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Basics for Bonding of Composites like SMC and BMC

As adhesives tailored to the use on composite materials have been developed by the various adhesive manufacturers bonding has become an indispensable technique for joining composite substrates either with each other or with other materials like coated metal. Adhesive bonding has proven for years now its reliability in several applications in the composite processing industry. The adhesive remains stronger then the composite substrate even after aging resulting mainly fiber tear during destructive tests. As an example the automotive industry is increasingly using composites not only as a light weight material but also because of the design opportunities as well as the competitiveness against steel in relatively low volume application like high end vehicles or individualized vehicles sharing one platform.

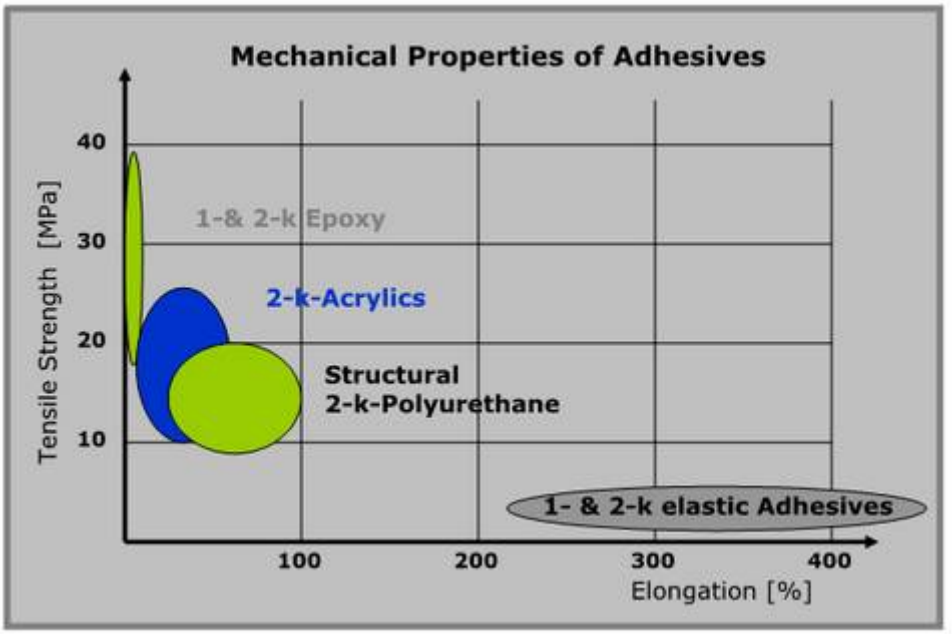
Benefits of Adhesive Bonding

- Outstanding fatigue resistance
- Suitable for dissimilar materials
- Even stress distribution to a large area
  - ➢ Thin and light-gauge materials can be joined
  - ➢ Integrity of materials maintained
- Provides thermal and electrical insulation as well as sound dampening and sealing performance
- Minimum if not no surface distortion, suitable for Class-A surfaces
- Increases productivity

Adhesives for Bonding Composites

State of the art adhesives tailored for bonding of composites are based on polyurethane-, acrylic-, epoxy- or MS-Polymer chemistry offering a wide range of mechanical properties as indicated in fig. 1.

Today single component moisture curing adhesives as well as two part adhesives are in use. Single component moisture curing adhesives (polyurethane or MS-Polymer based) offer the advantage of an easy application with a relatively low investment into the dispensing equipment, while two part adhesives do show a much faster cure allowing shorter cycle times.



Adhesive Selection

In most cases the well balanced mechanical properties of structural polyurethane adhesives are offering both a sufficient strength even at elevated temperature (short term up to about 190 °C, long term up to 100 °C) and sufficient low temperature (- 40 °C) elasticity to cope with vibration and different thermal elongation of the bonded parts; they are considered as being 'tough'. In addition they show a much faster strength build as moisture curing adhesives, especially if moderate heat is involved to accelerate the cure have. Fixture times of down to 2 – 3 minutes are realistic.

If a higher heat resistance is required either during one of the manufacturing steps such as those encountered in some automotive e-coat processing ovens or during service, epoxy based adhesives need to be considered. Epoxy adhesives in general are less flexible and in most cases require closer bond gap tolerances than polyurethanes.

