The Strength Inside your Model – Adhesives Part 1

John Bristow of Deluxe Materials '40 years and Getting Stronger', looks behind the glues we use and how to get the best out of them.

Aerolite was an early specialist adhesive used in WW II on the Airspeed Horsa. This AM cover from March 1944 shows three Horsas.

Almost unbelievable advances in adhesives technology over the past few years have benefitted aeromodelling immensely. In the early days, products like Croid, Ambroid, Duco, Comet, and Sigment cements were probably the only types available to modellers They all had a strong, unpleasant odour, dried slowly (compared with cyanoacrylate AKA ca/cyano/superglue) and became brittle with age. Then along came balsa cement that was stronger than balsa wood; its bond could be released with acetone and probably became the cause for the term 'glue sniffing'! Two part glues came much later, the first of which was Aerolite from the aircraft industry.

But glues have their origins dating back to as long ago as 4000 BC. They came into being when ancient tribes discovered that a sticky material (collagen) could be extracted from bones, hides and skin. These types of starting materials along with other animal scraps were processed to produce a glue liquor which was thickened and maybe other chemicals added. With these same basic processes bone glue, hide or skin glue and fish glue are produced.

Plants have also been used to produce vegetable glue such as gum Arabic from the acacia. Archaeologists excavating burial sites from 4000 BC have discovered clay pots repaired with glue made from tree sap. Ancient Greeks developed adhesives for use in carpentry, and created recipes for glue from egg whites, blood, bones, milk, cheese, vegetables and grains. The Romans used tar and beeswax for glue.

Around 1750, the first glue or adhesive patent was issued in Britain. The glue was made from fish. Patents were then rapidly issued for adhesives using natural rubber, animal bones, fish and starch. Even today many readers will know of the glue Cascamite which is made from milk protein (casein).

Synthesis

So the term adhesive is a general term which today includes products formulated from polymers produced in a modern chemical plant. These are often called synthetic 'resins', so named after the gooey substance found in pine trees, which was one of the first widely used adhesives. Glues may also be, as we have seen, natural adhesive products made from animal and plant parts.

The first two-part adhesive, Aerolite, a two-part urea formaldehyde glue, was developed by Aero Research Limited in 1934 in their quest to find a glue that would resist bacteria and moisture. This was the first adhesive of its type to be invented and manufactured in Britain and was used in resin-bonded plywood.

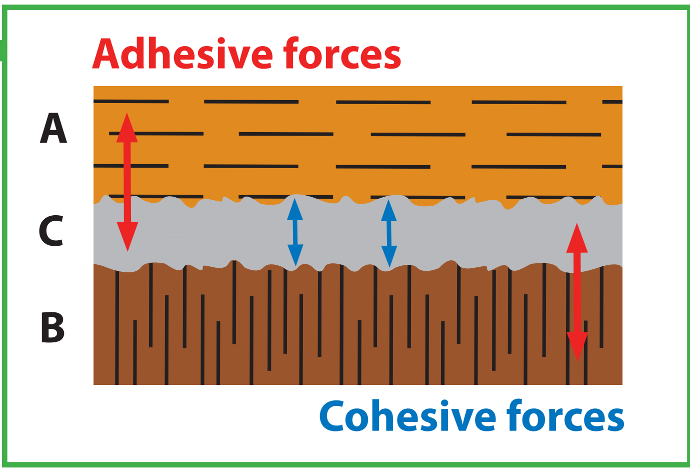
When World War II broke out, Aerolite was used to assemble the wooden Airspeed Horsa troop carrying gliders and the de Havilland Mosquito bomber, and its waterproof qualities were ideal for naval launches and patrol boats.

It was WW2 that accelerated chemical industry research e.g. for natural rubber alternatives for making tyres. Cyanoacrylates were discovered by accident in 1942 in the search for a material to make plastic gun sights.

Some Key Adhesive Dates

4000 BC - Collagen based glues first used.
1750 CE - First glue patent.
1912 - PVAc, Polyvinyl acetate produced on industrial scale after discovery in Germany.
1920s - Polymerisation technology developed bringing the first PVA polymer.
1936 - First epoxy resins synthesised in USA and Switzerland.
1942 - Discovery of cyanoacrylate glue.

The DH Mosquito was another early user of Aerolite. This is an RC scale version from the 2004 Flair Fly-in.



Adhesive forces in Red, Cohesive forces in Blue.

