Adhesives – How they work, why they work and how to use them properly Originally discussed on the THO Game Calls forum - Reprinted with permission from the author

Q: I read a tutorial on glues awhile back. Don't remember who it was but they worked in the adhesive industry, one of the major factors that I do remember is that most glues have a shelf life and it is shortened when you open the container.

A: Marvin, based on your description, that sounds like Dave Paul (HuntnCarve) that wrote the tutorial. Dave is a wealth of knowledge on woods and on adhesives.

A: Brian

Well it looks like I've been called out. LOL! Yes, I worked in the Adhesives Industry for about 20 years as a Technical Trouble shooter and in Technical sales. This coupled with a B.S. Degree in Wood Technology (Penn State University) served me well in solving a myriad of problems for companies all over North America. I was also "Quality Control -U.S. Flush Door Operations (Eleven Plants) for Masonite. That was until 3 years back and a corporate buyout, and downsizing when I lost my job. But that's another story.

I tell you this, not to brag. But to show that I have little bit of knowledge in the Wood Products/ Adhesive industries. I generally don't get involved in the debates on glues, and kiln drying lumber I read on the Internet boards. Always seems that there are some Internet experts that don't agree. So I stay out of things to save me the aggravation. It's selfish on my part. But like I said, I spent a lot of years solving the very same problems in the past. So it's more or less, old hat for me.

I wrote the following for Custom Predator Call Makers and Collectors Association and will include it here for you all to read, along with some information on adhesives types themselves. When I wrote this it was directed at trying to help the operator produce the best adhesive bond possible. I did not touch on the glues themselves. Which is another part of the equation. Some of the problems that can occur with adhesives are: They can be outdated (dependent on formulation and type. They can be frozen (not freeze /thaw stable). The manufacturer can make formulation mistakes. The product can be mislabeled, Etc..

The most important thing to remember is: There is no one adhesive that can do everything! Thus the vast number of adhesives out there. I am still awaiting the arrival of the "Miracle Adhesive".

So here goes with Part one.

Part One: This deals with machining and Joint preparation.

I've always said that the key to a good glue joint was first, proper machining of the surfaces being bonded. There are many ways to prepare the gluing surfaces of wood. Surface planing/ jointing, abrasive planing, rips sawing, and finally hand planing.

Surface planers and Jointers: Use a set of knives set in a cutter head. They operate on a periphery. So depending on the number of knives in the cutter head, and feed rate of the material being pushed into the cutter, the surface quality will vary. Under magnification one would observe a surface that looks like small waves on a lake. These waves would have peaks and valleys that could be measured as to how many occur within one inch (Lines per inch. "LPI). Ideally a high quality gluing surface should have about 16-18 LPI. As the two planed surfaces are placed together, they would almost appear to be producing an invisible seam before the adhesive is even applied. Hold the pieces to a light as they are to be glued. Do you see any light shining through between the pieces with no pressure being applied? Ideally you should not see any light. The allowable tolerance variation for good glue bond formation is a variance of minus . 005". That's about the thickness of a dollar bill. As the planed surfaces are brought together, the "peaks" are going to make sole contact with one another, and the valleys. Since the valleys are arc shaped, and the peaks "pointed", the fit is not going to be exact. But surface contact is being made. The adhesive will lay in between these gaps, and harden into a film. But the thing to

remember here is that the thinnest glueline is the strongest! A thick, puddled glue film will be weak, and prone to failure. So you can see why the greater number of “LPI” are important. Conversely, with too many LPI there is a tendency for the surface to be pounded smooth from the rapid beating of the knives. This type of surface exhibits a polished texture. Not conducive to good bond formation. On the other extreme, would be a rough mill planer. These planers are designed to roughly open, and flatten, a board surface to expose its grain and color, and any potential defects. Here there are typically 4-8 LPI, readily seen by eye. Not a good gluing surface at all!

Abrasive Planers: Operate on a periphery too, but the difference being the abrasive is wrapped completely around the drum. Or in the case of a big industrial sander, drawn across a fixed platen. This means that the lumber is continuously in contact with the abrasive as it passes by. So the surface produced will be flat. –No “peaks and valleys”. The problem arises in the quality of the surface produced, when an aggressive grit (#24-#36) is used. The optimum grit for producing the best adhesive bonds are #50-60 grit. Courser grits may efficiently remove material faster. But the resulting surface is masticated, and weak, with a lot of torn and tattered fibers. Yes, it will bond together. But any stress on the plane of this glueline will result in a fracture. An #80 grit abrasive will work, but has a tendency to break down and clog a lot faster. Once this happens, a polishing/burnishing will occur. Not good!

