HAND BOOK OF ADHESIVES

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HANDBOOK OF ADHESIVES

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Preface

There has been rapid development in the field of adhesives in recent years. Adhesive bonding has emerged as effective and economic in the fabrication of a variety of components and assemblies. Adhesives are finding applications in newer and newer fields. The aim of writing this book is to present the latest developments in the adhesive field in a simple and concise manner. The book has been written with a practical point of view avoiding theoretical discussions.

In the writing of the book special emphasis is given to adhesives based on synthetic resins. Adhesives based on animal, vegetable and mineral products and adhesives based on synthetic rubbers such as SBR and Neoprene are also fully discussed. A highlight of the book is inclusion of a number of formulations for adhesives for various applications. Although these formulations are obtained from reliable sources they should be taken as guide only. With little bit of experimentation, these formulae can be modified to the particular application in mind.

Besides regular chapters a great amount of valuable information is included in appendix section of the book in the form of charts and tables.

It is the sincere hope of the authors that the book will be useful to those who wish to go in for the manufacture of modern adhesives as well as those who are already in the field but would like to diversify. The book will serve as ready reference to all those who are interested in the field of adhesives.

The authors wish to thank all those who have helped them in the preparation of the book. Suggestions for further improvements of the book would be highly appreciated.

AUTHORS

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Chapter 1

Introduction

An adhesive may be described as a substance which is capable of holding materials or adherents together by surface-action. This process of joining the two or more surfaces is known as adhesion. The productions loosely covered by this definition of adhesive are cements, sealers, mucilages pressure and heat sensitive adhesives etc.

As far back as 1500 B.C. Egyptians used glue, gum-arabic, eggs etc., for wood veneering. Reeds for making papyrus were used to be held together using flour paste. Bible mentions the use of bitumen as mortar for building the Tower of Babel. It was also used for caulking and caulked their boats with wood tar and beeswax and also used egg-white as an adhesive. Some 150 years ago, painters used egg-white as a pigment binder. Later, glue, casein and starch based adhesives became popular, but they suffered the drawbacks of deterioration in damp weather, and due to moulds and bacteria. In 1930, new adhesives, based on synthetic resins and other materials, came into use. These adhesives had excellent resistance to moisture, mould growth and other conditions.

Phenol-formaldehyde was the first synthetic resin of importance, and was mainly used for wood work and plywood-manufacture. This was followed by urea formaldehyde, and resorcinol-formaldehyde etc. Later, demand of the aircraft industry for materials suitable for metal bonding led to the development of modified phenolic resins containing synthetic rubber components which displayed high shear and peel strengths. In the 1950s epoxy resin based adhesives came into use; they had 100 per cent reactive solid content and had revolutionary advantages over the traditional adhesives.

Why Adhesive Bonding

The basic function of an adhesive is to fasten the components of an assembly together and maintain the joined parts together under the service conditions. But the two parts can be bonded by other methods also, viz. soldering, welding, reveting, brazing, and screw or nail attachment; hence the question of particularly using the adhesive for bonding assumes importance. Often the mechanical fastening methods mentioned above cause distortion, discoloration and damage to the assembly; hence adhesive bonding may be the proper choice in this case. Mechanical bonding methods require special jigs, machining equipments (drills, welding machines etc.); thus, adhesive bonding in many cases is cheaper.

Advantages and Disadvantages of Adhesive Bonding

Advantages and disadvantages of adhesive bonding as compered to mechanical fastening, are being given below:

Advantages

(*i*) Adhesive bonding may be used for dissimilar and thin sheet material. In the later case other methods may cause distortion.

(*ii*) Complex shapes can be easily fabricated using adhesives.

(*iii*) The appearance of the final assembly is much better with adhesive bonding, due to the absence of rivet heads, and weld-marks etc.

(*iv*) Adhesive forms and methods of their applications are quite versatile and are adaptable to many production processes.

