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Adhesive Materials and Processing Selection For Environmentally Conscious Manufacturing

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ADHESIVE MATERIALS AND PROCESSING SELECTION FOR ENVIRONMENTALLY CONSCIOUS MANUFACTURING

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Abstract -- Manufacturers that use certain adhesives and related manufacturing processes must consider the impact they have on worker health, safety, and the environment. Product manufacturers must find alternate replacements for solvent-based adhesives and solvent cements. In addition, processes that use ozone-depleting solvents for hand-wipe cleaning operations as well as vapor degreasing must find suitable alternates in order to be environmentally compliant. Likewise, manufacturers that use etching solutions that contain chrome must find a replacement. This paper identifies some of the specific problems associated with using certain adhesives and manufacturing processes. Environmentally acceptable alternative adhesives and processes are presented.

INTRODUCTION

With few exceptions, everything we design must be attached in some way to something else. Adhesives offer one method of joining materials and assembling manufactured products. Advantages of adhesive assembly are many and include distribution of applied forces, minimization of localized stresses, appealing appearance, and light weight. Just look at the growing use of adhesives in automobile manufacturing.

Adhesive joining can be roughly divided into two segments: assembly joining and structural joining. Assembly joining uses an adhesive to hold two parts (materials) together. There is little or no load applied to the joint area other than the weight of the two adherents.

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The joint may be temporary, have no durability requirement, or later be encapsulated, in which case the joint may not be considered critical to the performance of the manufactured item. Structural joining is the formation on a load-bearing joint usually between two high strength materials. Elaborate surface preparation is performed on each adherent to obtain optimum strength and performance (environmental durability, fatigue resistance, and chemical resistance).

But adhesives, because they are primarily organic in chemistry, and some of their associated processes, have certain worker health, safety, and environmental issues associated with them. This paper will discuss these issues. Some alternate materials and/or processes will be described that will help a manufacturer who wishes to use adhesive joining technology operate within worker and environmental regulations. These issues are discussed in the following sections.

CLEANING AND SOIL (CONTAMINANT) REMOVAL

For many years companies have used halogenated solvents such as trichloroethylene (TCE) and trichloroethane (TCA) to remove soils from metal and many plastic and rubber substrates. These solvents were used in hand-wiping operations (usually for assembly joining) as well as in vapor degreasing (used for structural joining). These solvents removed a broad spectrum of organic soils, were rapid drying, non-flammable, widely available, and reasonably priced. Today, these two solvents are not considered environmentally acceptable for numerous reasons. Therefore, other cleaning agents must be used. If the truth were known, many companies don't know what soils or contaminants they have on their substrates and parts. TCA and TCE removed whatever was on the substrate. Therefore, the first two steps in finding alternate cleaning agents is to identify the contaminants needing to be removed and then to answer the question, How clean is clean? Once the soils and contaminants have been identified or at least categorized, finding a replacement cleaning agent is much easier. The following equation can be used as a general rule for cleaning.

(Cleaning Agent Concentration) x (Temperature) x (Time) x
(Mechanics) x (Fixturing) = Clean

HAND-WIPE CLEANING

Hand wiping consists of using a solvent-laden cloth to wipe the surfaces of the substrates to be bonded. Usually, after several passes the worker looks at the cloth to see if there is any discoloration on it. If it is "clean," then he/she stops wiping. For metals (high surface energy materials) a contact angle measurement can be used to test the cleanliness of the surface. A low contact angle indicates good wetting. A water-break-free test can also be used. Individual beads of water on the surface are indicative of soils or contaminants on the surface.

Evaluating cleanliness on plastic and rubber surfaces is more difficult since they are low surface energy materials. They are difficult to wet even when clean. For that reason many plastics and rubbers must be abraded, coated with a primer, and treated by corona treatment or some other means to ensure adhesive wetting. Since there are so many different plastic and rubber material formulations, it is difficult to make one general statement to cover all of them. Each individual plastic and rubber material formulation must be evaluated separately.

