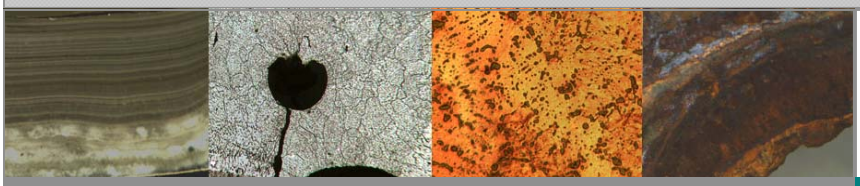
NUTS & BOLTS



New Hampshire MATERIALS LABORATORY, INC.
Your Problem Solving Partner

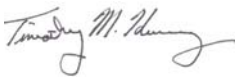
ADHESIVE FAILURE MODES AND ID OF ADHESION FAILURE

JUNE 2012 / ISSUE 7

Welcome to New Hampshire Materials Laboratory

Adhesives are not just a common household product. There are many types of natural and synthetic adhesives out on the market. They are not just a common household product due to their capability of bonding similar or dissimilar types of materials together, adhesions are often used in the world of manufacturing.

Occasionally, a manufacturer will have an adhesion failure and a need for our chemistry experts to help solve the problem. For this Nuts & Bolts, we exam adhesive failure modes, show what an adhesion failure looks like, and review adhesions under industry definitions.



Tim Kenney
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Adhesive Failure Modes and Possible Causes

The use of adhesives to bond objects together during manufacturing can often be an essential part of the process. The selection of the proper adhesive and its application is vital to the project being successful or ending in failure.

Unfortunately, adhesive failures do occur. These are several factors that help contribute to the failure of adhesives: environmental exposure, poor surface preparation, physical stresses, solvents or other contaminates. These factors can cause one of the following failure modes: Cohesive, Adhesive (also known as Interfacial), and Mixed.

Environmental conditions that can weaken the adhesive are temperature, sunlight, a chemically active environment such as saltwater, or samples being handled in an unclean environment. Poor surface preparation results in a

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Industry Definitions

Types of Adhesives

Phenolic resins can be used as either a base resin in an adhesive, a modifier in adhesive formulation, or a co-reactant to produce a new molecule with good mechanical and adhesive properties. Phenolics have good adhesion to most substrates, good high-temperature properties, are water weather resistant, resistant to burning, and are high strength. They are considering one of the lowest costing adhesives.

Epoxies are considered the most versatile of the structural adhesives. They generally are

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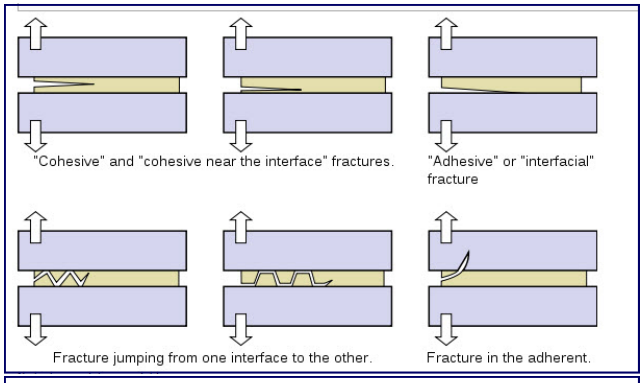
smooth oxide film, hydration of the aluminum oxide surface, an incompatibility of a surface treatment with the adhesive, the disengagement of the adhesive from the porous oxide, and an elastoplastic fracture of the adhesive. Physical stresses may cause separation of the surfaces. Solvents can deteriorate or dissolve the adhesive. Contamination during the manufacturing process can alter the surface chemistry of the material, instigating an adhesion failure.

Cohesive failure occurs due to the inability of the adhesive to resist the internal separation. During cohesive failure, the adhesive sticks to both surfaces, but can not hold them together. A cohesive failure is apparent by the surfaces of adherents after debonding. They will be covered with fractured adhesive.

Interfacial or Adhesive failure is debonding between the adhesive and the adherent.

A mixed failure happens when the crack propagates at some spots in a cohesive and in others in an interfacial manner. Mixed fracture surfaces can be characterized by a certain percentage of adhesive and cohesive areas.



Adhesive Failure Modes

A failure analysis can help determine the location and cause of an adhesive failure, help understand the mechanisms of the crack initiation and propagation, and identify the weakest link in the structure.

A recommendation or remedy to the problem may be found with the performance of a failure analysis or surface analysis. A surface analysis not only leads to a failure analysis but is also useful for routine quality control, process development, and scientific investigation

Characterized as being strong but brittle. Yet, it can be formulated to be more flexile without loss of tensile strength. Epoxies have the ability to bond a variety of substrates effectively, and can be formulated to cure at either room temperature or elevated temperatures, under dry or wet conditions.

