AMTS STANDARD WORKSHOP PRACTICE

Adhesive Bonding

Reference Number:
AMTS_SWP_12_2008

Date:
June 2008

Version:
A
# Contents

1 Technical Terms ................................................................. 3  
2 Scope ............................................................................. 3  
3 Primary References .......................................................... 4  
4 Adhesive Selection ............................................................ 5  
   4.1 Criteria for selecting adhesives .................................... 5  
   4.2 Types of bonding adhesives ........................................ 6  
      4.2.1 Bonding Epoxy 2 component ....................... 6  
      4.2.2 Polyurethane 2 component ......................... 6  
      4.2.3 Film strips adhesives .................................. 6  
      4.2.4 Laminating epoxy with additives ................. 6  
5 Surface Preparation ......................................................... 7  
   5.1 Introduction ............................................................... 7  
   5.2 Degreasing Methods ................................................. 8  
   5.3 Abrading methods .................................................... 8  
   5.4 Chemical pre-treatment .......................................... 9  
6 Bonding process ............................................................... 9  
   6.1 Preparation of an Adhesive ........................................ 9  
   6.2 Ensure that the surfaces are correctly aligned ............ 9  
   6.3 Surface preparation .................................................. 10  
   6.4 Priming the surface .................................................. 11  
   6.5 Applying the adhesive ............................................. 11  
   6.6 Clamping ................................................................. 12  
   6.7 Removal of excess adhesive .................................... 13  
   6.8 Adhesive Curing ....................................................... 13  
7 Quality Control ............................................................... 14  
   7.1 Adhesive quality determination ............................... 14  
      7.1.1 Preparing a test specimen .......................... 14  
      7.1.2 Visual inspection of the bond ................. 15
1 Technical Terms

**Acid etched:** The release of weak metal scale from the surfaces of metals to form an oxidation layer.

**Bond line thickness:** The thickness of the adhesive at a given point in a bond.

**Chemical pre-treatment:** Chemically altering the properties of a surface.

**Composite:** A material that consists of two or more materials joined to form a matrix.

**Conductor metals:** Metals that conduct electricity.

**Cure temperature:** The temperature that the adhesive need to reach in order to form covalent bonds.

**Curing:** A chemical reaction whereby the polymer chains interlink to form a three-dimensional network of covalent bonds.

**Film adhesives:** Adhesives in the form of sheets.

**Maximum service temperature:** The maximum temperature that the component will be exposed to.

**Polythene-interleaves:** Interleaves found on film adhesives to protect them from environmental influences.

**Pot life:** The time the adhesive takes to gel and become unusable.

**Resin:** Synonymous with thermosetting matrix.

**Tackiness:** The measure of an adhesive to stick to the surface of a material.

**Thermo couple:** Temperature sensitive material used to determine the temperature at a point.

**Thermo set:** Polymer whose molecular chains form a three-dimensional cross-linked structure of covalent bonds.

**Viscosity:** A measure of the resistance of a fluid to flow.

2 Scope

This procedure describes the preparation of materials and the application of adhesives used in adhesive bonding. The following sections are discussed with references to other applicable SWPs were applicable.
Adhesive Selection
- Criteria for selecting adhesives

Bonding types
- Bonding of composite components using liquid adhesives
- Bonding of composite components using laminating resin with additives
- Bonding of composite components using film adhesives

Preparation for adhesive bonding:
- Preparation of the surfaces using chemical and mechanical methods.
- Preparation of the adhesive (accurate mixing procedures and quality control)

Assembly of the components
- Use of jigs and clamps to accurately align components
- Alignment pins and holes used in moulds.

Curing of bonded components:
- General guidelines when composites are cured are given.
- SWP 009 – Curing of Composites gives a more in depth discussion for the curing of composites.

3 Primary References

Composite Materials in Aircraft Structures, Donald H. Middleton
4 Adhesive Selection

A large variety of bonding adhesives are available for various applications. It is necessary to select the appropriate adhesive for the required application. This section gives criteria for selecting adhesives and gives the most common types of adhesives available.

