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NON DESTRUCTIVE TESTING OF ARTIFICIAL DEFECTS IN COMPOSITE STRUCTURES BY THERMAL FULL FIELD MEASUREMENT METHODS

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ABSTRACT: This work is about a comparison of three different thermal full field measurement methods.

In order to achieve outstanding performance, it now seeks to optimize more and more the design and process of composite structures. These developments require steady and reliable technical inspections to assess the structural health of mechanical parts. For many industrial applications, non destructive techniques (NDT) offer an interesting and appropriate tool for such analysis, from manufacturing to service conditions.

Considering aviation industry, the AITM standards are based on the NDT ultrasonic testing for the certification of composite structures. However, such technique is very restrictive in terms of transducers, testing conditions and inspected part shape (local measurement technique). Accordingly, thermal full field measurement methods based on Infrared Thermography have been more widely used in recent years for structural investigation: global inspection (2D mapping in one shot (Fig 2), fast execution and analysis are significant benefits of these techniques [1].

This work intends to characterize and to compare three different IR thermographic techniques on two laminates (carbon-epoxy) and two sandwichs (carbon-glass-epoxy and carbon-epoxy with foam-core) composite specimens (Fig. 1). In addition, a carbon-epoxy composite structure, composed of two monolithic parts and a sandwich part, is also studied (Fig.1).

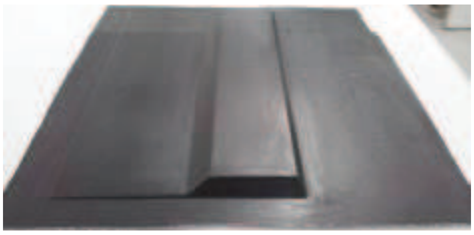
Even if there are generally more suitable for ultrasonic inspection, artificial defects conventionally used in aviation have been performed in these samples to identify the detection limit of the different NDT thermal techniques implemented in this study. Precisely, small flat discs with different diameters (from 15 mm to 2 mm diameter) have been realized (flat-bottomed holes simulating porosities) or/and inserted (Teflon inserts simulating delamination) at various depths of each specimen.

1- Carbon-epoxy laminated composite with flat-bottomed holes defects

2- Carbon-epoxy laminated composite including Teflon insert defects

3- Carbon-glass-epoxy sandwich composite including Teflon insert defects

4- Carbon-epoxy sandwich composite including Teflon insert defects



5- Carbon-epoxy composite structure including Teflon insert defects

Figure 1: Multi-layered and sandwich composite specimens

Three thermographic methods have been used, that differ in the nature of the stimulation signal:

- ✓ **IR thermography (IRT)**: the specimen is stimulated by a heat flow whose distribution can be considered as square pulse stimulation [2] ; this technique leads to a 2D amplitude map (Fig. 2),
- ✓ **Lock-in IR thermography (LIRT)**: lock-in system is associated to a heat flow; accordingly, the thermal stimulating process exhibits a sinusoidal form, whose wave frequency depends on the specimen thickness [3]; such approach allows to obtain two 2D maps, one corresponding to the amplitude and the other to the phase (Fig. 3),

- ✓ **Pulse IR thermography (PIRT)**: a Dirac pulse heat stimulation is used in this case [4] and a 2D amplitude map similar to the first method is obtained (Fig. 4).

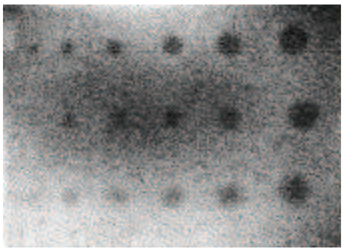


Figure 2: 2D amplitude map of IRT

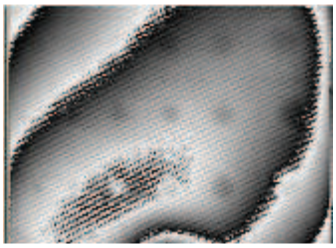


Figure 3: 2D phase (left) and amplitude (right) maps of LIRT

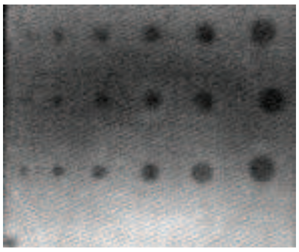


Figure 4: 2D amplitude map of PIRT

These three techniques can be used either in transmission setup (halogen lamp is on the opposite side of the camera) or in reflection setup (halogen lamp and camera on the same side) [2, 5]. For each method, the test procedure consists in acquiring a film of the response of the specimen induced by the thermal stimulation. The analysis of temperature map allows identifying the internal defects within the composite material.