(*v*) Adhesive bonding is sometimes more economical.

(*vi*) Adhesive bonding gives uniformly distributed stresses, the bond is continuous; this results in elimination of stress concentration and fatigue.

(*vii*) Adhesive bonding gives much lower increase in weight as compared to mechanical fastening.

(*viii*) Adhesive bonds are more flexible, hence they absorb vibrations and load variations more easily, resulting in reduced failures.

(*ix*) Adhesive bonding is particulary suitable for heat-sensitive materials which may get distorted or destroyed by mechanical fastening, e.g. welding.

(*x*) Adhesive bonding gives a non-conducting joint, thus galvanic corrosion between the two dissimilar metals is reduced or eliminated.

(*xi*) Adhesive bonding gives a bond which insulates against electricity, heat and sound etc. Also the joint also serves as barrier to moisture and chemicals.

Disadvantages

(*i*) Sometimes adhesive bonding becomes a costlier and time consuming process when special jigs for cleaning of surfaces, pressure and curing are required.

(*ii*) Adhesive bonds develop their full strength slowly—in contrast to welding.

(*iii*) To minimise peel and cleavage stresses a careful joint design is required.

(*iv*) Adhesive bonds usually cannot withstand higher service temperatures like mechanical bonds.

(*v*) Adhesive bonds have poor electrical and thermal conductivity unless modified by suitable fillers.

(*vi*) Adhesives bonded assemblies cannot be easily dismantled for repair.

(*vii*) Solvent based adhesives are prone to fire and toxicity hazards.

(*viii*) Thermoplastic adhesives have tendency to creep; thermosetting adhesives have low peel strength and also adhesive bonds are less durable.

(*ix*) Adhesive bonds are more prone to degradation by heat, light, moulds, bacterias, chemicals, plasticizers, radiation and other service conditions.

Ideal Adhesive

A good adhesive should have the following desirable properties:

(*i*) Maximum mechanical strength of the bond.

(*ii*) Minimum setting time or quick development of bond strength.

(*iii*) Ease and rapidity of application.

(*iv*) Resistance to moisture.

(*v*) Ability to withstand temperature variations or it should produce a flexible anti-cracking bond.

(*vi*) Resistance to the deterioration by ageing.

(*vii*) Chemically inert to the adherents.

(*viii*) Freedom from objectionable odour.

(*xi*) Freedom from fire and toxicity hazards.

As can be easily inferred from the above no single adhesive can have all the above desirable properties. Adhesive for particular industrial application is selected according to the more important service conditions required. To achieve desirable properties, certain modifying agents like plasticizers, stiffeners, driers and fillers etc., are incorporated in the adhesives. In certain cases blends are used to combine the desirable properties of one or more of the adhesive components.

Joint Design

In order to exploit the properties of the structural adhesives to the maximum, the joint has to be carefully designed. For this purpose two things should be kept in mind: the direction of the loads in service and the ease with which the joint can be formed. Detailed joint design is rather out of the scope of this book and only more important considerations are being given to those factors which have their influence on the design of adhesive itself.

There are 4 types of stresses, which a joint may be required to withstand, namely shear, tension, cleavage and seal. Shear loading imposes as an even stress across the whole bonded area. This type of joint is most economical and advantageous; hence a joint should as far as possible

be so designed that most of the load through the joint is of shear type. Under tension also the joint works as good as under shear.

Cleavage rype of loading occurs usually due to an offset tensile force for a moment. But the stress is not uniformly distributed and is concentrated at one side of the joint. To overcome this the bonded area has to be made large enough and this makes it less economical. For peeling one or both adherents should be flexible, this concentrates very high stress on the joint boundary resulting easy failure. This type of bond should be avoided as it is most uneconomical.