4.1 Criteria for Selecting Adhesives

When choosing an adhesive the following must be taken into account:

1. **Maximum operating temperature:**
   The maximum operating temperature of the component should not exceed the maximum allowable operating temperature of the adhesive being used. This will lead to severe weakening of the bond which will lead to joint failure.

2. **Elasticity**
   The properties of the adhesive after curing should match the properties of the components that are bonded together for example if two highly elastic components are bonded and the adhesive is not elastic after curing, the bond will fail when load is applied.

3. **Viscosity**
   A lower viscosity will create resistance against sagging.

4. **Shrinkage during curing**
   An adhesive that has a tendency to shrink when cured will cause deformation of the components when large areas are bonded.

5. **Cure temperature:**
   Film adhesives typically fall in a cure temperature of 120 – 180 °C. This temperature should not exceed the maximum temperature that the component can resist.

6. **Bond line thickness control:**
   Some adhesives contain micro-spheres to maintain the optimum bond thickness for the adhesive being used. This prevents the adhesive from being pushed out and the bond thickness becoming too small.

7. **Compatibility:**
   The adhesive should be compatible with both of the materials being used. If an adhesive is not available, one or both of the surfaces can be pre-treated to conform to the specifications of the adhesive. The manufacturer should be consulted on the best course of action in this regard.

8. **Pot life:**
   This is the time the adhesive will take to set. If it the bonding procedure is complicated and needs a long time to complete, an adhesive with a long pot life should be used. This will prevent the adhesive from hardening before the bond has been completed.
9. **Cost:**
When joining materials it is necessary to research alternatives in order to lessen the cost of the bond. An example of this is the use of a laminating resin with additives which provides a good quality bond. This is discussed in section 4.2.4

### 4.2 Types of bonding adhesives

#### 4.2.1 Bonding Epoxy 2 component

Epoxies are available for most bonding applications. The above mentioned criterion is used to determine the correct system for the application.

Epoxies are supplied in two components called the resin and the hardener. The components are mixed according to the manufacturer data sheet in the correct ratios. Note that the manufacturer will specify if the ratios are by weight or by volume.

The low viscosity of bonding epoxies enables easy application without having to use additives and normally have good gap filling properties.

#### 4.2.2 Polyurethane 2 component

Poly-urethanes are good bonding adhesives similar to epoxies. Polyurethanes are designed for bonding of a wide variety of materials.

#### 4.2.3 Film strips adhesives

Film strip adhesives are pre-prepared adhesives which are easily used when bonding flat areas. These adhesives usually consist of precatalysed modified epoxies, often with a synthetic rubber additive, which forms a toughened dispersion of fine rubber particles upon curing. The adhesive consist of two covering sheets with the bonding material enclosed between them. After the two components have been assembled heat must be applied to both the components to initiate the bonding process and be kept at a raised temperature during the curing process.

A serious disadvantage of precatalysed film adhesives is that the cure reaction will slowly progress – even under refrigeration to -20°C. For this reason the shelf life is only 6-12 months for most film adhesives.

Because of the low storage temperature film adhesives should be allowed to heat up to room temperature before use to prevent moisture from forming on the bonding surfaces through oxidation. The moisture will prevent the adhesive from bonding with the surface of the components and lead to a low quality bond.

#### 4.2.4 Laminating epoxy with additives

Laminating epoxies normally have properties that make it unsuitable for bonding composite components. By adding additives, e.g. Cotton flocks, Cab-o-sil (Fused Quartz) and Glass Micro
balloons the viscosity and gap filling properties can be improved. Laminating epoxies with additives is a highly cost effective bonding adhesive, but requires accurate mixing procedures to ensure consistency.

The effect of the additives on the resin is as follows:

**Cotton flocks:**
- Improves the mechanical properties (shear strength)

**Cab-o-sil (Fused Quartz):**
- Increases viscosity (More sag resistant)
- Improves the mechanical properties (shear strength)

**Glass Micro balloons:**
- Increases volume
- Low mechanical strength – good for bonding foam cores and non-structural surface filling.

