Effect of Cure Temperature on the Glass Transition Temperature and Mechanical Properties of Epoxy Adhesives

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Abstract

This paper describes the influence of the curing temperature on the physical and mechanical properties of three structural adhesives. This work was undertaken to improve the understanding of the effect of curing temperature in the glass transition temperature, Tg, and stiffness of epoxy adhesives [1]. The mechanical properties of the adhesives were measured in bulk specimens. Tg was measured by dynamic mechanical analysis using an in-house developed apparatus. The curing process was the same for all tests, consisting of a curing stage followed by a post cure stage. The initial stage was performed at different temperatures while the post curing stage was always performed at room temperature until the adhesive was completely cured. The mechanical properties and the Tg was found to vary as a function of the cure temperature of the adhesive. When cured below the glass transition temperature of the fully cured network, Tgc, the strength and stiffness of the adhesive increase as the cure temperature increases and the Tg is higher than the cure temperature [2 - 3]. When cured above Tgc, the strength and stiffness decrease as the cure temperature increases and the Tg is higher than the cure temperature [4].

Introduction

An isothermal time-temperature-transformation (TTT) cure diagram have three critical temperatures are marked on the temperature axis: Tgel, the transition of the completely unreacted thermoset of the fully cured network; Tg, the temperature at which gelation and vitrification coincide; and Tgc, the glass transition temperature of the fully cured network. At temperatures below Tgel, reaction is therefore slow to occur and takes place in the glassy state. At temperatures between Tg and Tgc, the gelation precedes vitrification, then to a cross-linked rubbery network forms and finally to a glass. With increasing cure the Tg of the network increase continuously, that is, increasing crosslink density, to Tg. Above Tgel the network remains in the rubbery state after gelation, can occur a thermal degradation or oxidative cross-linking. The network degradation can occur and the properties altered [5].

Principles of a novel method of Tg measurements

Tg is measured by registering the damping of the specimen as a function of temperature. Tg is obtained by determining the temperature at which the peak value of damping is observed. The heating rate should be such as to ensure a homogeneous temperature distribution in the specimen. However, it cannot be too great not to cause a post-cure in the specimen.

Experimental results

The specimens are formed by the layers of the beam, adhesive and the sheet and are adhered together using the adhesive to be tested. The Tg was measured during the heating and cooling stages.

Experimental details

Adhesive and cure process

Three epoxy adhesives with different values of Tg were selected, the Araldite® 2011, the Araldite® AV 138M / HV 998, and Sikadur®-30 LP.

- Adhesive AV 138M / HV 998: for the adhesive Araldite® AV 138M / HV 998, the best performance (highest strength and stiffness), and Sikadur®-30 LP achieved, there is an opposite behaviour, i.e. the strength and stiffness decrease as the cure temperature increases.
- For the adhesive Sikadur®-30 LP, the best performance (highest strength and stiffness), and Sikadur®-30 LP achieved, there is an opposite behaviour, i.e. the strength and stiffness decrease as the cure temperature decreases.

- Tensile test

Conclusions

In this study, the Tg and mechanical properties were measured for three epoxy adhesives (Araldite® 2011, Araldite® AV 138M / HV 998 and Sikadur®-30 LP) as a function of the curing temperature. The following conclusions can be drawn:

1. When below the Tgel, at which the Tg is achieved, there is an opposite behaviour, i.e. the strength and stiffness decrease as the cure temperature increases.
2. For the adhesive Araldite® 2011 the greater strength and stiffness is obtained for the curing temperature of 40 °C and Tg is obtained for a curing temperature of 60 °C, then it can be concluded that the curing temperature to obtain the best performance (highest strength and stiffness), and Tg is achieved for a cure temperature of between 40 and 60 °C.
3. For the adhesive Araldite®-30 LP, the best performance (highest strength and stiffness), and Tg is achieved for a cure temperature of 100 °C.
4. For the adhesive Sikadur®-30 LP, the best performance (highest strength and stiffness), and Tg is achieved for a cure temperature greater than 120 °C.
5. Tgel and the mechanical properties, as expected, have a similar behaviour.

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References