4.4 ADHESIVE BONDING

Adhesives must be adaptable to the manufacturing environment. The sequence of operations associated with bonding is as distinct from welding or mechanical fastening as the equipment employed. This section gives an overview of the adhesive bonding process, including the dispensing (and mixing) of the adhesive, handling the assembly while the adhesive sets, the compatibility of the adhesive with the adherends, and compatibility with downstream processing.

4.4.1 DISPENSING ADHESIVES

The manufacturing problems associated with dispensing adhesives depend to a great extent on whether a one or two-part adhesive is being dispensed.

4.4.1.1 One-part Adhesives

One-part adhesives are relatively easy to dispense. The amount of adhesive dispensed and the location of the adhesive on the adherends must be controlled in order to bond effectively. One-part adhesives have high viscosities, hence after-flow (stringers) can be a problem. Viscosity problems are avoided by keeping the pot at a constant temperature. In general, the dispensing of these adhesives is trouble free.

4.4.1.2 Two-part Adhesives

Two-part adhesives begin curing as soon as they are mixed; therefore the timing associated with mixing and dispensing is critical for achieving well bonded joints. A fairly sophisticated delivery system, such as the one illustrated in Figure 4.4.1.2-1, is needed to mix the adhesive properly and deliver it to the joint at the proper time.

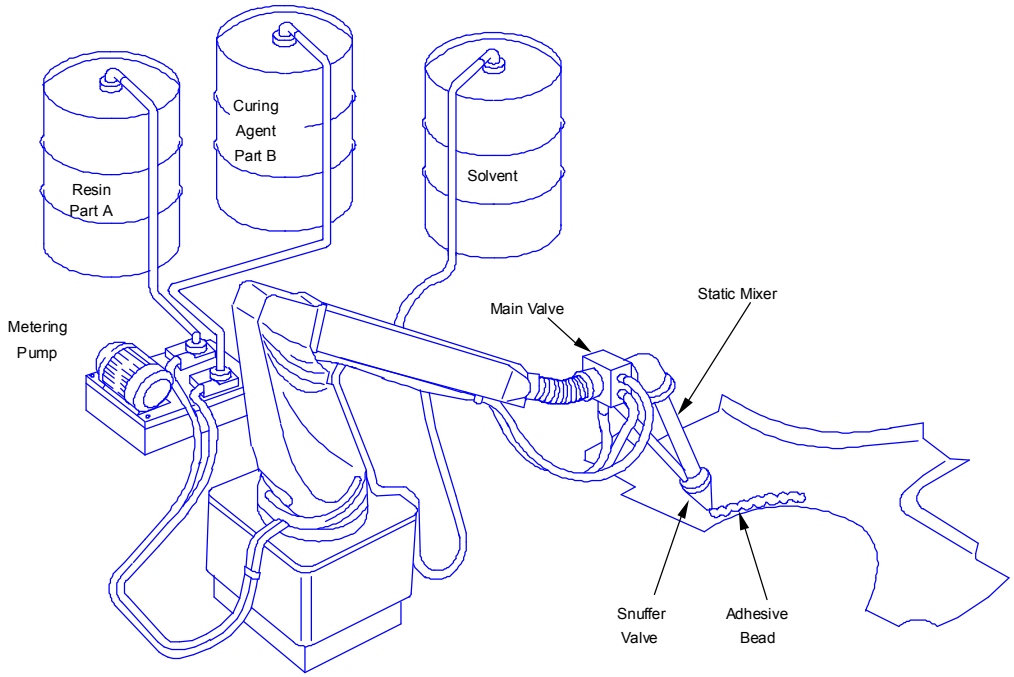

Figure 4.4.1.2-1 Typical two-part adhesive robot dispensing system [1]

Resin viscosity, mix ratios, mix chemistry, and mix times must all be controlled. Downtime is routinely needed to purge and clean the dispensing equipment. Backup equipment and labor must be available to prevent work stoppages. Disposable mixers can be used to reduce downtime, but they entail additional costs. Nevertheless, two-part adhesives develop handling strength rapidly, and require less fixturing than one-part adhesives. These characteristics make them a reasonable choice for many joining applications.