By using a combination of additives, the properties can be manipulated to suit the required application. Refer to SWP xxx Laminating Resins with Additives (Fillers)

## 5 Surface Preparation

### 5.1 Introduction

A clean, dry surface is a prerequisite for the effective joining of components. The adhesive will either adhere to the surface of the components or to any foreign materials that are present at the time of bonding. If foreign materials are present the area to which the adhesive adheres is smaller and will lead to a weakened bond.

The most common methods in preparing a surface for bonding are:

1. Degrease only.
2. Degrease, abrade and degrease again.
3. Degrease and chemically pre-treat.

The methods mentioned above are dependant on the materials being bonded and the adhesive being used.

When bonding epoxy laminates, the use of a suitable peel ply as the last layer in their manufacture is recommended, otherwise prepare as above. Trials may be required to test peel ply and it is usually advisable to provide an additional light sanding and solvent wipe once the peel ply has been pulled off.
5.2 Degreasing Methods

The surface is cleaned using a solvent to remove any materials from the bonding surface. The solvent should be compatible with the adhesive and the material being bonded. Using the wrong solvent will adversely affect the bond and the manufacturer should be consulted in this regard.

Note: These methods are most commonly used in practice but the manufacturer of the adhesive should be consulted on the most effective solvent to use on the surface.

Test for a clean surface:

The most common test is the water break test. A drop of distilled water is applied to the prepared surface and the contact angle noted. The reason for using this test is to check whether the fluid wets the surface. If the fluid spreads out over the surface, a large contact angle is formed. This means the fluids does wet the surface and the surface preparation was successful.

![Figure 5.2-1: Water Break Test](image)

The image on the right shows a surface with a large contact angle.

5.3 Abrading methods

Abraiding a polished surface will help the adhesive to form a better bond with the surface. The surface can be mechanically abraded or sandblasted. A general rule is not to abrade the surface more than 0.1 microns. This will trap air bubbles in the bond which will lessen the bonding surface.

Usually a composite surface finished with peel ply will give a good bond after removing the peel ply. However better results are achieved by abrading and cleaning the surface with a suitable solvent (e.g. acetone).
Caution: Sanding composites laminates gives off a fine dust that may cause skin and/or respiratory irritation unless suitable skin and respiratory protection is used. Sanding also creates static charges that attract dirt or other contaminants.

5.4 Chemical pre-treatment

The chemical pretreatment of surfaces is the most effective method for achieving a high quality bond with a long bond life.

Etching metals with acids removes the weak metal scale from the surface, producing an oxidation layer where the adhesive can bond. Typical treatments are: chromium acid for aluminum and hydrochloric acid for stainless steel. Some metals require an alkaline treatment such as alkaline peroxide for titanium.

For bonding Ferro cement, etch with a 5% solution of hydrochloric acid, wash with fresh water, then dry.

6 Bonding process

6.1 Preparation of an Adhesive

Preparation of the adhesive is a critical step in the bonding procedure. Inaccuracy during the mixing process can be the single contributing factor to bond failure and all steps must be taken to ensure that the adhesive is prepared according to manufacturer specifications.

When using laminating epoxy with additives, the resin and the hardener is mixed thoroughly before adding the additives. It is best to measure the additives accurately to ensure consistency.

6.2 Ensure that the surfaces are correctly aligned

Before applying any adhesive to surfaces it is important to check the alignment. This is done to ensure that the bond line thickness is maintained. The bondline thickness can be controlled by calculating the volume of the adhesive that is required to complete the bond and applying it evenly on the surface.

The manufacturer should be consulted on the optimum bond line thickness for the adhesive in use.
6.3 Surface preparation

Ensure that the surfaces are degreased, abraded and cleaned before applying the adhesive. Also ensure surfaces are moisture free and that all peel ply is removed from the bonding surfaces. (Peel ply must have a trace lining to make it more visible.)

Using a vacuum cleaner on the bonding areas will suck sanding dust from small cavities, enlarging the bonding area.
6.4 Priming the surface

Priming the surface helps to remove air to ensure maximum bonding surface. The adhesive is prepared to a lower viscosity, making it flow easier. This adhesive is then applied using a brush.

The priming adhesive or liquid may sometimes be a different bonding material with lower viscosity that is compatible with the materials being bonded. Consult with the manufacturer to ensure compatibility.