If large parts are involved, like in the railway industry with the bonding of outer composite panels to the steel framework a highly flexible adhesive is required to compensate the relative movement of the parts during the life cycle. In contrast to the structural adhesives the relative low strength of such adhesive failure during testing takes place within the adhesive layer (cohesive failure). By increasing the bond area the lack of strength is compensated. For low volume applications allowing long fixture times of several hours high elongation moisture curing adhesives are in use; if a fast strength build is required again 2-part low modulus adhesives are in use.

During the process of selecting an adhesive for a specific application many different parameters have to be taken into account. Adhesive selection for plastic substrates does not only include evaluating adhesion and strength within the appropriate temperature range but the mechanical properties of the substrates (strength, stiffness, Young's Modulus, elongation, …) as a function of temperature needed to be taken into account.

In addition to the already mentioned criteria for adhesive selection other process related parameter like

- open time (maximum time between dispensing of the adhesive to the part and joining of the parts)
- cure response (time to reach the required strength for a further handling of the bonded part)
- cure conditions (ambient cure or heat accelerated cure)
- rheology of the adhesive (sag resistant to allow application to vertical parts vs. self leveling)
- color
- …

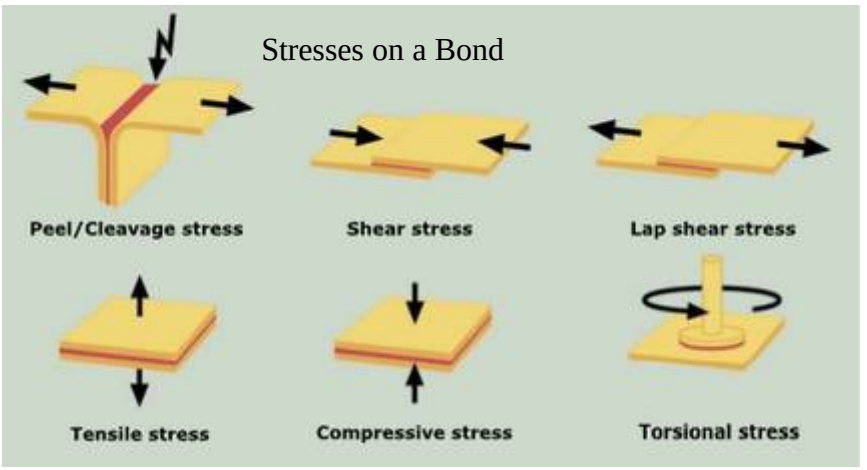
have to be considered as well.

Designing for Adhesive Bonding

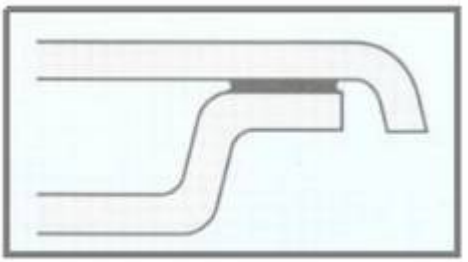
In order to form a bonded joint which performs satisfactory under the expected service conditions for the planned lifetime of the structure not only the chemical and physical properties of both the adhesive and the adherents needed to be considered already during the design phase of a part. Irrespective of joint geometry, the basic design criteria have to be followed.

Basic Criteria for Bond Design

- The maximum bonded area should be used
- The bond should be stressed in its strong directions (shear, tensile, torsion), stress in weak directions (peel, cleavage) should be minimized
- Residual stresses due to differential thermal elongation of the bonded parts should be allowed for
- Ideally all bond areas should be normal to the direction of the clamping force



Typically bond flanges should range from 16 to 25 mm. A minimum flange width of 6 mm may be used on smaller parts such as spoilers. A minimum of 3 mm clearance from the tangent should he allowed between the edge of the inner panel and the return flange on the outer panel to allow for positive location in the fixture and adhesive deroping. Nominal bondline thickness of 0,5 to 1,5 mm will be suitable for most application with structural adhesives. For low modulus adhesives in many cases a thicker bond are used in order to get the most benefit out of the elastic adhesive.