The latitude to vary the mix ratio of a two-part adhesive is convenient; then open time and viscosity can be varied, within limits, to adjust the bonding process to production parameters. Changes should be made with caution, because they will tend to affect the physical properties of the adhesive, depending on the sensitivity of the adhesive to mix ratio. An adhesive that is not overly sensitive to mix ratio is advantageous since it will offer more latitude for variation, and consequently more latitude to accommodate manufacturing variables. In any case, maintenance schedules and dispensing parameters must be revised as the mix ratio is changed.

A major disadvantage in the use of two-part adhesives is the possibility of the adhesive curing in the dispenser. This problem may be avoided either by frequent maintenance of the dispensers or by the use of disposable static mixers. The static mixer should be placed at the dispensing tip; otherwise the tubing and conduit that are placed after the static mixer must be discarded with the mixer.

The key advantage of two-part adhesives over one-part adhesives is the ability to achieve handling strength rapidly. They also respond very quickly to mild heating, so that localized heat sources can be used to accelerate the chemical reaction after dispensing (Figure 4.4.1.2-2).

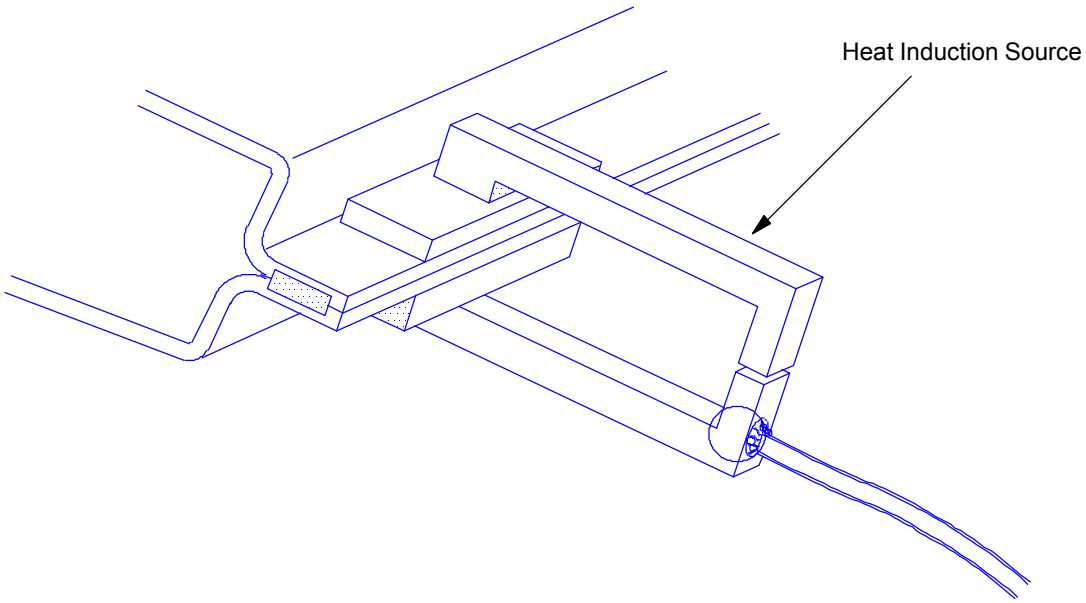

Figure 4.4.1.2-2 Localized heating can be applied to accelerate the chemical reaction and develop handling strength[1]

Productivity is improved because of the shorter cycle time. In each application, the balance between the amount of fixturing required, allowable variations in the physical properties of the adhesive, and the cycle time must be determined. Input from the entire design, manufacturing, and materials team is essential to reach an appropriate balance.

4.4.2 HANDLING STRENGTH AND FIXTURING

Handling strength must be developed rapidly in a bonded joint so that the assembly can quickly move to the next processing step. This is a key concern when using any adhesive. One method, mentioned above, is to apply localized heat sources to accelerate the chemical reaction.

Fixturing is often used to maintain the integrity of the assembled joint until the adhesive develops handling strength. Many fixturing methods are available for use with one-part and slow curing two-part adhesives. Three are commonly employed for sheet steel:

1. Mechanical fixturing methods, such as rivets, Tog-L-Loc™, or widely spaced spot welds, are illustrated in Figure 4.4.2-1 and Figure 4.4.2-2. These fasteners may be used to enhance the structural performance of the joint, as described in Section 3.4, or they may be used only to support the parts during handling, with the cured adhesive providing the strength needed in service.

