Composites Part B 91 (2016) 337–345

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Assessment of the effect of defects on mechanical properties of adhesive bonded joints by using non destructive methods

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ARTICLE INFO

Article history:
Received 6 November 2015
Received in revised form
21 January 2016
Accepted 27 January 2016
Available online 9 February 2016

Keywords:
Lock-in thermography
D. Ultrasonics
B. Defects
B. Mechanical properties
A. Glass fibres

ABSTRACT

Mechanical performance of the adhesive joints depends on many parameters including width, depth and continuity of the adhesive layer applied. In this work, lock-in thermography and ultrasound methods were used to detect the dimension of defects of adhesive joints while tensile tests were carried out to assess their strength and stiffness. Both the effect of bond defects and the possibility to use non destructive method for the prediction of strength and stiffness of joints have been discussed considering a statistical analysis of data. Models, useful for predicting mechanical behavior of joints on the basis of their defects, have been developed.

1. Introduction

Advanced composite materials are widely used in high technology structures because of their high performance in terms of high moduli, high corrosion, fatigue and tensile resistance, and low weight [1]. But almost every designed structure requires component members to be connected. Adhesive bonding is a joining method with high potential which has been reviewed in detail [2]. With new composite materials being introduced in the market, adhesives become the number one choice to joint composite structures [3,4]. An adhesive joint is an optimal type of joining composite materials as it allows a uniform load distributing over a larger area than other methods of joining, requires no holes, adds very little weight to the structure and has superior mechanical resistance. Mechanical performance of the adhesive joints depends on many parameters including width, depth and continuity of the adhesive layer applied [5].

Although adhesively bonded joints have many advantages over other structural joining methods, mainly related to their efficient load transfer in thin components and structural repairs, their general application has suffered due to the difficulty in inspecting bondline quality following manufacture and in-service life [6] and sensitivity of bondline integrity to environmental attack and physico-chemical conditions of the substrates. In this regard, different works in literature deal with the adhesive joint behavior under static loading and dynamic ones by means of numerical and experimental approaches [7,8]. In particular, in his work Ascione [9] showed the numerical results about the influence of an adhesion defect on the ultimate capacity of an adhesive double lap joint.

Complete voids, disbonds and porosity are the simplest forms of defect to detect non-destructively and the majority of non-destructive testing performed on bonded structures aims to detect such defects [10].

Hart-Smith [11], discussed the effects of any flaws and porosity on the shear load transfer for both thin and thick adherends. A significant effect of bond defects is obtained in the case that the dimension of defect is large enough to alter the distribution of the load transfer through the bond and if it is located at the ends of the overlap. Thus, the importance of non-destructive characterization (NDE) of composites and their structures grows with the increasing use of these materials and it is necessary to ensure industry

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http://dx.doi.org/10.1016/j.compositesb.2016.01.059
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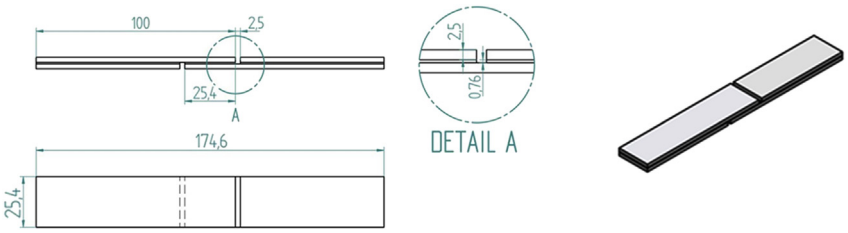

Fig. 1. Planar and three-dimensional geometry of the joints.

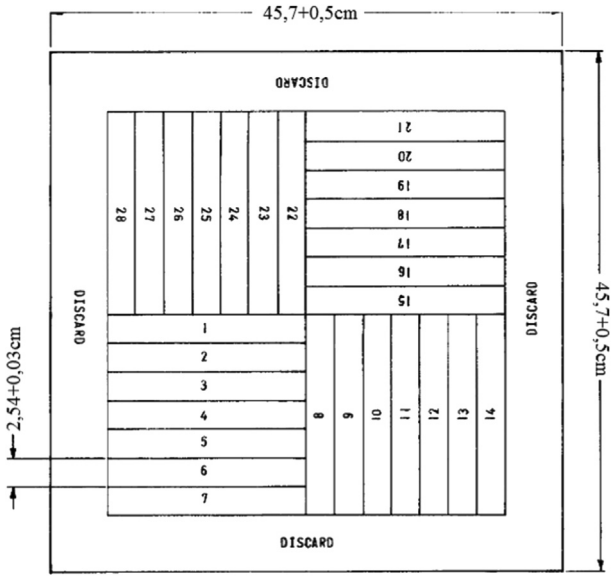

Fig. 2. Geometry of the panel according to ASTM D 3165.

requirements for safety and reliability of materials and their structures.