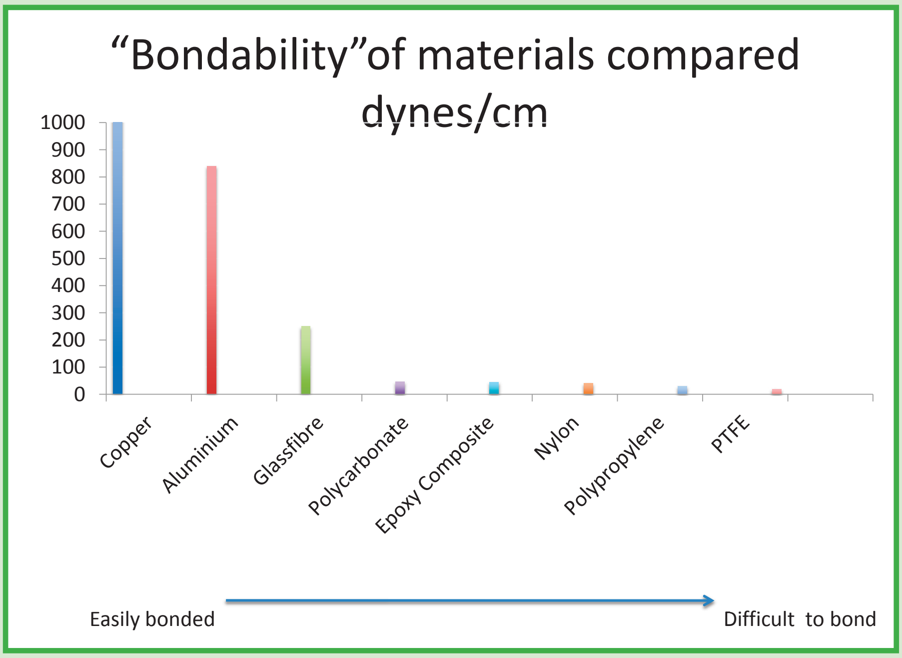
1951 - Re-discovery of cyanoacrylate and its application as an adhesive.

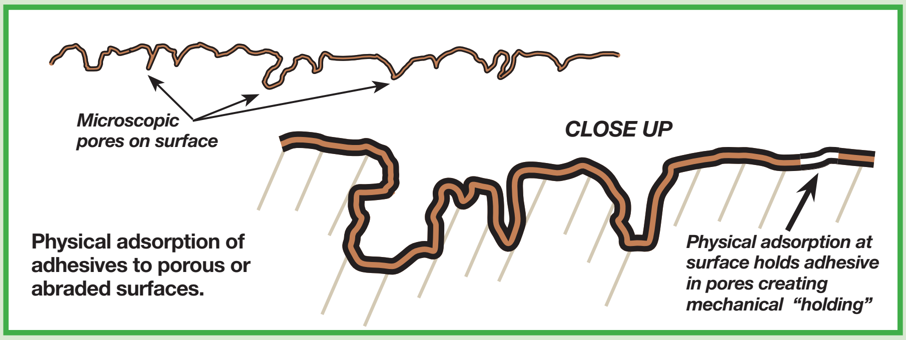
How do Adhesives Work?

The definition of an adhesive is 'any substance applied to the surfaces of materials that binds them together and resists separation.' So how do they work?

Essentially, like many things in the world, it is all about forces. The two key forces at work in a joint between two surfaces are both adhesive and cohesive (see diagram). Let's say you want to stick together two bits of wood, A and B, with an adhesive called C. You need three different forces here: adhesive forces to hold A to C, adhesive forces to stick C to B, and cohesive forces to hold the adhesive, C together.

If that's not obvious, think about sticking a training shoe to the ceiling. The glue clearly has to stick both to the training shoe and to the ceiling. But if the glue itself is weak, it doesn't matter how well it sticks to the shoe or the ceiling because it will simply break apart in the middle.





Cohesive Forces (acting within an Adhesive)

These come from 3 main areas:

• Electrical or electrostatic attraction between molecules. Like a magnet, opposite charges attract and this creates a network structure of molecules in the adhesive that help to 'hold' it together. This type of force is relatively weak.

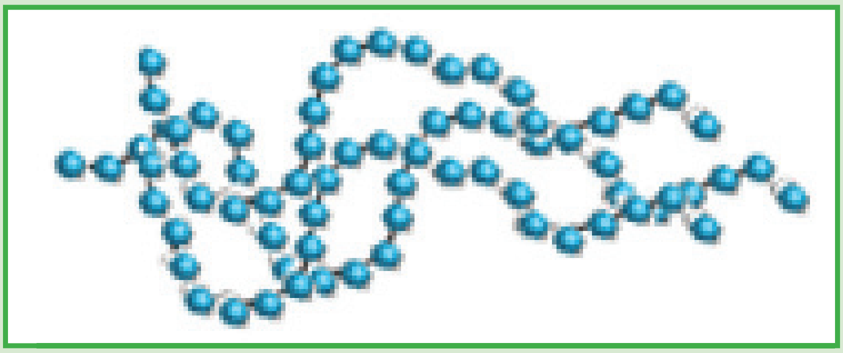
• A mechanical force caused by the entanglement of the molecules. This is particularly the case with PVA type glue that has a long chain complex molecule.

• Chemical reaction between the adhesive molecules in the joint (rather than just physical entanglement). This helps to explain why adhesives such as epoxies produce great strength across gaps.