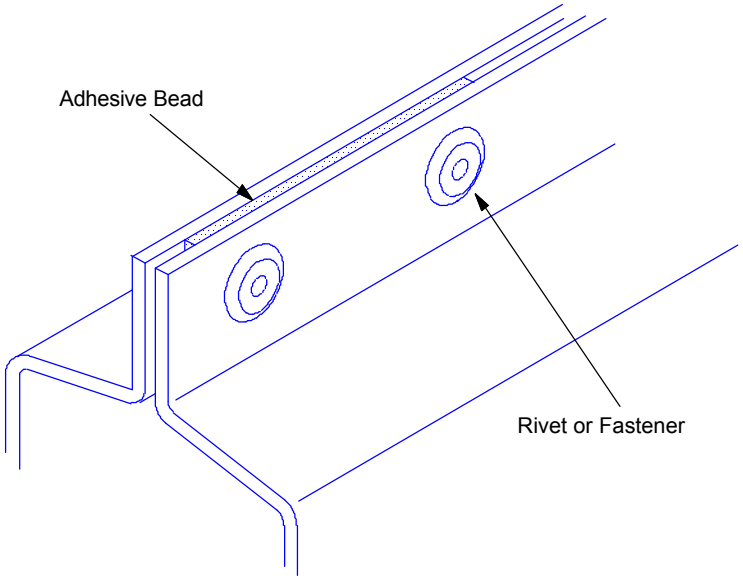

Figure 4.4.2-1 Mechanical fasteners, such as rivets, can be employed to develop handling strength[1]

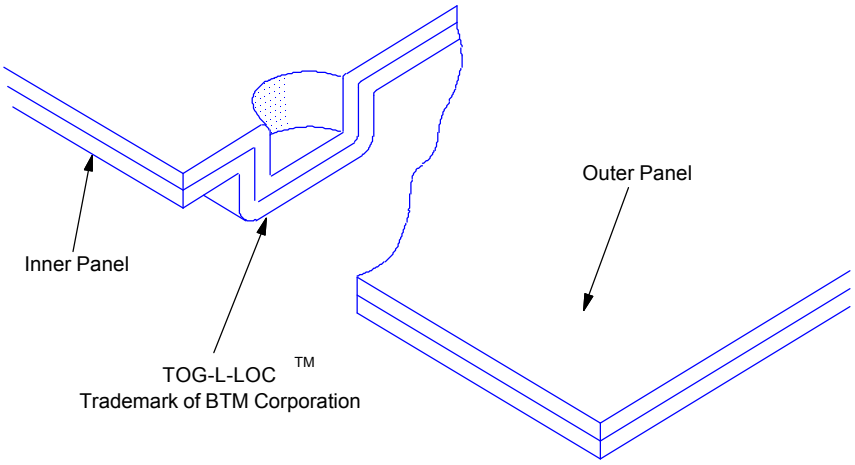

Figure 4.4.2-2 Mechanical fastening can be employed to develop handling strength [1]

2. The sheet can be bent in a variety of ways to secure the joint. Figure 4.4.2-3 and Figure 4.4.2-4 show examples of this type of fixturing.

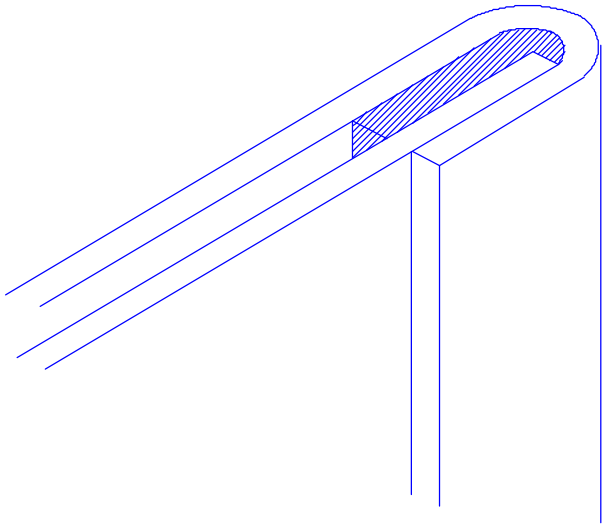

Figure 4.4.2-3 A hem flange can be used to fixture components while the adhesive develops handling strength. The adhesive has been confined by the flange, eliminating squeeze-out or run-out[1]