During the production phase, and also in service with critical structures, it is essential to use non-destructive tests to assess the quality and fitness for the purpose of the product. The non-destructive test does not measure strength directly but measures a parameter which can be correlated to strength. It is, therefore, essential that a suitable non-destructive test is chosen and that its results are correctly interpreted. The objective of any form of non-destructive test is to correlate the joint strength with some physical, chemical or other parameter that can be measured without causing damage.

Acoustic imaging methods and thermography are some of the diffused choices among non-destructive techniques as they allow not only to detect the presence of defects but also to characterize them in terms of size, shape, and location [5,12–18].

In this paper, the effect of bond defects on mechanical properties of adhesive bonded joints were evaluated in terms of strength and stiffness. In particular, both destructive and non destructive tests were carried out on adhesive joints designed according to ASTM D 3165. Lock-in thermography and ultrasound methods were used to assess the dimension of defects while tensile tests were carried out to assess their strength and stiffness. Both the effect of bond defects and the possibility to use non destructive method for the prediction of strength and stiffness of joints have discussed considering a statistical analysis of data.

2. Experimental materials and methods

2.1. Specimens

Single lap adhesive joints have been prepared according to ASTM D 3165 using glass fiber reinforced thermosetting plastic (vinyl ester GFRP) substrate and a two part epoxy adhesive: AME6000 INF (Ashland Composite Polymers) and ADH 90.91 (Altana Electrical Insulation) [10]. Adherends are characterized by

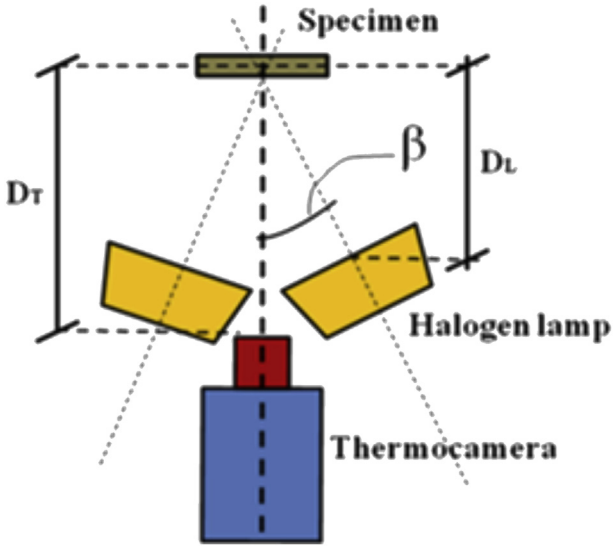

Fig. 3. Schematic set-up used for lock-in thermography ($\beta = 30°$, $DT = 30$ cm, $DL = 20$ cm).

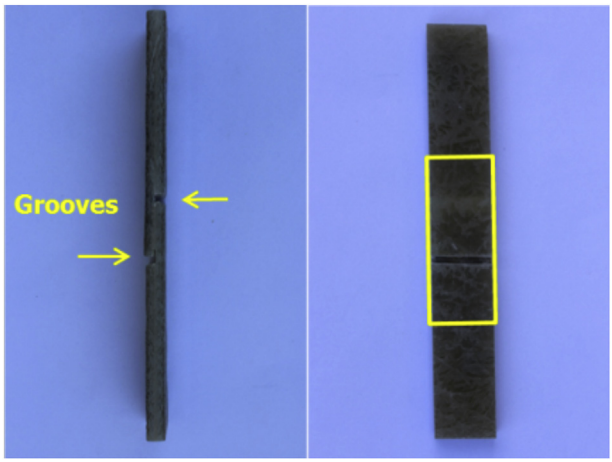

Fig. 4. Investigated area by non-destructive methods.