Considering the evaluation and comparison of the capabilities of the thermal measurement techniques, a specific attention has been given to the two following points:

- ✓ the defect detection limit, that is the smallest diameter that can be detected, in order to know the equipment limits ; precisely, a special focus is put on the critical defect size determined by aviation rules (defect of 6 mm diameter),
- ✓ the specific application fields for each technique (kind of defects, specimen shapes, results expected).

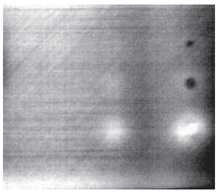
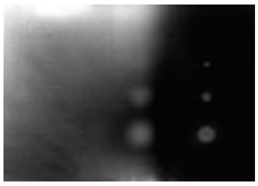
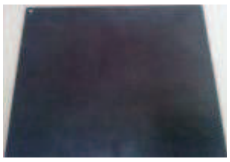
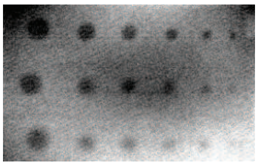
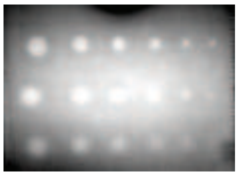
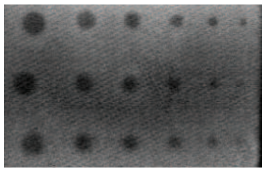
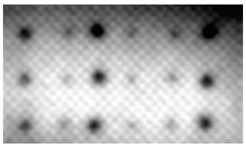
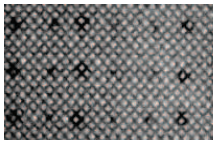
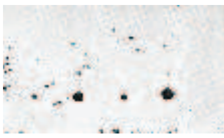
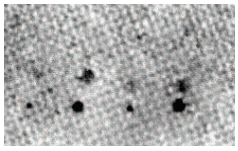
At first, a qualitative analysis has been carried out. For simplicity reasons, results are presented for the four mono-material samples whose study can be done in one shot because of their size. Globally, the three techniques lead to similar results (see table 1). Yet, maps obtained with the LIRT are less noisy than the other two methods. Indeed, this measurement technique is more efficient since the phase map exhibits a more important contrast. On the other hand, one notes that PIRT gives complementary results to the LIRT, mainly for the sandwich structure.

Regarding quantitative aspects, the analysis will be done for each kind of composite structure (laminated or sandwich) taking into account the five specimen. Two criteria have been chosen to compare the techniques:

- ✓ the number of defects detected,
- ✓ the detection precision, expressed through the gap between the diameter detected and the dimension of the artificial defect; figure 5 illustrates such results for laminated materials.

Accordingly, some guidelines can be provided to assist the investigation of composite structures in choosing one or the other thermographic techniques.

Table 1. Comparison between the three different full-field measurement NDT results

Specimens	IRT	LIRT	PIRT
1- 			
2- 			
3- 			
4- 			

REFERENCES

1. Meola C., Carlomagno G. M., Squillace A., Vitiello A. (2006) Non-destructive evaluation of aerospace materials with lock-in thermography, *Engineering Failure Analysis* 13, 380–388.

2. Péronnet E., Eyma F., Welemane H. and Mistou S. (2012) Characterization and Comparison of Defects Detection Limits of Ultrasonic Non Destructive Techniques, *Key Engineering Materials*, 498, 79-88.

3. Choi M., Kang K., Park J., Kim W., Kim K. (2008) Quantitative determination of a subsurface defect of reference specimen by lock-in infrared thermography, *NDT&E International* 41, 119–124.

4. Ibarra Castanedo, C. (2005) *Quantitative subsurface defect evaluation by pulsed phase thermography : depth retrieval with the phase*, LAVAL University , QUEBEC.

5. Dattoma V., Marcuccio R., Pappalettere C., Smith G. M. (2001) Thermographic investigation of sandwich structure made of composite material, *NDT&E International* 34, 515-520.