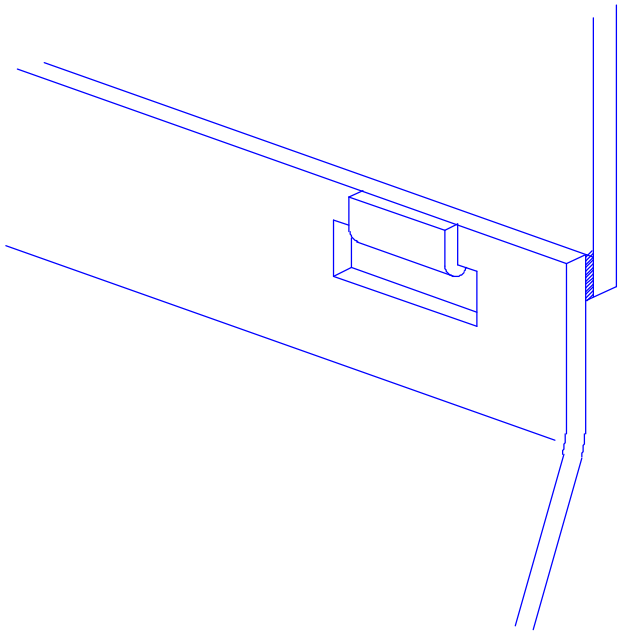

Figure 4.4.2-4 "Toy tabs" are a convenient means of fixturing [1]

3. A small amount of a faster curing adhesive, such as a hot melt, can be used for fixturing. Care must be taken so that the hot melt does not flow out of the joint in the paint ovens.

4.4.2.1 Trip Curing

Trip curing mechanisms are a convenient alternative to fixturing and a means to achieve handling strength quickly. These techniques initiate the cure of the adhesive shortly after dispensing. One such mechanism is induction heating, which can be used with some one-part epoxies (Figure 4.4.1.2-2). The cure of one-part urethane adhesives can be accelerated by injecting water into the adhesive stream. Other trip curing mechanisms involve pretreating the sheet with a catalyst (Figure 4.4.2.1-1) or adding a pressure activated catalyst within the adhesive (Figure 4.4.2.1-2). The last two methods are, strictly speaking, two-part adhesives. However, since the catalyst's function is only to partially cure the adhesive, and since no mixing occurs while dispensing the adhesive, they may be considered one-part adhesives with trip curing. There are efforts currently underway to use metal coatings or lubricants to trip cure adhesives.

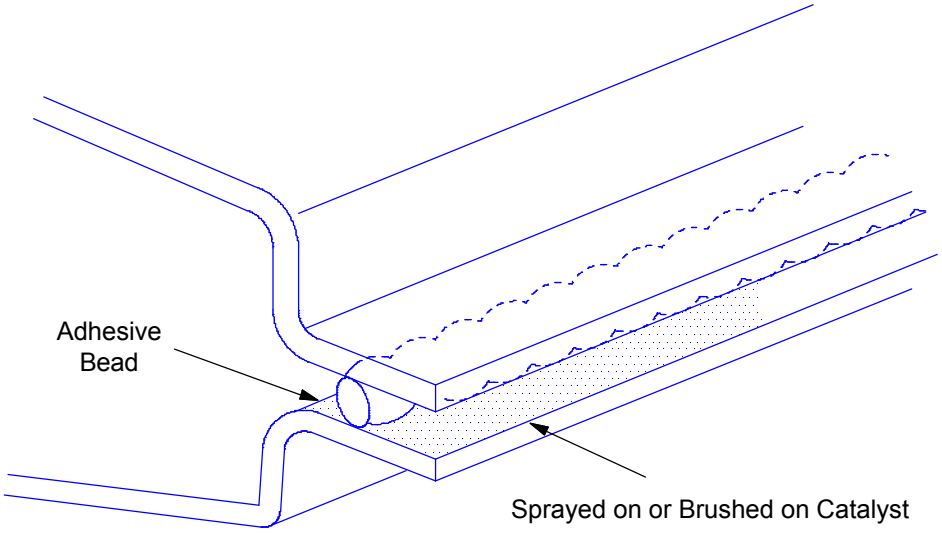

Figure 4.4.2.1-1 A catalyst may be applied to one of the steel surfaces to act as a trip-curing mechanism