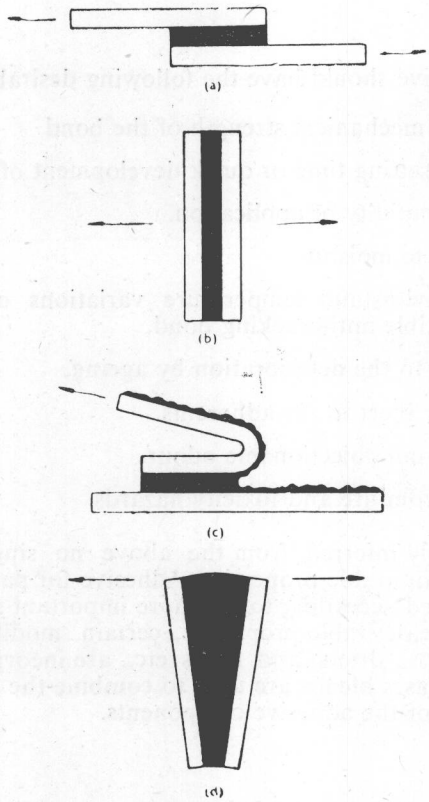

Fig. 1. The mechanism of four important stresses (a) shear (b) tension (c) cleavage (d) peel.

In practice the joints are not simple and also different types of stresses are always present, though one or more of them predominate. Like the four types of basic stresses given above, four basic types of joints are also given below.

The joint should be so designed as to have the bonded area as large as possible, and so that the adhesive is stressed in the direction of its maximum strength. As mentioned above, the joint should be so designed

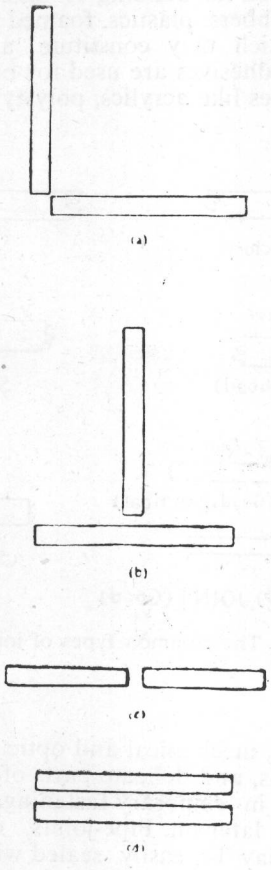

Fig. 2. The four basic types ot joints (a) angle (b) tee, (c) butt, (d) surface.

that the loading occurs in such a way that the maximum properties of the bonded area contribute to the joint strength; this particularly is the case with shear and tension stresses. Some of the popular common types of adhesive joints are given below. Though due to specific high performance requirements, for example in aircraft, the adhesive joints may be quite complex.

Application Area for Adhesive Bonding

Adhesives are used for bonding of surfaces, when the mechanical bonding methods result in distortion, discoloration, corrosion and other troubles. Sometimes adhesive bonding is used due to reduced cost and performance improvement. Adhesive bonding is sometimes used to complement other fastening methods in an assembly.

Adhesives may be used for bonding of dissimilar materials, such as combinations of metals, rubbers, plastics, foamed materials, fabrics, wood etc., and for metals which may constitute a corrosion couple e.g. iron to copper or brass. Adhesives are used for bonding of heat sensitive materials e.g. thermoplastics like acrylics, polystyrenes, glass etc. Fragile

