7 Epoxy resin adhesives*
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7.1 Introduction

The use of structural adhesives in the manufacture of load-bearing components has grown extensively in recent years. This can be attributed to a number of desirable qualities which adhesive bonding allows in comparison with more traditional joining techniques such as riveting and welding. These include:

(i) Allowance of a relatively uniform stress distribution, resulting in improved fatigue performance.
(ii) The ability to join dissimilar substrate materials which, due to their dielectric nature, minimises the possibility of electrolytic corrosion between dissimilar metals.
(iii) Allows the joining of thin-gauge metals to each other, in particular honeycomb assemblies, resulting in the availability of lightweight structures exhibiting high strength to weight ratios.
(iv) Allows both increased design flexibility and the ability to fabricate complex shapes.
(v) The possibility of reduced production costs in comparison to welding and riveting.

Although there is a range of chemically different structural adhesives (Wake, 1982), those based upon epoxy resins have, over recent years, earned a reputation for combining both high load-bearing characteristics together with ease of processing, and can be regarded as workhorse products. A number of highly favourable characteristics can be regarded as responsible for this popularity.

(i) They exhibit excellent adhesion to most metallic alloys and various other substrate types.
(ii) They are capable of operation at temperatures up to approximately 150°C for both short- and long-term applications.
(iii) They are highly versatile in the sense that a wide range of processing, cure and property characteristics can be achieved.
(iv) They cure by reaction mechanisms which do not result in the generation of volatile by-products, e.g. water. Thus processing is

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relatively easy, without the necessity for high applied pressures during the bonding operation.

(v) They exhibit good wetting properties when applied to well prepared surfaces and exhibit relatively low shrinkage during cure.

A study of the literature concerning epoxies reveals the vast number of formulation variables which can be employed for many applications including adhesives (Lee and Neville, 1967; Potter, 1970; May, 1988). Many different types of epoxide resins exist ranging from the essentially workhorse epoxy, the diglycidylether of bisphenol A (DGEBA) to the more complex systems based upon tri- and tetrafunctional resins (see chapter 1).

Perhaps rather more daunting, a large number of curing agents can be employed to convert the epoxy prepolymer to a crosslinked network, with a large number of these being capable of use in adhesive formulations (chapter 2). In addition, adhesive formulations can contain and benefit from further additives including fillers, toughening agents, coupling agents etc. (chapter 4), as well as being available in liquid, paste, film or carried film form, thus demonstrating the wide variation in epoxy adhesive types available for the potential user.

In this chapter, an attempt will be made to discuss the factors pertinent to the successful use of epoxy-based adhesives. Within this context, consideration will be given firstly to the theories of adhesion, i.e. why materials stick together including the important aspect of substrate wetting. Substrate surface pretreatments, generally considered vital for adhesive bonding with all adhesive types, including epoxies, will be briefly discussed together with an account of the test methods available for assessing important mechanical properties. Formulation aspects pertinent to epoxy adhesive applications will also be briefly reviewed together with accounts of the properties and, of particular importance, durability characteristics. Finally some examples of where epoxy-based adhesives have been successfully employed will be discussed.

7.2 Theories of adhesion and wetting phenomena

Kinloch (1980) has defined an adhesive as being a material which, when applied to substrate surfaces, can join them together and resist separation.

To provide a fairly wide and balanced account of the various facets of epoxy resin adhesive technology it is of interest to outline briefly the various factors and theories which underpin this definition. This will involve a discussion of two major factors, namely theories of adhesion and wetting. The former will hopefully provide the reader with an insight into the major question: why do materials stick to one another, whilst the latter will address the important subject of wetting which has been described by Sharpe and Schonhorn (1964) as the single most important factor likely to influence the strength of an adhesive joint.