Choices of adhesives—general introduction to structure adhesives

OPTI 521 tutorial report
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Dec. 6th 2016

Abstract:

This tutorial report focus on the choices of adhesives. The most common type of adhesives, characteristics of each type are introduced. The basic procedure for polymer adhesives as well as the corresponded mechanical properties and test methods are introduced.

Introduction:

As we all know, the basic function of adhesives is joining parts (different material, different pieces). Compared to mechanical joints, like fasteners, adhesives own their own advantages, like lighter weight, eliminate or minimize corrosion, eliminate joint fatigue, distribute lodes over wider surface area and so on. Compare to metal like solder or glass like inorganic glass powder, adhesives is relatively quick and simple to operate.

Table1. basic adhesive way

type	Polymers (chemical)	Solder (metal)	Inorganic glass powder
figure			
application	Nearly all situation	Bond metal pieces	Opto-electronic packaging

Adhesive types do not follow any common nomenclature, however, we can describe them in our own way to avoid confusion. Optical adhesives are usually glass-to-glass adhesives, which imply the transmission quality. Structure adhesives are more for mechanical parts of a system. Elastomers use rubbery properties for sealing and to provide compliance. In this tutorial, instead of cement optical components together (doublets and achromats) we focus on the situation of optics-to-mechanics or structural adhesives.

properties:

There is no intermediate state for adhesives. ”best” when they work correctly, “worst” when they fail. To make it effective, it must be able to wet the substrate, It must harden and it must be able to transmit load between the two surfaces/substrates being adhered well. Thousands of adhesives are available now, and each of them owe their own characteristics, which affect their performances.

Wetting

An ability of an uncured adhesive to make intimate contact with the substrate in order to facilitate a bond. Surface tension 30~35 dynes/cm3

Viscosity

A fluid’s resistance to flow. The “thickness” of the fluid

Cure

multi-part adhesives- harden by mixing two or more components, individual components of a multi-component adhesive are not adhesive by nature, they react with each other after being mixed and show full adhesion only on curing.

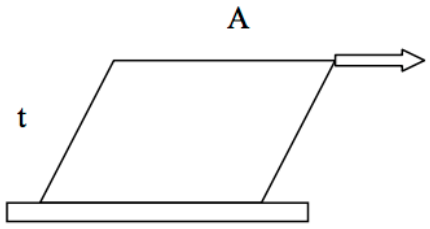
one part adhesives- cured by chemical reaction with external energy source,for example, UV light, heat and moisture.

Stiffness

Stiffness of adhesive which can be defined for shear and axial stiffness is an important parameter. For stiffness analysis, we have to use the proper modulus for stiffness analysis, which depend on the bonded thickness and area.

Shear stiffness ---thermal effect, out gassing process

Shear stiffness K_s is $K_s = \frac{\delta F_{shear}}{\delta y} = \frac{GA}{t}$



axial stiffness

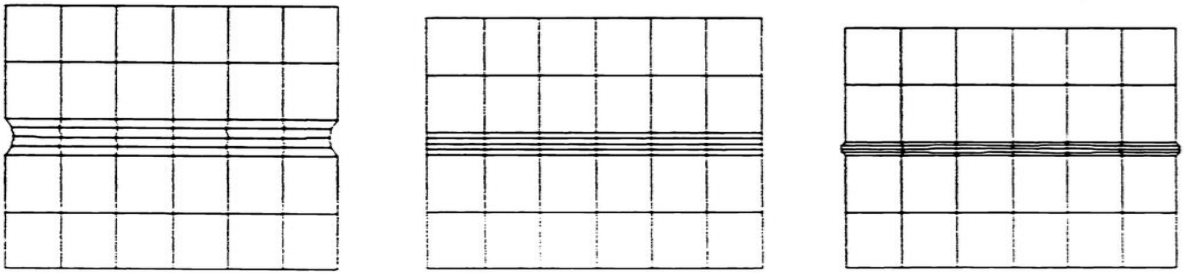
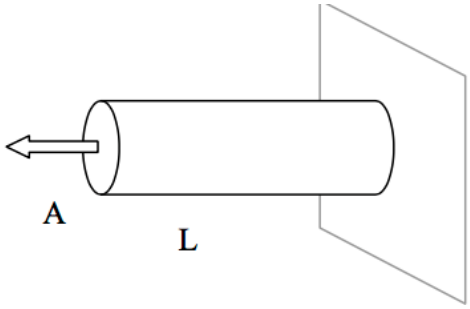


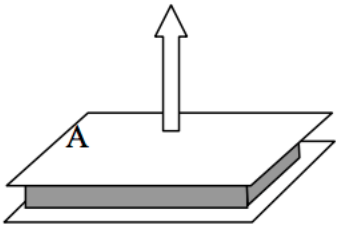
figure1. tensile loading(left) no loading(middle) compressive loading(right)

tensile elongation
when axial length>> width young's modulus

$$K_1 = \frac{\delta F_{axial}}{\delta z} = \frac{E_0 A}{L}$$



when thickness << width bulk modulus



$$K_2 = \frac{\delta F_{axial}}{\delta z} = \frac{E_B A}{t}$$

compression

Axial stiffness K_z is $K_z = \frac{\delta F_{axial}}{\delta z} = \frac{E_C A}{t}$

Where E_C is the *compression modulus,* which depends on geometry

$$E_C = E_0\left(1+\phi S^2\right)$$

E_0 = Young's modulus
S = Shape factor
ϕ = material compressibility coefficient (=0.64 for RTV)

while shape factor

$$S = \frac{Load\ area}{Bulge\ area} = \frac{A}{perimeter \times thickness} = \frac{l \times w}{(2w+2l) \times t}$$

From which we now that thinner it is, larger young's modulus it is, stiffer it is.