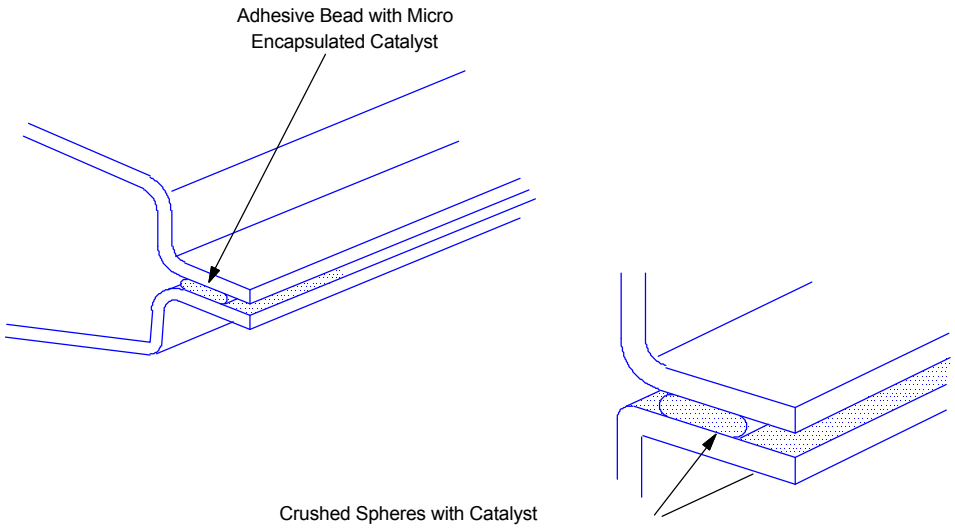

Figure 4.4.2.1-2 The catalyst may be encapsulated in micro glassbeads that crush and release the catalyst as the adhesive bead is compressed

4.4.3 SUBSTRATE CONSIDERATIONS

The compatibility of the substrate with the adhesive is very important. The steel surface, its coating, and any working fluids such as drawing compounds, lubricants, and mill oils must be evaluated for adhesive compatibility.

The performance of one-part epoxies is not generally affected by mill oils. The high viscosity epoxies displace most of the oil and they absorb the remainder. The longer the adhesive sits on the steel before curing, the more oil it can absorb. This absorption capability makes one-part epoxies more reliable and less sensitive to surface contaminants.

One-part acrylics and two-part epoxies can be applied to mill-oiled surfaces if there is no substantial puddling of oil. However, two-part urethane adhesives require a prepared surface, such as a solvent wipe or priming, for bonding.

Drawing compounds pose a special problem since they are diluted with water. If moisture is trapped at the adhesive/steel interface, it can cause a one-part adhesive to expand uncontrollably when heated, disrupting the bond. The presence of trapped moisture will also reduce the long term properties of most adhesives. Therefore it is important that drawing compounds or other sources of water be removed from the adherends before applying the adhesive.

When steel is joined to plastic, special care must be taken because mold release agents on the plastic often interfere with adhesive bonding. Materials such as sheet molding compounds (SMC) require special attention since the mold release agent is an integral part of the material. SMC parts require wiping or abrading the substrate prior to bonding. Primerless adhesive systems aimed specifically at SMC applications are being developed.

Adhesives are sensitive to surface conditions; thus substrate compatibility is essential. An effective way to avoid compatibility problems would be to standardize all surface treatments, including those used by steel suppliers, those used within the stamping plants and those used within the assembly plants.

4.4.4 COMPATIBILITY WITH DOWNSTREAM PROCESSING

The adhesive should not affect any processing done after bonding, nor should the bond be affected by subsequent processing. The adhesive must be inert. This is especially important when bonding automotive assemblies, since an assembly will go through cleaning, pretreating, rinsing and painting before heat curing, and it is undesirable to have any of these processes contaminated with adhesive. It is best to use an adhesive that cures before the assembly arrives at the next processing step. If the adhesive cannot be completely cured, any degree of cure will improve its inertness; therefore, trip curing may be helpful. Contamination problems can be avoided by using a high-viscosity adhesive that will not wash out of the assembly and by using an adhesive resistant to subsequent chemical processing.

Adhesive read-through is an occasional downstream problem. Read-through is observed on an exterior panel when an adhesive on its inside surface shrinks excessively in a paint oven. It is most visible when an inner panel is bonded to an outer panel such as a deck lid or hood. As expected, thin panels are more prone to read-through than thick panels. Low shrinkage adhesives and proper production control can minimize or eliminate this problem.

REFERENCES FOR SECTION 4.4

1. Adapted from “Adhesive Bonding of Sheet Steels”, 1987, American Iron and Steel Institute, Washington, D.C.