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Optimization of thermal joint behaviour for the detection of bonding defects by infrared thermography

M. Barus^a, H. Weleman^a, V. Nassiet^a, M.L. Pastor^b, A. Cantarel^b, F. Collombet^c, L. Crouzeix^c, J.C. Batsale^d

^a Laboratoire Génie de Production (LGP), INP-ENIT, Univ. de Toulouse, Tarbes, France

^b Institut Clément Ader (ICA), Univ. de Toulouse, UMR-CNRS 5312, UT3, IUT de Tarbes, France

^c Institut Clément Ader (ICA), Univ. de Toulouse, UMR-CNRS 5312, UT3, Toulouse, France

^d I2M, Arts et Métiers ParisTech, Département TREFLE, UMR-CNRS 5295, Bordeaux, France

Abstract — Since many years, the repair of primary aircraft structures constitutes one of the main challenges for the aviation industry. To address such issue, the use of bonded solutions seems particularly interesting. Indeed, this process leads to a more regular diffusion of the stresses (than the riveted solution) inside the repaired assembly and allows to preserve the aerodynamic profile [1]. Despite numerous studies, this technique yet remains uncertified due to the lack of redundancy of the repair elements and to the difficulties encountered to evaluate the structural health of the joint. In the particular case of Carbon Fibers Reinforced Plastics (CFRP) widely used in the aeronautical field, several Non-Destructive Testing (NDT) methods are not able to detect internal bonding defects. Specially, the weak thermal contrast between the properties of the constitutive parts of the repair and, above all, the small thickness of the epoxy joint and the depth of the bonded interface represent strong issues for such investigation (Fig. 1).

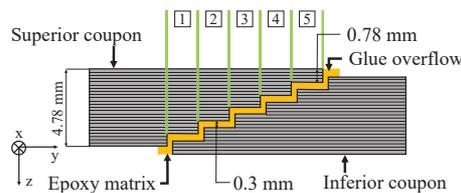
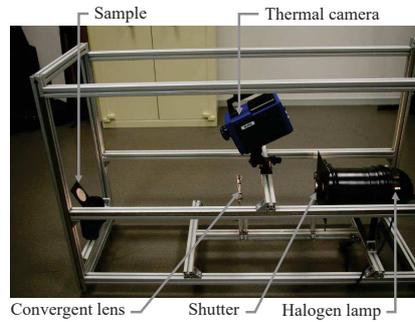


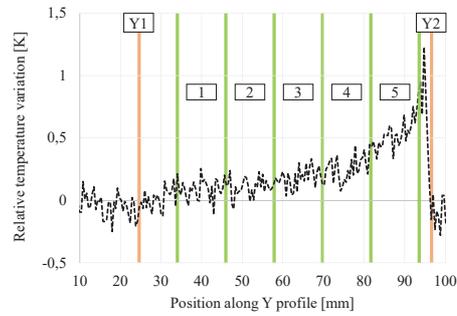
Figure 1: Schematic representation of the lateral view of the step lap repaired assembly.

Even if ultrasonic methods are for now the most commonly used in the aviation industry, Infrared Thermography (IRT) appears to be a new attractive solution that offers the possibility to analyze large areas without contact. In the way to answer to industrial constraints, authors have recently proposed an easy handling and data processing NDT method. This procedure [2], based on a step heating approach combined with an important control of boundary conditions (Fig. 2-a), has allowed to improve the detection of bonded interfaces inside CFRP repaired assemblies. Thereby, it is now possible to distinguish the specific response of an epoxy joint at a depth of 2.4 mm within the laminate through the study of the thermal contrast (Fig. 2-b).

Even with this new improved IRT procedure, the detection of a bonding defect is still very difficult due to the very low thermal gradients between the different parts of the assembly. To overcome such difficulty, an interesting solution consists in designing the joint material in view of non destructive thermal inspection. The strategy proposed in this paper is thus to enhance the thermal gradients between bonded parts and their defects by modifying the thermal properties of the epoxy joint. The influence of the glue joint thermal behaviour (insulating or conductive) was first simulated using the numerical model developed in [2]. It appears that the use of a conductive joint increases the thermal contrast between the joint and a bonded defect and thus improves its detection. Next, boron nitride was numerically identified as a relevant additive to enhance the thermal conductivity of the epoxy joint. Experimental tests representative of the industrial context were finally conducted on defective assemblies and validated the ability to capture internal bonding defects (Fig. 3). In addition to the optimization of the glue joint thermal behaviour, a data processing based on the Singular Values Decomposition (SVD) method was



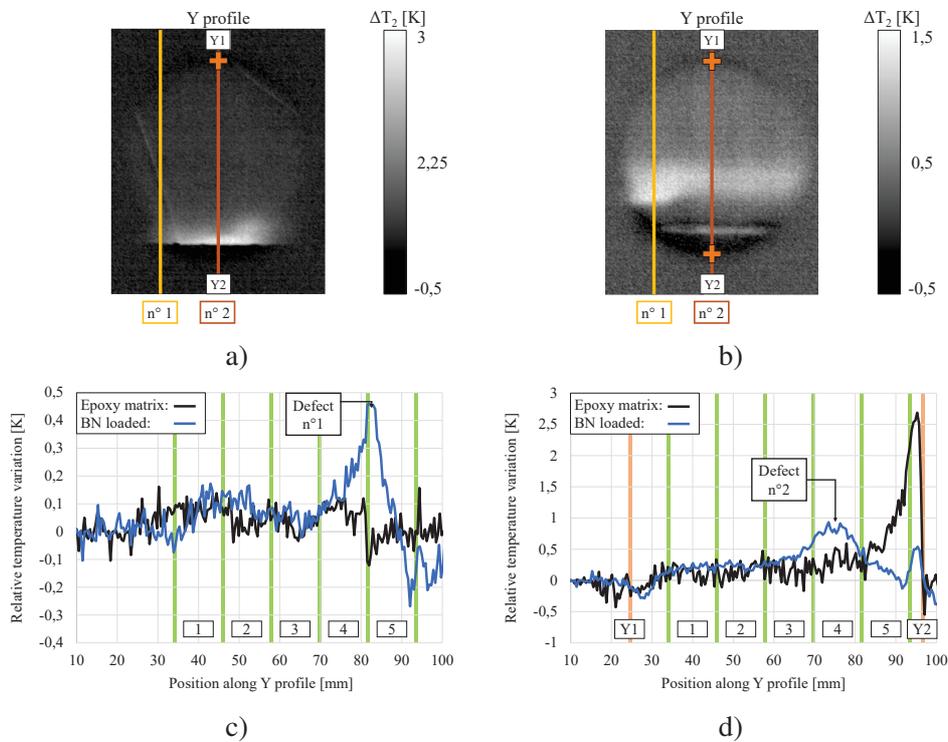
a)



b)

Figure 2: New IRT procedure: active IRT thermal bench (a), Specific thermal response of the epoxy joint at the end of the heating phase (b).

used to reduce the measurement noise and improve even more the interpretation of experimental results. Further works are now being conducted in order to study the influence of boron nitride additives on the mechanical strength of the repaired assemblies.



a)

b)

c)

d)

Figure 3: Specific thermal response of the epoxy joint for defective bonded assemblies: thermal fields for epoxy matrix (a) thermal fields for boron nitrite loaded epoxy matrix (b), relative temperature evolution along yellow profile (passing through defect n°1 at a depth of 0.78 mm) (c), and along orange Y profile (passing through defect n°2 at a depth of 1.56 mm) (d).

Keywords — Polymer-matrix composites, thermal properties, numerical analysis, thermal analysis

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