Strength

The strength of an adhesive indicates the maximum amount of stress that can be applied in a particular geometry (i.e. tensile, compressive, shear, peel, or cleavage) without failure of the adhesive. For permanent bonds, this should be high; for temporary bonds, it should be low. Structural adhesives typically have a tensile or shear strength in excess of 1,000 psi.

figure 2. examples of out of adhesive strength

Hardness

Will change corresponded with time, good compliance need higher hardness.

figure 3. example of hardness of material(from left to right: soft to hard)

Thermal Properties

Temperature can strongly affect the properties of adhesives. In fact, this is one of the major tradeoffs when considering the use of adhesives vs. mechanical fasteners. The following are several important temperature related properties of adhesives.

Maximum Continuous Operating Temperature

This is the highest temperature that the cured adhesive can endure for an extended time without deteriorating. For epoxies, this is usually 125 degrees C or higher. Adhesive suppliers normally report both the maximum and minimum recommended extended exposure temperatures for their formulations and it is important to consider both extremes in the context of the proposed application.

Coefficient of Thermal Expansion (CTE)

Materials expand linearly with an increase in temperature. The coefficient of thermal expansion is the constant of proportionality between the temperature change and the induced thermal strain:

$$\Delta L = L\alpha\Delta T$$

The CTEs of adhesives are typically much higher than the structural materials that they are joining (e.g. 30-300 ppm/deg C for adhesives compared to 23 ppm/deg C for aluminum and 7ppm/deg C for BK7). Typically, the designer attempts to match the CTEs of the two substrates as closely as possible and then find an adhesive with a CTE near that value. If there is a large mismatch between the CTE of the adhesive and substrate(s), large stresses can result upon temperature variations. If the adhesive has a low Young's modulus, the stresses resulting from thermal expansion can be lessened. But, in general, low CTE adhesives are desired.

Creep rate

This could perhaps be best described as a long term shape change and is critical for applications where dimensional stability is important. Keep in mind that creep rate is exponentially proportional to temperature and is also influenced by stress and humidity

Common categories:

Epoxies: available in one and two-part liquids and pastes, these provide the highest strength and elevated temperature resistance.

figure4. two-part epoxy

Acrylics: are two-part liquids and pastes to bond the widest variety of substrates including hard-to-bond plastics and oily metals. The distinction is high strength bonding without the surface preparation needed for epoxies and urethanes.

figure5. acrylice

Cyanoacrylate: are high strength liquid formulations known as instant adhesives. On rigid plastic, glass, metal, rubber, and other low porosity substrates, they harden in seconds through reaction with surface moisture.

figure 6. Cyanoacrylate

Urethane adhesives: are generally lower cost two-part liquids and pastes that cure quickly to an elastic bond in applications requiring flexibility between dissimilar materials. Impact resistance is a distinctive characteristic.

figure 7. Urethane

UV curable adhesives: When exposed to a suitable UV light source, UV curable compounds usually cure in a matter of seconds. Upon cure, they exhibit minimal shrinkage. Excellent bond strength to metals, ceramics, many plastics and most rubbers.

Table 2. list of adhesives

List of Adhesives

Name	Type	Form	Work Time	Cure Time Handling Strength	Use and Properties
Hardman D-50	Urethane	HARDMAN DOUBLE/BUBBLE® Green/Beige Package #04022	3-5 min	60 min	Shear strength, peel strength, good impact and fatigue resistance
Hardman A-85	Urethane	HARDMAN TUFF STUFF DOUBLE-BUBBLE Purple-Beige Package #04024	5-8 min	45 min	Fast setting, low temperature flexibility
Hardman-Red Non-Sag	Epoxy	Fast-Setting Non–Sag Epoxy 2 DOUBLE/BUBBLE Red Package #04008	3 min	15-30 min	Extra fast setting, non-sag adhesive
Loctite 326	Acrylic	LOCTITE® 326 + Primer 7649	5-10 min	24 hrs	For nonporous surfaces & fitted parts that require high-strength adhesive.
Loctite 435	Cyanoacrylate	LOCTITE® 435™	1-2 min	24 hrs	Strong bonds to nonporous materials
Elmer's Glue-All	PVAC BASED	ELMER'S GLUE-ALL	8-10 min	24 hrs	General purpose, fast-setting. Paper, wood, other porous & semi-porous materials
NOA 61	UV Curable	UV Curing Norland Optical Adhesive #61	Precure: 10 sec	Full cure: 5-10 min	Bond lenses, prisms & mirrors
UV 630	UV Curable	Permabond UV630	6 seconds		Glass, metal & plastics.
Duco Cement	Nitro cellulose cement	Devcon Duco Cement	10 min	16 hrs	Multipurpose glue for bonding wood, leather, glass, ceramics, Garolite and steel, stainless steel, aluminum, cast iron, & bronze

Choice guideline

You should know:

Do not use adhesive if your requirement is to joint part for a long time(>10 years), unless past experience prove it.

Always use pedigreed engineering adhesive.

Preparation:

performance

How long you want to use it, which is about bond longevity.

Material, which material you want to use.

Function, compliance or joint two different part or change stuff out look for any other reason

Stress analysis

Exact bond geometry, especially stress near corners and fillets.

Operating environment

Temperature humidity chemical species present

Substrate particulars

Metal: heat treatment or acid situation during your application

Glass: do not affect the optical properties

Apart from that, make sure no critical damage or dust on the surface you want to use, datasheet is always a good reference for you to look at.

Conclusion

In this tutorial, a general introduction to structure adhesives is given, important properties, types of material, as well as a choice guideline included.

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