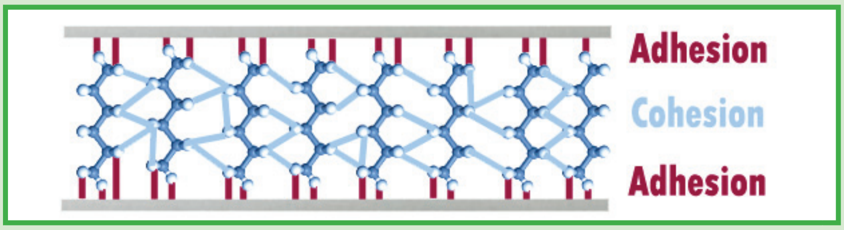
A new generation of PVA glues has appeared that feature cross-linked bonds between individual polymers. The cross-linking reaction is a slower process (compared with epoxy glue curing) but imparts improved properties including:

• Greater cohesive strength
• Water resistance
• Joint stability

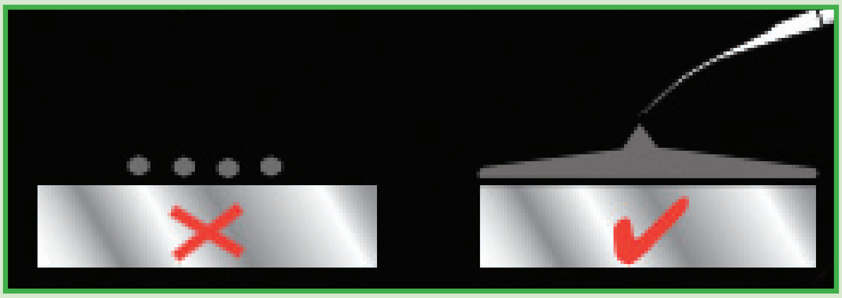
A modern low viscosity adhesive that can penetrate porous surfaces and has a low surface energy is a useful addition to the modellers armoury for foam and plastics.



Cohesive force due to the entanglement of long chain molecules.



Epoxies produce greater strength across gaps because of the chemical reaction between adhesive molecules in the joint.



Surface affinity – the adhesive must 'wet' the surface to be effective.

Surface primers such as Tricky Stick are useful to prepare 'low energy' plastics for cyano glue. This increases the surface energy above that of the cyano glue, allowing it to be bonded in seconds.

Adhesive Forces (acting at the Surfaces)

The adhesive forces at the surface are generated in a similar way, and come from two sources: a) within the adhesive molecule itself (the red arrows on the initial diagram) and b) between the adhesive and the surface to which it is applied.

In addition, we have the concepts of:
• Physical bonding or Adsorption (surface wetting)
• Chemical bonding or Chemisorption

1 Physical bonding – Adsorption

Here the adhesive must 'wet' the surface to which it is applied. Again weak electrostatic forces between the glue molecules and the molecules on the surface come into play. For adhesives to work well like this, they have to spread and wet the surfaces very well. If the adhesive beads up, it means that the adhesive has a greater affinity for itself rather than the surface to which it is being bonded. Silicone glue is one example of an adhesive with that will bond low energy surfaces.

To explain the concept of surface energy - this is a measure of the attraction that individual molecules (e.g. of glue) have for other molecules and also for themselves. So, if the glue molecules have a low surface energy they will have a higher attraction to the molecules on the surface being bonded than to themselves, they will spread onto the surface, forming a strong glue joint.

Conversely, if the molecules have a higher surface energy than the surface, they are more attractive to themselves and will bead up and remain as a droplet. The surface energy or 'bondability' of various materials is shown in the accompanying bar graph – it is not for no reason that PTFE is known as non-stick!

With physical bonding, there's no actual chemical bond between the adhesive and the surface it's sticking to, just a huge number of tiny attractive forces that also carry it into the microscopic voids thus increasing the adhesive force. This process is called adsorption. The analogy I would use is that the glue can seep into those voids and grip, like a climber's fingers anchoring into holes in a rock face.

Our Super 'Phatic! glue not only has low viscosity to penetrate porous surfaces but, has low surface energy so unlike PVA has an affinity to foam and plastics, making it ideal for gluing hinges, plastic to wood, carbon to foam etc.

Tricks or techniques can be played with both adhesives and surfaces to allow improved bonding; these include:
• Surface modification (chemical etching, surface roughening, flame treatment, solvent cleaning)
• Surface primers for low energy plastics for cyano glue. This increases the surface energy above that of the cyano glue, allowing it to be bonded in seconds.

Another 'trick' is used with Aero Tech one of our specialist epoxy glues designed to bond epoxy composites. Instead of modifying the composite surface, we have modified the epoxy glue, lowering the surface energy to below the composite thus allowing it to wet the surface and set up a strong physical (& chemical) bond. There is more on this in part 2.

2 Chemical bonds - Chemisorption

In some cases, adhesives can make much stronger chemical bonds with the materials they touch through a very strong chemical connection—they effectively form a new chemical compound at the join (shown as the red bonds on the epoxy cross-link diagram). That process is called chemisorption. Epoxy glues have many reactive sites where strong bonds can form with high-energy metals, glasses, ceramics etc. The combination of great adhesive and cohesive strength makes epoxy an exceptionally strong adhesive specially where there are gaps to fill.