Typical Bond Design for SMC Parts

In case bonding takes place to high-visibility-surfaces with the requirement of a Class-A-Surface some additional principles are of importance. The primary visual concern for bonded assemblies is bond line read-through. There are several contributory factors towards bond line read-through. They include coefficient of expansion differences between the inner and outer panels, variable part thickness or adhesive thickness and squeeze out at the bond flange, as well as variable temperatures or pressures applied in the bond fixture. The use of moulded in spacers also includes the risk of read through effects.

Trunk Lid of BMW's M3 CSL consisting of two bonded SMC parts

For Class-A surfaces, especially high-visibility horizontal applications such as hood assemblies, it is desirable for the bond location to be limited to the panel perimeter and surface contour changes. This greatly reduces the risk of bond read-through. Elastic low modulus adhesives can be used in such areas as in most cases these adhesive do not have to carry a high load, they are just acting as so called ‘anti-flutter-adhesive’. All closed sections must he vented to keep from trapping air in the assembly. Trapped air might expand and distort the surface when exposed to paint oven temperatures. Vents can he provided by interrupting the adhesive line or by providing a vent hole. It is best to design locating features, which help the part be self-locating in the bonding fixture on the inner panel. If these features are located on the outer panel, they may read through to the Class-A surface, which also applies to mould in spacer to define the bondline thickness.

The design engineer should keep in mind that the two panels will be brought together in a bonding fixture with a bead of adhesive that must he compressed. Ideally all bond areas should be normal to the direction of the clamping force. Adhesive application to vertical surfaces should he avoided to prevent the wiping and removal of adhesive as the parts come together. In large complex assemblies it may he necessary to use multiple overlapping inner panels to eliminate adhesive wiping.

Surface Preparation prior Bonding

A prerequisite for forming a good bond is a sufficient wetting of the substrate by the liquid adhesive. The degree of wetting, which amongst others is determined by the surface tension of the substrate and the adhesive, is a criterion for the quality of the adhesion. With adhesive forces just having a rather short range it is obvious that the determining factor for the actual adhesion is the accessibility of a number of physically and chemically active structures on the substrates surface. Any contamination can have an adverse effect.

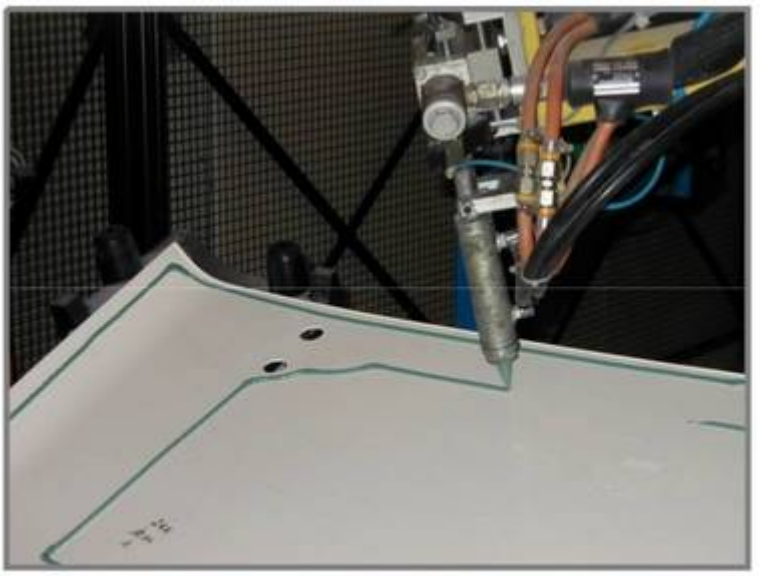
State of the art adhesives for bonding of many composites like SMC and BMC do just require a dry- or solvent wipe to remove contaminations like dust, oil, and excessive mould releases. Modern adhesives are capable to tolerate a certain amount of mould release agent on the surface as long as the cure takes place in a heated fixture. The applied temperature does therefore not only accelerate the cure of the adhesive to allow short cycle times but also acts as a 'primer' absorbing release agent and assuring good anchorage of the adhesive to the substrate. In case composites made from other polymers have to be bonded surface treatment might become more important

For ambient curing 2-part adhesives and moisture curing 1-part adhesives a light sanding of the surface or the use of primers might be required. Primers may affect the appearance of Class-A surfaces if applied directly to areas that will be coated. Precautions should he taken to make sure primers do not come into contact with Class-A surfaces.