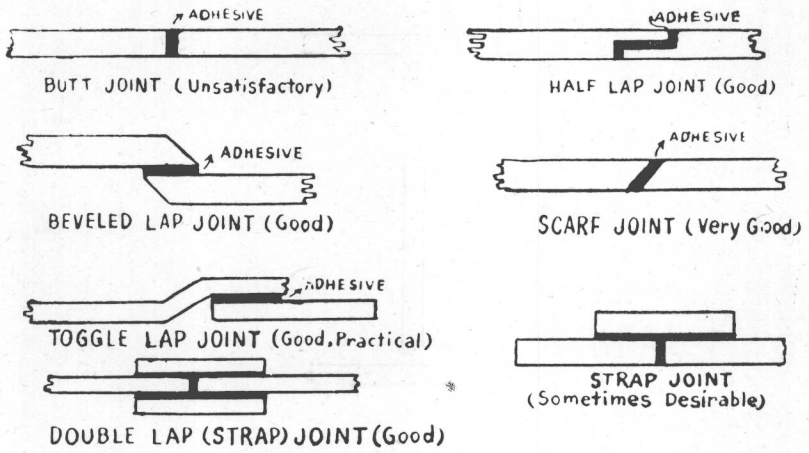

Fig. 3. The common types of joints.

components like electrical, mechanical and optical instrument parts; metallic, plastic and glass foils, and delicate parts of cameras and watches etc. Adhesive bonding is used in temporary fastenings also, where the bond is required to be dismantled later on. Pipe-joints, capsules of components, containers, seems etc. may be easily sealed with adhesives. Reinforced structures like stiffeners for wall panelling, boxes and containers, partitions, chassis parts of automobiles, aircraft body parts etc. are also nowadays being bonded using adhesives.

Structural applications of adhesives include load bearing structures in the aircraft fuselage, automotive and civil engineering industries, e.g., clutch facings and brakelinings where adhesives are being used nowadays in place of rivets. Adhesive applications in laminated structures include sandwich construcations based on honey comb materials of aluminium, foamed plastic, porcelain enamel skins etc., heat exchanges, sheet laminates of plywood, timber beams, plastics, metals, vinyl to steel, copper to phenolic printed circuit boards, wood to metal and rubber sheet to metal, core laminates of electrical dynamos, transformers and motors etc.

Bonded inserts; e.g. plug inserts, studs, rivets, concentrics and shafts, tubes, window frames, furniture assembly, shaft-rotor joints of motors and gears etc., tools, reinforced plastics with metal inserts and paint brush bristles are also some of the applications of adhesives.

Chapter 2

Adhesive Bonding

After the proper selection of adhesive and joint design, the adherent surfaces have to be properly prepared or treated, so that the adhesive has the maximum adhesion to the surfaces. The presence of contaminants at the surfaces may drastically reduce the bond strength if the surfaces are not prepared properly. The adhesive is then applied to the surfaces and the bond is finally cured to develop the maximum strength. These various steps, in adhesive bonding, are being given in detail.

Surface Preparation

For best adhesion, the adherent surfaces are cleaned or converted to a suitable condition before bonding. Various surface preparation methods are available and the choice of method largely depends on the adherent's material, its condition, type of adhesive, loading, service conditions, life, and processing cost involved. Usually abrasives and solvents are used to remove surface contaminations which may otherwise hinder the surface wetting by the adhesives. More thorough surface treatment such as surface roughening promotes mechanical adhesion, whereas chemical treatment modifies the surface physically and chemically to increase its specific adhesion properties.

Mechanical treatments are used when chemical treatment methods cannot be used. Mechanical methods include abrasion with sand blasting, emery paper etc. In the chemical method, the degreased surfaces are dipped into solutions of suitable reagents, which may be hot sometimes, followed by washing and drying. Nowadays apart from mechanical and chemical methods, certain other methods such as flame-treatment, corona discharge etc. have come into use with certain inert plastics, such as polyethylene, polypropylene and PTFE etc. General methods of pretreatment of various adherents are given below :

Metal Adherents

The metallic surfaces are usually contaminated with oils and greases. Degreasing is carried out by steam or by solvent dipping or by vapour degreasing. Usually benzene, trichloroethylene and perchloroethylene are used for this purpose. Dirt and inorganic contaminants may be removed by alkalies or detergent solutions. When the metal surface is badly oxidised or scaled to wirebrushing or sand blasting is resorted to; this produces some surface roughening also. Chemical methods include immersion in cold or hot acidic or alkaline baths. For thicker oxide