Numerous alternate wiping solvents are available. Some are a blend of several different solvents to create a range of solvency and cleaning efficacy. A company must decide what it is comfortable using in its facility -- a high vapor pressure (HVP) cleaning agent versus a low vapor pressure (LVP) cleaning agent. HVP cleaners are high volatile organic chemicals (HVOCs) and are characterized as having low flash points and rapid evaporation. LVP cleaners are low volatile organic chemicals (LVOCs) and are characterized as having higher flash points and slower evaporation. Each company must address the issue of what hand-wiping cleaning agent they should use, both from a cleaning efficacy as well as worker health, safety, and environmental standpoint.

CLEANING FOR STRUCTURAL JOINING APPLICATIONS

With the reduction in use of TCE and TCA in vapor degreasers, alternate cleaning agents and methods had to be found. Fortunately, the metal plating, or conversion coating, industry has experience using detergent cleaners with water. Many of these cleaners are alkaline. This knowledge is being transferred to industries doing structural adhesive joining. There are some precautions that need to be reported. For example, steels and magnesium alloys are very resistant to strong alkaline cleaners. However, aluminum is easily attacked by alkaline cleaners and

silicates must be added to the cleaning bath to protect the aluminum from excessive etching. This also requires that more thorough rinsing be done to remove any silicate that may remain on the aluminum surface. Copper, zinc, and brass can be effectively cleaned using milder detergents, lower bath temperatures, and shorter treatment times. Ultrasonic cleaning equipment is an excellent mechanical means of assisting the detergent and water cleaning agent. Some ultrasonic cleaning equipment contains heaters which raise the cleaning agent temperature and thus improve cleaning efficacy.

CHEMICAL ETCHING FOR ALUMINUM ALLOY STRUCTURAL JOINING

For years the standard for aluminum alloy structural joining was the Forest Products Laboratory (FPL) sulfuric acid/sodium dichromate etch formulation. However, this formulation is not acceptable by today's environmental regulations because of the sodium dichromate. The Boeing Company developed the phosphoric acid anodizing (PAA) process which is much better because it produces a deeper and more stable aluminum oxide skeleton for adhesive attachment. This improved etching results in improved structural adhesive joining durability. It is used extensively in the aircraft industry. However, for many other adhesive structural joining applications it is not necessary, and therefore, the additional expense is not justified.

An alternate aluminum etching formulation was developed at Picatinny Arsenal, NJ. It is identified as the P-2 etch and contains sulfuric acid and ferric sulfate. Aluminum parts are processed (etched) in a similar manner as they would be processed with the FPL etch. The P-2 etch is more environmentally acceptable since it does not contain chrome. For adhesive producers who must test their products with aluminum alloys or manufacturers who do aluminum bonding, the P-2 etch has been found to be an acceptable replacement. The FPL and P-2 etch formulations can be found in ASTM-D-2651, Preparation of Metal Surfaces for Adhesive Bonding. The P-2 formulation and process are listed below.

P-2 Etch for Aluminum

Materials and Process	Concentration and Process Parameters
Sulfuric Acid	370 grams
Ferric Sulfate	150 grams
Deionized Water	1 liter
Bath Temperature	140 to 150°F
Immersion Time	10 to 12 minutes

ENVIRONMENTAL CONCERNS ASSOCIATED WITH SELECTED ADHESIVES

Solvent-based adhesives may contain 70-80% aromatic and/or aliphatic solvents, with the remainder as adhesive. In some solvent-based adhesives, the solvent acts as a convenient carrier for easy application onto the substrate. Upon evaporation of the solvent, the adhesive is ready to adhere to whatever it is applied. With single-component adhesives, the bonding is instantaneous. With two-component systems, the adhesive must cure or crosslink to develop adhesion, such as with urethane adhesives. Product manufacturers especially like the one-component systems because the solvent evaporates quickly and thus the process promotes rapid product assembly cycles. However, because of the high solvent contents, adhesive manufacturers are discontinuing these products.

