NDT&E International 85 (2017) 27–33

Contents lists available at ScienceDirect

NDT&E International

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

Bonded repair issues for composites: An investigation approach based on infrared thermography

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ARTICLE INFO

Keywords:
Composite repair
Experimental procedure
Infrared thermography
Heat transfer
Numerical model

ABSTRACT

An original approach based on active Infrared Thermography (IT) addresses the very challenging issue of the nondestructive analysis of bonded repaired CFRP laminates. Difficulties come from the weak property contrast between parts of repaired assemblies and thickness of the joint. Strong attention is given here to the control of experimental tests conditions (heat load, boundary conditions), which allows to develop a physically consistent numerical model of the thermal problem. Comparison between measured and simulated surface temperature fields shows very good agreement regarding temporal and spatial evolutions for composites with different lay-up and offers new solutions for the NonDestructive Testing (NDT) of bonded repaired composites.

1. Introduction

Design of modern aircraft structures is mainly based on the use of large and noneasily dismantled composite parts. One of the main challenges for aeronautics stands thus in finding relevant and efficient solutions for their structural repair to account for local damages that may be induced in service (bird or vehicle collisions, impacts during plane loading/unloading or maintenance operations,..). This question is specially difficult to address in the context of CFRP with complex and anisotropic mechanical behavior, but raises for a few years now a growing interest in view of economic issues [1].

The repair purpose is to restore structural properties and strength of the original design. Today, doublers-based solutions using mechanically fastened extra layers of reinforcement are the most conventional techniques for primary structures since they ensure redundancy in structural elements. Yet, it is to note that such process often leads to the creation of new damages during drilling and bolting/riveting phase [2] and, in all cases, leads to extra weight for the repaired structure since the patch dimensions (thickness and surface) may be significant compared to the damage extent. For adhesively bonded repair however, the removed damaged volume is reconstructed by bonding a patch of same material as original on the parent one. This reduces additional weight and tends to preserve the original aerodynamic profile (flush surface), which is of great interest for the repair of external skin panels for instance [3,4]. In case of laminates, such repair procedure achieves also significatively the load transfer within the repaired area, providing a uniform shear dominant stress state and minimizing peel stresses in the adhesive layer [5,6].

For bonded repairs, adhesive bonding of the parent and repair materials requires most attention. The bond strength depends on several factors (type of adhesive, surface aspect, joint design, curing conditions,…) and, above all, is extremely sensitive to the existence of defects (porosity, kiss-bonding, delamination) inside the glue joint. In order to contribute to the reliability assessment of such repair technique, this work intends to provide a nondestructive approach based on active InfraRed Thermography (IRT) able to capture information on bonded joints of repaired primary structures. Precisely, IRT is an optical measurement technique of surface thermal fields usually used for the investigation of structural health (conventional NDT) or damage monitoring in aircraft structures [7,8]. In the active configuration, the acquisition of infrared radiation emitted at the part surface and induced by an excitation source (such as ultrasonic waves [9], electromagnetic fields [10], vibrations [11] and, most often, light source [12,13]) allows to identify defects inside materials. It is to note

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http://dx.doi.org/10.1016/j.ndteint.2016.10.003
Received 19 May 2016; Received in revised form 12 October 2016; Accepted 14 October 2016
Available online 15 October 2016
0963-8695/