Figure 6.4-1: Applying adhesive using a brush.

6.5 Applying the adhesive

The next step in the bonding process is the application of the adhesive. Various tools for the application of adhesives are available commercially. A very effective and easy alternative is the use of a clean plastic bag as shown in figure 6.5-1. The bag is cheap and can be disposed of afterwards unlike a glue gun that has to be cleaned after each application.
The adhesive should be spread evenly along the surface. Using an excess amount of adhesive will ensure that all the air is pushed out of the bond.

6.6 Clamping

When joining components it must be ensured that the components are positioned or aligned correctly. Accurate aligning of components can be achieved by:

- Jigs
• Alignment holes / pins
• Component shape when designed for accurate bonding (puzzle-like shape)

Clamping is normally required to ensure that the components stay in position during the curing process. Clamping methods that can be used are:

• Clamps, pegs with spring clamp action
• Clamping or bolting jigs in position
• Vacuum clamping (with vacuum bag)
• Gravity (applying weights on the parts)
• Riveting parts together
• Bolt parts together
• Jigs

6.7 Removal of excess adhesive

Excess adhesive should be removed after components have been clamped. Stress concentrations are minimized by leaving a fillet along the edge of the components.

![Figure 6.7-1: Excess Adhesive](image)

6.8 Adhesive Curing

The curing process is dependent on the type of adhesive being used. The manufacturer should be consulted on the most effective method of curing. For a more in depth discussion refer to SWP009 – Curing of Composites
General guidelines:

- The specified temperature is for the adhesive. The temperature of the adhesive should be monitored and not that of the oven. The use of thermocouples is handy in this application. They should be positioned along the bond line to ensure that the correct temperature is maintained in the adhesive.

- During the curing process the components must not be moved as this may disturb the bond.

- Heating of the oven should be done gradually to allow the components time to adjust to the temperature. If the oven is heated too quickly, deformation of the components may occur. A generally accepted rate is 1 – 5 °C/min.

- After the curing process is completed, pressure on the components should be maintained to prevent them from deforming when cooling. This may occur as a result of the materials not cooling at the same rate.

7 Quality Control

The best measure of quality control is the repeatability of a process. If the same conditions can be created uniformly throughout a process, the quality of the product will remain consistent. Best consistency is achieved in a controlled environment, like moisture and temperature control in a room.

7.1 Adhesive quality determination

Ensuring the quality of an adhesive bond requires that consistent methods are followed. Preparing test specimens is required to determine the quality of the bond.

7.1.1 Preparing a test specimen

A test specimen should be prepared during the actual bonding process. The reference number on each of the specimens should be traceable to the following:

- By whom the batch was mixed.
- Where the adhesive was used (e.g. which part of the assembly).
- When the batch was mixed.

These can then be subjected to a destructive test to establish the quality of the adhesive bond. The specimens must be assembled with the same adhesive batch mixture and subjected to curing pressure, -temperature and -time identical to the actual bonded part. Refer to SWP001 on Test Specimens.
7.1.2 Visual inspection of the bond

Visual inspection of the bond will reveal any discontinuities or voids in the bond line. Discontinuities will increase the chance of bond failures as the contact area of the adhesive with the component is reduced.

![Bondline](image)

Figure 7.1-1 Shows a good bond line (top) and a bad bond line (bottom)
Appendix I: Fault Diagnostics of bond failure.

<table>
<thead>
<tr>
<th>Fault</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond fails leaving bear, clean surface.</td>
<td>1. Surface not properly pre-treated.</td>
<td>1. Check pre-treatment procedures.</td>
</tr>
<tr>
<td></td>
<td>2. Protective layering not removed.</td>
<td>2. Ensure surfaces are not contaminated after pre-treatment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Remove protective covers before bonding.</td>
</tr>
<tr>
<td></td>
<td>2. Inaccurate mixing of components.</td>
<td>2. Quality control of mixing procedures.</td>
</tr>
<tr>
<td></td>
<td>2. Initial poor fit of parts.</td>
<td>2. Check alignment before bonding.</td>
</tr>
</tbody>
</table>