Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 2 (2016) 269–276

Structural Integrity Procedia

www.elsevier.com/locate/procedia

21st European Conference on Fracture, ECF21, 20-24 June 2016, Catania, Italy

Double cantilever beam tests on a viscoelastic adhesive: effects of the loading rate

Nicolas Aurore[a]*, Jumel Julien[a]

[a] *Univ. Bordeaux, I2M, UMR 5295, F-33400 Talence, France*

Abstract

Adhesive bonding technology is a promising alternative to traditional joining techniques. Indeed, bonded joint shows higher strength and fatigue life than bolted or riveted joints having identical weight. However, bonded joints are sometime reputed to be little reliable since significant dispersion could be observed while measuring their strength but also due to strong sensitivity to adhesion defect and poor surface preparation. Damage tolerance philosophy is now recommended for more reliable design of critical bonded parts by precise prediction of decohesion initiation and propagation along the bondline.

Double cantilever beam (DCB) test is the most popular method to characterize the decohesion resistance of bonded interface by measuring their fracture energy or their R-curve in case significant nonlinear behaviour is observed. These past years, several efficient analysis techniques have been proposed to evaluate the fracture energy but also some optimization techniques to identify more complex interface behaviour. However, most of these techniques consider non time dependent behaviour while thermoset adhesives are known to be viscoelastic and in some condition can also show viscoplastic behaviour. Such effects are important to evaluate when bonded joint sustain stationary loads since they could lead to delayed fracture and slow crack growth.

In the present work, we evidence some strain rate sensitivity at the bondline scale by performing DCB test under different opening rate conditions. At first, the viscoelastic behaviour of the adhesive is studied by performing creep test in a Dynamic Mechanical Analyser. The DCB tests results are interpreted with several methods including the Simple Beam Theory. It is shown that fracture energy is not an appropriate quantity to evaluate the crack propagation condition.

Peer-review under responsibility of the Scientific Committee of ECF21.

Keywords: Viscoelastic behaviour; Double Cantilever Beam

* *E-mail address:* aurore.nicolas@u-bordeaux.fr

Copyright © 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer review under responsibility of the Scientific Committee of ECF21.
10.1016/j.prostr.2016.06.035

Introduction

Double Cantilever Beam (DCB) test is the most common test used to determine the fracture toughness of adhesive bonds since the 1960s and the work of Ripling et Mostovoy (1964). Its testing procedure has been approve by a large majority due to its easily manufactured specimens and a simple standardised analysis (ASTM D3433) as can be seen in the work of Blackman and Kinloch (2000 and 2001) and Salem et al. (2013 and 2014). The sample consists of two flexible adherends bonded along part of their length. During Double Cantilever Beam test a force is applied normally to the bond surface at one end of each adherend. The fracture toughness of the specimen Gc can then be calculated using Simple Beam Theory (SBT) after evaluation of the joint's compliance. However this theory, though used on most on the employed adhesive, is restricted to those exhibiting linear elastic behavior (Irwin and Kies, 1952). Indeed in the case of viscoelastic adhesive, such as the own studied in this paper, time dependent damage will laid to a delayed fracture nucleation, mechanism very different from the one described in SBT.

Due to its large range of use, many studies have been performed on DCB tests over the year, still the effect of loading rate on the behaviour of the bond remains a seldom investigated field. Needleman and Rosakis (1999) have shown that loading rate has an unneglectable effect on crack initiation and the maximum stress supported by the bond and a few papers have shown inside on the influence of a high loading rate on the fracture of the joint, the first effect being a non-stable crack growth (Blackman et al.,1995, 2009, 2011).Those studies took an interest on the variation of Gc with loading rate, evidencing a drastic loss of fracture energy at high strain rate.

1. Experimental aspects

The experimental part of this study is divided into two parts: characterization of the bulk adhesive through DMA (Dynamic Mechanical Analysis) and creep tests and study of the crack propagation in adhesive joints through DCB (Double Cantilever Beam) tests.

1.1. Bulk adhesive and creep tests

The SW2216 – 3M© adhesive studied here is a two components epoxy paste used in aerospace applications. Resin and hardener are mixed and deposited on the adherends following supplier recommendations by using a SEMCO® 250-A pneumatic gun. Crosslinking is effected at room temperature (ca. 23°C) during five days, then a postcure is performed by heating the specimen during an hour at 66°C. Two millimeters thick dogbone samples (ISO 527-2/B) were obtained by applying pressure (2 bar) during crosslinking to the resin placed in a PTFE mold lying between two aluminum plates.

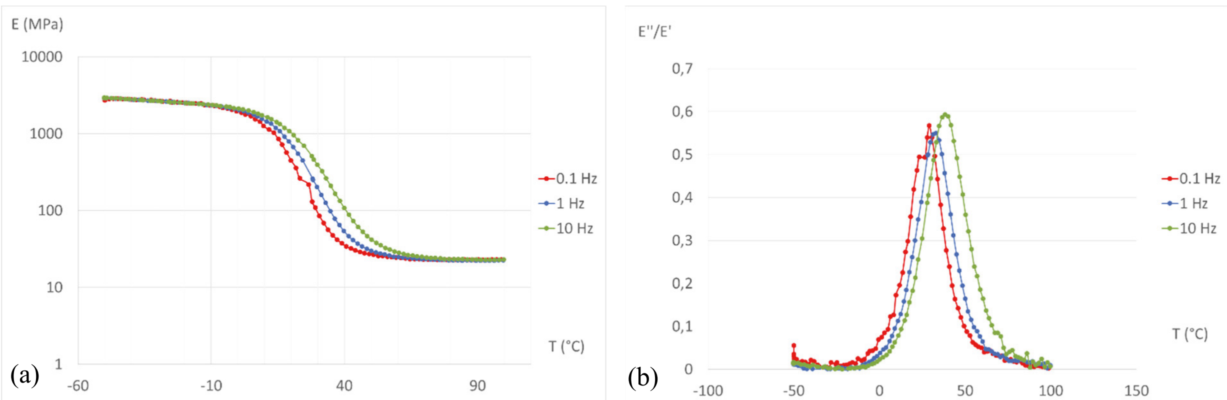

Fig. 1. DMA results for Young modulus (a) and loss factor (b)