Tip: Place and observe a drop of water on a wood surface to be glued. What happens? If the water quickly disperses this is good! As the adhesive will react the same way, promoting good wetting. If however, the water droplet sits there, beaded up for several minutes. Then it is telling you that the surface quality is not ideal. If the droplet starts to curve away from the surface, (meniscus), this is really bad! Causes: Polished surfaces from dull knives; Wax, extractives, oil/grease are present. Remedy: Resurface the piece after making the necessary adjustments to knives. Remove surface contaminants.

Hand Plane/Microtone: A hand plane uses a razor sharp blade, to slice a shaving of wood away from the surface. This is perhaps the very best surface on which to bond. The wood fibers are cleanly cut, and the resulting “fit” between the two pieces is precise. A Microtone is a machine that feeds a board of lumber across a fixed, stationary, knife. One example would be a veneer slicer. Smaller versions of these machines are used in labs to prepare wood substrates for gluing. Not very practical in a shop. So the old jointers hand plane gets the nod. Problem is, many folk don’t know how to properly use one, let alone keep it sharp! It does however produce one of the finest gluing surfaces possible.

Straightline Rip Saw: A straightline rip saw is just a table saw with a split chain feed that pulls the lumber through the blade. The saw blade is typically on top and the chain on the bottom. Being that must folks don’t use such a machine in their home shops, I’ll abandon this machine and go right into table saws.

A table saw with a good rip blade, or combination blade can be used to produce a good gluing surface. The ripped edge should be smooth, with no pronounced saw kerf. There should be no burns or scorch marks what so ever. If one were to rub a crayon or pencil across the sawn edge, they should observe an “X” pattern. This is showing that both the front of the saw blade (as the piece of lumber first enters the blade), and the back of the blade (as the lumber leaves the blade) are in alignment. A single saw kerf pattern of downward sweeping marks, indicates that the saw is exhibiting “heel”. And it is not cutting properly. One of the causes is that the fence is not parallel to the saw blade. An out of tension saw blade can also exhibit this defect. Either way, it needs to be corrected.

Regardless of the surface preparation used, if the fit between the pieces being glued is not precise. Then a poor bond will result. The use of excessive clamping force only makes the problem worse by causing "permanent deformation" of the wood surfaces. A good example of

permanent deformation would be a hammer lightly tapping on a board surface. –Nothing occurs, and the surface is not damaged. Now strike the same board a little harder. A dent is formed. The cell walls of the wood fibers have been crushed. They will never go back to their original form, and will always be an area of weakness. Excessive clamping force causes the same scenario. In effect, a “plane” of weakness is built right into the glue line. Any subsequent movement of the wood, caused by drying, or by machining, will result in what appears to be a glue line failure. Close examination (under magnification) would show that the adhesive did its job. But the wood itself fractured. So if the fit between the pieces being bonded is not precise. They will have to be re-machined. Do not think that tightening down on the clamps will remedy the problem!

When a water based adhesive is used to form a bond between wood surfaces, localized swelling of the wood fiber is going to occur along the glue line. This is a result of the water in the adhesive being absorbed. Now if the glued up piece is machined, the swollen fibers are going to be removed before they’ve had a chance to equalize. Then after the pieces equalize (moisture is evenly distributed throughout the piece), these previously swollen areas are going to recede below the adjacent surfaces. This will cause the glue line to appear as a noticeable, and feelable line. –It is called a sunken joint. The way to eliminate this “sunken glue line” is to allow adequate curing time of the laminated pieces. Under ideal circumstances, this will occur in about 72 hours (3 days). The longer the pieces sit before machining, the better the end product will be as far as sunken joints goes. It will greatly benefit a person to scrape any excess glue away before proceeding with the 72 hour cure. The excess glue is harboring, and inhibiting moisture equalization at the surface level.

Part Two: Adhesives

There are many types of glues out there. The simplest being what is known as a PVA (Polyvinyl Acetate). This is your common, run of the mill woodworkers glue. These glues are all water based, and may come in a few colors (they all start out as white. So that "yellow woodworkers" brand is no stronger than the original white version). These glues may also vary in viscosities. -From a Thixotropic (non sag/run) assembly glue. To a low viscosity doweling glue. They also may contain fillers; Clay, starch, shell flour, wood flour, etc.. This gives them different properties. Ex. Filled products don't load sanding belts, but are harder on tooling. At a manufacturers level, the fillers cheapen the product by extending it. So they make more money by extending the base resin.