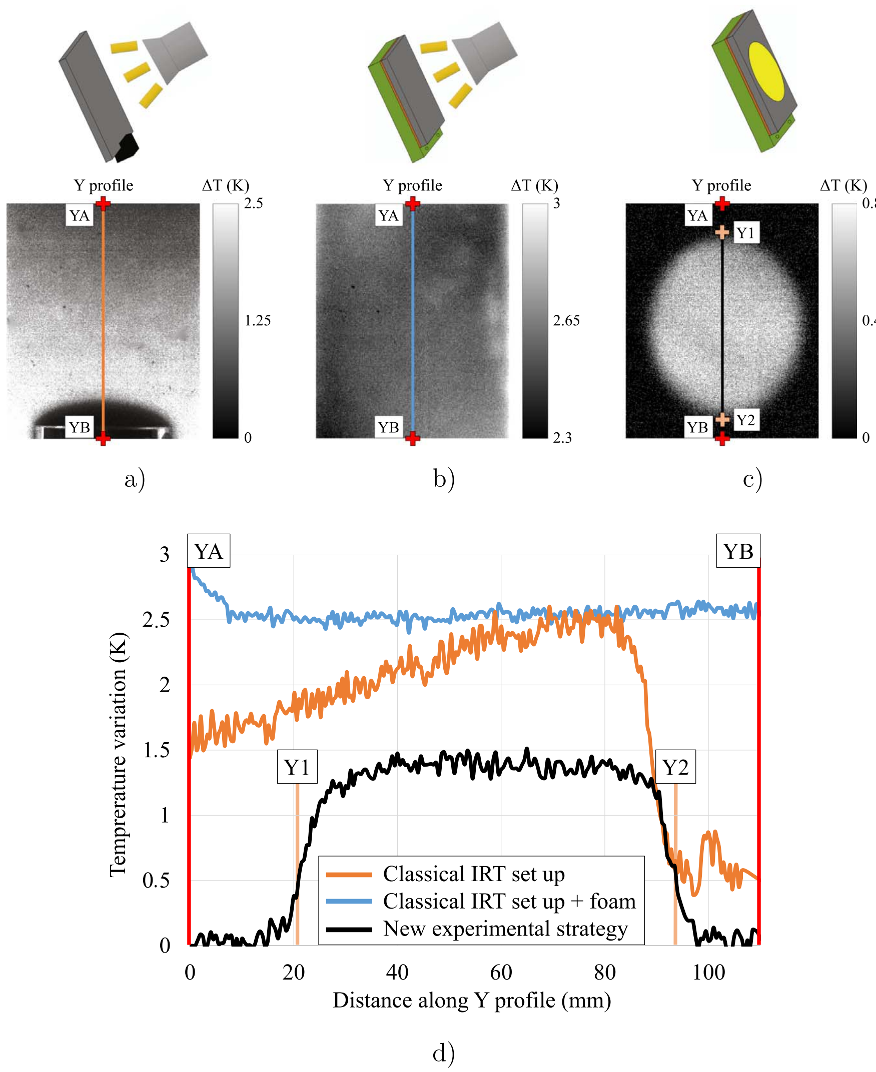

Fig. 1. Surface temperature variation ΔT for an Inconel material: conventional device (a), insulated sample (b) and new procedure (c). Thermal fields (a,b,c) and Y temperature profiles (d) at t=12 s (step heat load begins at t=2 s). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

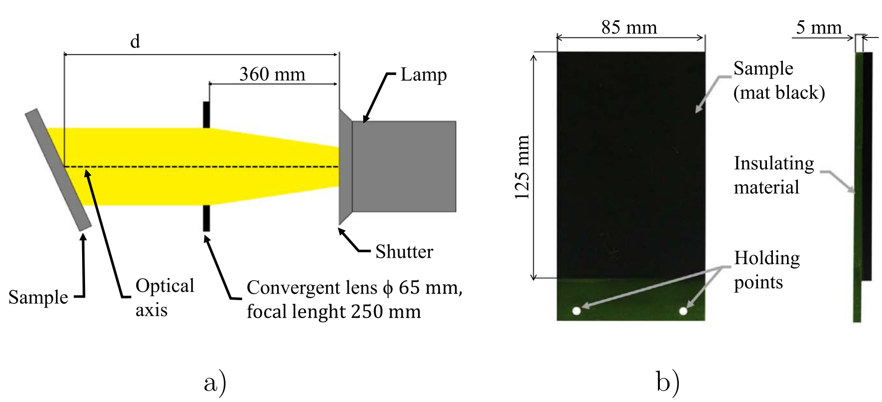

Fig. 2. Optical system (a) and sample insulation on back-side (b).

that some post-processing of derived thermal fields may be necessary to reveal and localize more precisely these heterogeneities [10,14,15].

Regarding applications in the repair context, active IRT usually focusses on the detection of artificial defects introduced within the glue joint: Teflon inserts to simulate delaminations and disbondings [16–18], grease mould release to represent kiss-bonding or dry fibers to account for porosities [19]. IRT is less common in the repair field. The detection capacity of this technique is essentially related to a high property contrast – and thus gap in thermal response – between different parts of the repaired assembly. That is why existing works often deal with optimal configurations such as composite patch pasted on metallic [16,17] or concrete parent structure [18,20], or association of parent and patch made of different composites [21].

The configuration considered in this study corresponds to the industrial context of repaired aircraft primary structures, namely of carbon-epoxy composites (parent and patch) bonded by an epoxy glue.