

INTRODUCTION TO EPOXY ADHESIVES

Background

Epoxy is used in rocketry for laminating, coating, and bonding. It is also used for resin casting parts. A wide variety of formulations and fillers are available for these purposes. This article introduces the use of epoxy as an adhesive and coating agent for hobby use in rocketry. It is intended to supplement, rather than replace, manufacturers' literature.

Epoxy is heavy. (68.3 lbs/ft³, 0.635 oz/in³, or 1.18 times the density of water). Try to avoid using excess epoxy in your rockets. Consider using lightweight fillers for fin fillets and fairing purposes.

Mixing Tips

The most common problems with epoxy are not enough mixing time and incorrect mixing ratios.

Both the part A (resin) and part B (hardener) are important components and critical to the final properties of the epoxy. Mix ratios change from one type of epoxy to another, so carefully measure the components following the manufacturer's recommendations and mix thoroughly. A one minute minimum mixing time is a good rule of thumb.

Because epoxy formulations differ from manufacturer to manufacturer do not mix resins or hardeners from different manufacturers'. The results are unpredictable and may not work at all.

Hardener selection and temperature, control the working time and cure time of epoxy. In general, for every 10 degrees F that the mixing temperature falls below 77 degrees, the gel time of the mix will double. The opposite will occur as temperatures increase above 77 degrees. The gel time of the mix will be cut in half for every 18 degree rise.

Mixed epoxy is exothermic (generates heat). A larger quantity of mixed epoxy will create more heat and have a shorter working time and overall cure time. Small batches of epoxy create less heat than large batches and also have longer working and cure times. Spreading the mixed epoxy in a thin layer over the mixing surface can help to extend working time. If the epoxy is becoming noticeably warm "in the pot" you need to switch to a slower cure hardener.

If epoxy doesn't cure within 48 hours in a warm room, the mix is bad. You will have to redo the work. When in doubt over the age or storage conditions for epoxy, mix a test batch to check for cure before using it on your rocket.

Cold and/or damp weather isn't good for working with epoxy although some formulations are more tolerant of these conditions.

Slow cures can cause a waxy film, called amine blush, to appear on some cured epoxy surfaces. (Most epoxies are now formulated to avoid blush.) To prepare surfaces between applications, wash the surface with warm water and a 3M Scotch Brite pad just before applying subsequent coatings. Before the water evaporates, dry the surface with paper towels and sand any remaining glossy areas with 120-grit paper. Let the surface dry thoroughly.

Fillers

Fillers may be added to epoxy to increase strength and workability. Fillers also affect cure time, so read the manufacturers literature for their recommended fillers for specific applications. Below are some examples of typical fillers:

3M K15 SCOTCHLITE Hollow Glass Spheres - for use when a sandable, medium density solid is required for fairing, and non-structural applications.

Fumed Colloidal Silica (Tradenames: CAB-O-SIL, Aerosil, West System 404) - general purpose use when an extremely hard solid with high density is needed, i.e. structural bonding, filling and filleting. Silica has the unique properties of being very smooth spreading, strong and thixotropic (non-sagging). Thixotropic qualities are especially helpful in allowing your fairing paste to hold its shape, and preventing run-off on vertical and overhead work. According to the amount added, you can achieve a viscosity from thin catsup to peanut butter. It can be used for gluing, laminating and making a very smooth fairing compound. Silica is difficult to sand, so smooth it and clean up well before the mixture cures.

COTTON LINTERS - used frequently in wooden boatbuilding applications. Good thixotropic properties but tends to form a somewhat lumpy paste.

MILLED FIBERS (1/32" milled fiberglass) - for use when epoxy must fill a void and provide extremely high strength and resistance to cracking, i.e. structural filleting or bonding hardware.

PHENOLIC MICRO-BALLOONS (Organic Phenolic Hollow Spheres) - for use when low density, light weight, and sandable paint ready surfaces are required, i.e. fairing.

Surface Preparation

One of the major causes of a failed epoxy bond is inadequate surface preparation. Surfaces to be bonded should be clean, dry, and slightly rough. Preparation usually includes sanding followed by a solvent wipe-down.

When preparing paper tubes, either sand through or otherwise remove the finish layer (glassine or white paper) in the bond areas.

G10 fins and components need to be thoroughly sanded in order to achieve a good bond.

Solvents

Various solvents are used to prepare surfaces for bonding, or for thinning epoxy for better penetration. All have their particular applications, advantages and dangers.

Common white vinegar may work as a solvent and neutralizer for some epoxies. If it works for you, great! (Don't be surprised if it doesn't). It is not recommended for clean up of epoxy surfaces to be re-coated.

Rubbing alcohol can be used for clean up. However, the high water content makes it unsuitable for thinning epoxy or for surface wipe-down.

Denatured alcohol is ethyl alcohol, usually near 100% plus some stuff to make it taste horrible. It can be used for clean-up, surface wipe-down, and for thinning epoxy with some loss of strength (approximately 30% loss). A model rocketry trick is to moisten the bond areas with denatured alcohol before applying the epoxy. This helps wick the epoxy into the balsa and tube substrates, creating a stronger joint. (The thinned epoxy is still much stronger than the paper or balsa.)

Acetone and MEK are benzene based from the ketone family, which means that they have a sickly sweet smell and are bad for you in myriad ways. Don't breathe the fumes. Also, they penetrate your skin and can carry epoxy with it. Unfortunately, they are really effective for clean-up use. Acetone more so than MEK. They are not recommended for thinning epoxy due to associated loss of physical properties. Beware of recycled versions. These can carry contaminants that can cause bonding and finishing problems ("fish-eye").