Simple PVA's typically remain useable for several years. -Though a manufacturer will only usually warrant them for a 6 month shelf life. Chances are, the bottle you purchase at the hardware store is out of date if they are not rotating their stock. But that being said, the glue will still be useable, as we've all proven. Is it at its best and strongest? Probably not. But it still will produce a bond that is stronger than the wood itself. Here it would be recommended to stir the adhesive to redistribute any settling of fillers. Stirring will also uniform the viscosity. If the adhesive becomes frozen, (though it might be labeled "freeze thaw stable") it is still best to discard it. Freeze thaw stable adhesives can supposedly be re-warmed, and stirred back to normal, for a few cycles. But it's still best not to take a chance on trying to use it.

Crosslink PVA's (Ex. Titebond II, III, etc.)

These are specialized versions of common PVA's that generally incorporate the addition of an acid catalyst of some sort. The catalyst increases "crosslinking" of the polymer chains that comprise the PVA emulsion (resin). This added crosslinking promotes water resistance and heat resistance. These types of adhesive will also generally contain fillers and extenders. The down side of a precatalyzed adhesive is that it greatly reduces the adhesives shelf life. As these adhesives age, they become thicker, and thicker. Stirring will break down the viscosity to a useable level. But the internal crosslinking will have reduced the adhesives strength. So here it is best to try and find the freshest material available. Don't purchase too much.

Liquid Moisture cured Urethanes: (Ex. Gorilla Glue)
These are highly specialized resins that use water as a catalyst. They are highly water resistant when cured (may be labeled as water proof?). They also exhibit very good heat resistance. Depending on the formulation, they can be designed to cure in seconds, to hours. So read the directions carefully. In my testing of these adhesives I have found that lightly dampening both surfaces with water (allow it to flash off) then applying the adhesive to one of the surfaces works best. Because these adhesives (the ones we purchase off the shelf) are formulated for long shelf life. They inherently have a "slow" curing mechanism. Most people make the mistake of applying the glue, then immediately going to full clamping force. These adhesives need time to "wet out" the surfaces. By applying the adhesive, and then bringing both surfaces together with no clamping pressure (closed assembly time). The adhesive is able to start wetting out the gluing surfaces. I generally allow 10 minutes of closed assembly Note:(with urethane adhesives) before applying full clamping pressure. In laboratory block shear tests, the closed assembly time increased the bond strength markedly.
Liquid Urethane adhesives produce gas (typically CO2) as they react. This is what causes the foam. Do not take the foam as a "gap filler"! It is not! A foam filled void will be weak and prone to failure! So make sure the joint is tight before even applying a urethane adhesive. Getting off the subject for a minute. The only "gap" filling adhesive is an Epoxy or a Urethane Hot Melt. Don't fall for literature and claims about water based adhesives being able to fill a gap. Yes, it will fill it. No, it will not be a strong bond.
After the pieces are clamped at full clamping pressure, allow them to cure at room temperature(still referring to a Urethane adhesive) for at least 6 hours. Overnight if possible. The warmer the room, the better. Typically all adhesives respond better to higher temperatures, as the curing reaction becomes exponential with an increase in temperature. So here, 70°is better than 65°, and 75°is better than 70°, etc... Colder tempe ratures generally result in problems. I used to always recommend that gluing temperatures be above 65°for optimum bond formation. So if you have a cold shop, you need to store your glue, and lumber else where in a warm area. -Cold lumber and its mass will act as a heat sink, and quickly chill a heated adhesive. So don't think that because the glue is warm, that it will remedy the problem. It doesn't work that way!
Okay, for now I am going to stop. I've obviously left out a lot of adhesive types (UF resins, PF resins, Casein, Resorcinols, etc) because I do not see them being used as much in the private shops. I've only lightly touched on the above mentioned. I obviously cannot cover everything about them. Same goes with one brand versus another. I will say that Adhesive Manufacturers often buy bulk resin from the same source, or manufacture and resell their adhesives to other competitors. Surprise! So sometimes the only difference between brand X and brand Y is the fancy label. -But yet Brand X will work great in one fellows shop. But not in another's?? And he will swear by brand Y and cuss at Brand X? LOL!
There's a lot more I can contribute to the above written? That's if you all want to hear it? There are a lot of gluing problems that I might be able to shed some light upon. It's up to you folks. Might be easier if you ask a particular question? I'll try my best to help. I'll be the first to admit I don't have all the answers. But I have the connections in the industry to try and find them out. The one thing I respectfully will not do is get into arguments. That sound fair?
Dave
Oh, I forgot. Do not dip any pieces of wood in water!!! You will be applying way too much water for the adhesive to utilize. Lightly wipe the pieces. Any residual water not used up in the reaction will come back to haunt you! Cracking, checking, sunken joints, finish blushing, etc..Trust me on this one.
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