The product manufacturer must find a replacement adhesive. The manufacturer has developed his production line operation around the use of an adhesive with a fast-evaporating solvent. A direct, drop-in replacement is difficult to find. However, there are options, but the production line may have to be modified to accommodate the new environmentally friendly alternatives.

Waterborne adhesive is one option to use. Water does not evaporate as fast as organic solvents. The production line will have to be extended to accommodate a longer evaporation time for the water. Heaters can be installed to increase the evaporation rate by heating the part or blowing heated air across the part surface.

Reactive hot-melt adhesive is another option to use. Shifting to high-solids, hot-melt production offers increased operating efficiency, often measured in faster cycle time as well as

reduced environmental risk. The adhesive is purchased as a solid material, and any cleanup involves a solid material rather than a liquid, which is much more difficult to dispose of than a solid.

Pressure sensitive adhesive (PSA) is a third option to use. These adhesive films are sometimes referred to as transfer films. They can be 100% adhesive or can have a carrier with them. The advantage of a PSA is that it is a solid instead of a liquid, can be cut to the exact size, provides a controlled adhesive bond line, and bonds instantly upon contact. A product manufacturing company may consider purchasing a subassembly with the PSA already in position.

SOLVENT CEMENTING

Noncrystalline, amorphous-type thermoplastics have been joined to themselves using suitable solvents, solvent polymer solutions, or monomer compositions. When two dissimilar plastic materials are joined, the polymeric-solvent technique is usually recommended, but care must be exercised in the selection because both adherents must be compatible with the solvent used. As with solvent-based adhesive joining, solvent cementing is not considered environmentally acceptable. Alternate adhesives and joining processes are available and are finding increasing and widespread use in manufacturing. This is especially true of the manufacture of disposable plastic medical products. Two options are available: cyanoacrylates and ultraviolet-cured acrylate/urethanes. These products are often referred to as "bond-on-demand" adhesives.

SOLVENT CEMENT REPLACEMENTS -- CYANOACRYLATE ADHESIVES (CA)

An ethyl cyanoacrylate adhesive is normally selected for joining plastic materials. A small drop of adhesive is applied to one substrate and the parts are assembled. Moisture on the surface causes an immediate polymerization and joining of the two substrates. Original cyanoacrylate adhesive formulations produced joints that were brittle. New formulations produce joints with improved flexibility, durability, and temperature resistance. Joints made with cyanoacrylate adhesives are very strong in tension. Development of primers has permitted the use of cyanoacrylates for joining polyolefin (polyethylene and polypropylene) plastics, typically

low surface energy materials. A common problem with the use of cyanoacrylate adhesives is the use of too much adhesive. It would seem that if a little is good, then a lot must be better. This assumption is incorrect! Very thin bond lines produce very strong adhesive joints. For this reason, automated dispensing equipment is recommended to achieve repeatable, high quality joints.

ULTRAVIOLET-CURED ACRYLIC/URETHANES

This class of adhesive contains a photoinitiator that is sensitive to ultraviolet light. Upon exposure to UV light, polymerization occurs in a matter of seconds. UV-cured adhesives are normally used with transparent plastics in order to get the light to the adhesive. UV-initiated adhesives may also contain latent curing agents to assist curing where UV light cannot reach the adhesive. UV-cured adhesives are normally packaged in opaque syringes. These adhesives lend themselves to automated production operations because of their extremely fast polymerization.

SUMMARY

There are several adhesives and processes that have been used for joining of materials which are not considered acceptable today. However, there are alternatives that companies can incorporate to improve worker health and safety and meet environmental regulations. In many cases, a better quality product results from the change. Users of adhesives need to examine their manufacturing operations to identify any manufacturing materials and processes that are not environmentally compliant. Alternate adhesives and processes need to be evaluated as replacements. No company should be in a position where the adhesive and/or chemical process supplier informs them that the product(s) they are using has been removed from the marketplace. When that occurs, the manufacturing company has a really big problem on its hands!