Aneaerobics remain liquid until isolated from oxygen in the presence of metal ions, such as iron or copper. It rapidly “cures” or hardens to form a tough cross-linked plastic with tenacious adhesion to many metals. Though anaerobic applications differ widely, in most cases the adhesive provides high shear strength.

Elastomeric are rubber base adhesives. The properties and characteristics of rubber base adhesive include:

- Versatility/Flexibility
- Variety of Type
- Fast Cures/Quick Assembly
- High Elongation/Peel Strength
- Durability
- High Strength Bonds
- Gap-Filling Capabilities
- Superior Electrical Insulation Properties

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Identification of an Adhesive Failure

Cyanoacrylates are single-part solvent free adhesives which can strongly bond a wide variety of materials. They cure at room temperature by anionic polymerization initiated either by absorbed moisture or by alkaline sites on the surface. Industries which make use of cyanoacrylates include automotive, beauty aid, plumbing, transportation, electrical and electronics, consumer products, and medical devices.

Modern cyanoacrylate adhesives have been developed to bond polypropylene, polyethylene, PTFE, and other polyolefins. They often cure in just seconds at room temperature and can be formulated to resist high temperatures. Cyanoacrylates are often cost effective because very little adhesive needs to be applied. There are no solvents to worry about, and no special drying equipment necessary to cure the adhesive. This adhesive is extremely versatile and capable of bonding a wide variety of similar and dissimilar materials together.

Adhesion failures can occur if the adhesive manufacturer's recommendations are not followed while bonding materials together. New Hampshire Materials Laboratory (NHML) has seen such failures. Below is a description of what an adhesive failure looks like, and how a testing laboratory can help determine the cause.

In our example, a stainless steel clamp has been bonded with cyanoacrylate glue to the outer surface of a Silicone rubber hose pretreated with a primer. The use of the primer is intended to enhance bonding of the cyanoacrylate to Silicone rubber. With proper application of the primer and adhesive, the clamp should bond with the Silicone rubber hose without separation even under a modest amount of force.

A failure was noticed to be occurring between the metal clamp and the adhesive when sufficient force was applied. The Silicone hose gave way leaving a patch of Silicone rubber stuck to the inner surface of the metal clamp. Yet, there were no signs of failure between the adhesive and the Silicone hose. This type of failure not only can cause a manufacturer headaches but time and money.

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- Thermally and Electrically Conductive
- Outstanding Chemical and Water Resistance
- Cryogenic and High Temperature Serviceability
- Resistance to Vibration, Shock, Impact, and Thermal Cycling.

Silicone primarily available as pressure sensitive adhesives (PSAs) some can be cured with aminosilanes to perform as higher strength adhesives.

Cyanoacrylates are single freed adhesives that form strong bonds on a wide variety of substrates.

Polysulfides are normally associated with high performance sealants for construction, marine, insulating glass, automotive, or aircraft industry.

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In this circumstance, our chemistry department, with the help of Fourier Transform Infrared Spectroscopy (FTIR), would look at all the variables involved to help determine the root cause of the failure. The first variable we need to eliminate is the possibility of contamination on the inner surface of the stainless steel clamp. If the clamp surface is found to be clean and no contamination is found, the next variable to consider is there a problem with the cyanoacrylate glue itself. A sample of the “failed” glue and a sample of the “virgin” cured glue straight from the dispenser would be compared for differences. If no apparent differences occurred, the next question may be is there a problem with the primer used on the Silicone hose.

Let’s pretend the chemist did not know a primer was being used on the Silicone hose and the adhesion failure still remained a mystery. After further consideration, the chemist decides to take further FTIR spectra of the sample where the bond failure occurred. This time a foreign substance was found that did not match the cyanoacrylate glue spectra. During the consultation with the customer, the chemistry staff finds that a primer is being used on the Silicone hose to enhance the adhesion of the glue. A sample of the primer is obtained and a FTIR is performed. The FTIR spectra identified the primer to be problem.

NHML chemistry staff concluded that during application of the primer to the Silicone, some primer was inadvertently coming into contact with the inner surface of the stainless steel bands. This primer is intended to enhance bonding of the cyanoacrylate to Silicone rubber, however it is not recommended for metal surfaces. Therefore they concluded that even the smallest amounts of primer presence at the clamp/Silicone interface was weaking the bond, and resulting in failures when the bond was stressed.

With some investigative work by the NHML chemistry department, the source of the failure was identified. They were able recommend that the primer be kept away from the stainless steel clamp as the primer was not compatible with the stainless steel and cyanoacrlate.

This is only one type of adhesion failure NHML has seen. With the help of our staff experts, a manufacture can save themselves time, money, and headaches when faced with a failure whether adhesive or other types. We have the knowledge and equipment needed to help solve the problem.

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