Lacquer Thinner is a complex mixture of solvents. Nothing that you want to breathe or otherwise expose your body to. Lacquer thinner absorbs moisture out of the air, and may lead to "blush" problems in the epoxy film if you prep your surfaces with it. For cleanup it doesn't much matter. It is not recommended for thinning epoxy.

Health risks

Protect your body from epoxy. Don't get it on your skin. Don't get it in your eyes. Don't breathe the fumes. The dust from partially cured epoxy is also hazardous.

Epoxies are sensitizing agents. A symptom that you have become sensitized to epoxy is called "Resin Rash" where your skin starts itching and forms a red rash. This often occurs on the hands after multiple exposures to epoxy without proper safety protection. For an example of a rocketeer developing epoxy sensitivity, Read "Dangerous Dave Gawliks" story at:

<http://www.ddave.com/safety.htm>

Other possible health risks include endocrine system damage, low sperm count, and eye damage.

Note that use of solvents for surface preparation may greatly increase your health risks! Solvents can be quite hazardous by themselves and they may also transport dissolved epoxy through the skin or into the air.

Work smart and be safe!

Use appropriate eye protection.

Apply a skin barrier cream to hands and forearms. Also, use disposable nitrile gloves. Latex gloves are not a good choice due to porosity and poor durability. Change gloves whenever they become contaminated or damaged.

Use a waterless hand cleaner for removing epoxy from the skin. Follow up with a thorough soap and water wash.

Practice good personal hygiene. Shower after working. Also, wash or dispose of clothing after working.

Good ventilation is important. Work outside if practical.

Organize your work to maximize efficiency and minimize exposure.

Have adequate space to layout the work. Make sure that your ingredients and tools are within reach when you need them.

Use disposable mixing sticks, mixing surfaces, and application tools wherever possible. Have disposable wipes or rags handy. Use disposable drop cloths and paper to control spills.

Do not attempt to warm epoxy resin, hardener, or mixtures in the microwave. Also, be aware that adding heat from any source to mixed epoxy, "in the pot", can cause a runaway reaction and possibly a fire.

Epoxies and other stuff I Use

For convenience on small projects, try Devcon 2-Ton. This is a 1:1 mix epoxy typically found at hobby shops and packaged in small squeeze bottles. Simply squeeze out two identical beads on a paper plate to measure. For larger batches, use a pre-marked single use plastic measuring cup. Modify with a filler as required for gaps and fillets. Drawbacks include expense and poor physical properties (still adequate for most uses). Compare Devcon's advertised 2-Ton (4400 psi) tensile strength against the 7846 psi strength listed for West System's 105/205 epoxy. Also, note that it is too thick for laminating use.

For more advanced applications, use West System 105 resin and 205 hardener with metering pumps. It's a good general purpose epoxy available at most marine stores. Better epoxy values exist but West products are consistent and locally available.

Both West System and SystemThree have excellent user information available for free from their websites.

For the exotic, take a shot at SystemThree Clear Coat. Super thin viscosity useful for coating, laminating and repairs to damaged substrates. Expensive! But worth it!

The best filler I've found is West System 404. I have the other types listed above on hand but the 404 is always within reach. A spoon is used to transfer the powder from the container to the mixing pallet (paper plate).

Solvents: Rubbing alcohol, Denatured alcohol, and acetone in that order.

Nitrile gloves by the box. Available at Harbor Freight.

Invisible Glove, skin barrier coating.

Waterless orange hand cleaner with pumice.

Blue paper shop towels, bought in bulk from Costco.

Wax paper. Non stick surface.

"Craft Sticks" (popsicle sticks). Box of 1000 seconds available from Jo-Ann Fabrics, Artco, Michaels, and All Hobbies for approximately \$4.00.

Tongue depressor size sticks. Same sources as above and The Dollar Store.

Small diameter dowels. The Dollar Store.

Bamboo skewers, "extra heavy" size. Available at Albertson's supermarket. Useful for internal fillets in fin box assemblies on small rockets.

Disposable brushes. Acid brush type. Available at Harbor Freight. Also, polyester bristle brushes in different widths from The Dollar Store.

6" and 12" diameter paper plates. Bought in bulk quantities from Costco for mixing epoxy and collecting drips.

Veterinary Syringes, 50 ml and 10 ml, useful for measuring small quantities of epoxy. Available from Cenex and other farm suppliers.

Wagner heat gun. Useful for heating parts before application and for thinning epoxy *after* application in order to wet out laminates, penetrate substrates, and promote flow into cracks. Avoid overheating the epoxy. Temperatures above 125 F will damage epoxy.

Masking tape. Holds parts in alignment while the epoxy cures.

Binder style fin jigs, Shop fabricated as needed to hold fins in alignment while epoxy cures

Horizontal rocket cradle.

I always wear safety glasses with side shields in the shop and sometimes augment them with a full face shield.

Some Retail Epoxy Systems and Sources (not inclusive)

Devcon 2-Ton epoxy: <http://www.devcon.com/index.html> (All Hobbies, Puyallup)

West System: <http://www.westsystem.com> (West Marine Stores)

TAP Plastics: <http://www.tapplastics.com/index.html> (Bellevue Store)

MAS Epoxies: <http://www.masepoxies.com/> (mail order)

SystemThree: <http://www.systemthree.com/index.html> (mail order, Auburn pick-up)

Fiberlay: <http://www.fiberlay.com/> (Seattle store, mail order)

Fiberglass <http://www.fibreglast.com/> (mail order)

Tacoma Fiberglass: (Tacoma retail store only)

SystemThree offers a \$10.00 sample kit that is a bargain introduction to epoxy.