Recently the 'Open Air Plasma' technology has been evaluated with positive results for the use on SMC/BMC as well as on composites based on other polymers in order to eliminate the manual solvent-wipe or sanding process and replace it by an automatic and controllable process.

Adhesive Dispensing

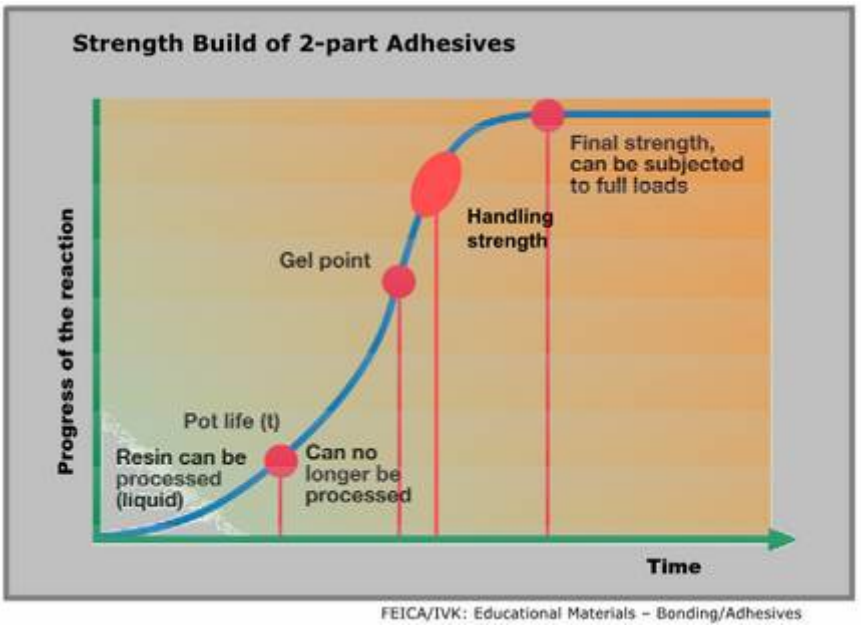
The dispensing equipment is closely related to the selected adhesive. Single-part adhesives eliminate the need for in-plant mixing equipment which reduces the investment in the dispensing equipment. Meter-mix-dispenser to be used for two-part adhesives in most cases are using disposable static mixer tips avoiding the need of cleaning the mixer at regular intervals or if pot life is exceeded with environmentally critical solvent mixtures. In general adhesive dispenser can be equipped with a wide range of quality assurance features according to the specific requirements.



Adhesive Dispensing

Adhesive Cure – In the Bonding Fixture

It is important to fixture the panels so they will not slide out of position during cure while the adhesive is wet. Usually the bond fixture is designed to positively locate and hold the panels in the correct position until the adhesive has reached a sufficient handling strength to allow a safe further handling of the part. In order to reduce cycle times in most cases heated fixtures are in use. Typical temperatures for SMC parts range from 85 °C to 135 °C, with resulting fixture times of approximately 60 to 180 seconds. The heat can either be provided by electrically-, oil- or steam-heated aluminium moulds or by so called hot-air-impingement fixtures. In such a fixture the heat is distributed by a steady stream of hot air which is distributed to the bond line by a system of hoses and pipes with small orifices which direct the hot air to the surface to be heated. The advantage of a hot-air-impingement fixture compared to the conventional fixtures is a significant faster heat-up rate which allows reduced cycle times and a higher efficiency. The use of radio frequency or microwave to generate cure is also possible. Metal part to be bonded can be heated by induction and adhesives



FEICA/IVK: Educational Materials – Bonding/Adhesives

itself respond quite well to microwave but the resulting temperature depends on the bond line thickness which more and more is not defined as tolerances in the parts are compensated by a varying bond line thickness. Adding nano scaled ferrites into the adhesive to increase the efficiency of the microwave as well as utilizing the inbuilt temperature protection of the nano particles have been made but there are still quite a few other problems which need to be resolved till this new technology can by introduced into production.

Heated Fixture for Bonding an Automotive trunklid