	480,000
Flexural Strength (psi)	ASTM D-790	17,100	14,400	15,950 - 17,400	16,827	NA
Flexural Modulus (psi)		5.36E+05	5.40E+00	NA	4.63E+05	NA
Glass Transition Temperature (°F)	Differential Scanning Calorimeter	134	133	195	NA	151 / 196

*NOTE: Typical data according to WL 5.3203 Parts 1 and 2 of the German Aviation Materials Manual not ASTM.

C-172 Cowl

- Multiple coats of paint made damage look much worse than actual.



C-172 Cowl Cont.

- Once paint was removed a proper assessment was made



Hole revealed when Bondo was removed. Repaired & painted.



C-172 Cowl Cont.



Wheel Pant Repair

- Piper Cherokee wheel pant



Wheel Pant Repair Cont.

- Grind area with small grinder beyond the damage.
 - For primary structure either a 7:1 or 11:1 scarf taper
 - EX: 1/8 inch thick laminate: $.125 \times 7 = .875$ so grind taper 7/8" beyond the edges of the damage.
 - For thinner base laminate recommend 11:1 taper
 - Have found that 7:1 is adequate for 1/4 inch or thicker skin laminate

Insert MCB beam pix here

Wheel Pant Repair Cont.

- Grind about 1 inch on either side of crack
- Grind inside on wheel pant 1 to 1-1/2 inches beyond cracks found in the pant mounting area
- Repair area
- Apply peel ply
- Set out in sunlight



Wheel Pant Repair Cont.

- Repaired with two plies of 7725 style glass (twill)
 - This style of glass is readily available
 - Has very good drape over small radius
 - Compatible with all resins
- Used Sunrez 7300C UV cure vinyl ester resin
 - Cures in 10 minutes in the sun
 - Used peel ply to account for air inhibited surface
 - Polyester and vinyl ester surfaces remain tacky when exposed to air
 - Can purchase off the shelf polyester with wax additive to prevent this



Wheel Pant Repair Cont.

- Sand, fill/fair, sand, prime, sand & paint



RV8 Wing Tip Repair with Vacuum

- Pilot strikes telephone pole guy wire while taxiing
- Wingtip split at seam and rear trailing edge corner opened up
- Small crack radiated perpendicular to seam
- Accomplished the repair with epoxy and fiberglass
- Repair integrity was important, not just cosmetic
- Time was of the essence
 - SARL race contestant the next day

RV8 Wing Tip Repair Cont.

- Could easily determine the extent of damage by inspection of inside of wing tip
- Small angle grinder made it easy to get inside tight spot to prepare the surfaces. Some hand sanding was required (80 or 120 grit is adequate)
- Used WEST System epoxy as it was readily available
 - Not concerned with Tg as final outside color was light gray (low solar heating)
- The only fiberglass on hand was stiff and required vacuum bag on inside and outside repairs to conform
- Built make shift oven to accelerate cure

RV8 Wing Tip Repair Cont.

- Removed adequate paint around damage to allow repair
- Applied two plies of glass inside and outside
- Used a vacuum bag inside and outside to consolidate stiff fiberglass on repaired areas
- Fabricated R-Max polyurethane board for the oven
 - Used thermostat controlled heat gun as heat and circulation source
- Curing completed in three hours
 - Light sand and prime with light gray aerosol primer

RV8 Wing Tip Repair Cont.



RV8 Wing Tip Repair Cont.



RV8 Wing Tip Repair Cont.



Final Repair Steps and Finishing

- Common finishing preparation methods
 - Surface finishing can be accomplished with common automotive techniques
 - Sand repaired area to 120 or 180 grit
 - Polyester body putty (sparingly) or epoxy dry-micro
 - High build polyester primer
 - Sand and block to 400 or 600 grit profile
 - Apply final topcoat

Etcetera

Additional and Helpful Information

No No's

- Rags (read bond breaker)
 - Cloth rags are not used no matter how often they are washed or washed with
 - Preferred are the Scott Blue Shop or the Multi-Ply, Reinforced Nylon Fiber Utility Towel
- Fabric Handling - not handle with bare hands
- Shop heating - I do not recommend kerosene heat as it puts contaminants in the air and so on the surface of your work
- Diluents in resin - some have used alcohols to thin out epoxy resin - DON'T! Keep your resins at temperatures in the 80's or 90's. Use a heat box if you have to (wooden box with light bulb & thermostat).
- Open Fabric storage - keep your fabric in a bag to be free of dust and moisture: preserves sizing
- Open Resin storage - epoxies last a long time when stored cool & dry
- Solvent wiping / cleaning - many like to clean with acetone or MEK; these are potential bond breakers. I recommend isopropyl alcohol as it does not have any recycled adds due to the medical requirements. Try to get 92%.
- Additives (fumed silica aka cabosil, micro-balloons, flox) - cabosil at less than 2% for thixing and balloons or flox as required. Cabosil has no strength. Additives are introduced after resin & hardener is thoroughly mixed

Water Break Test Surface Check



Source List

- Teflon Tape: CS Hyde Company, 1” wide Skived PTFE Part# 15-2A, 2” wide Skived PTFE Part# 15-2A (found it on Amazon recently)
- Airtech Flashbreaker Tape - Airtech (www.airtechonline.com) or Freeman Supply (www.freemansupply.com)
- Scissors: Kretzer Finny 74525 10.0” - Extra Heavy Duty, Industrial Scissors (on the web ~\$40) or John A. Eberly, Inc. Textile and Sewing Scissors and Shears Professional Cutlery Industrial Tools and Supplies, Box 8047 Syracuse NY 13217, 800-532-3759
- Wheel Cutters: Olfa Rotary Cutter sold at many fabric stores
- Fiberglass Rollers: E S Manufacturing, St Petersburg, FL (www.esmfg.com)
- Tongue Depressors: non-sterile - any local medical supply
- Resins: Aircraft Spruce
- Vacuum bag supplies: Coast-Line International (coast-lineintl.com)

Questions?

- Join us at the Composites Workshop for a hands-on demonstration
 - Easy processing demonstration
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