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Contribution of IR thermography to assess lightning-strike impact resistance of carbon fiber composite materials

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Abstract

The resistance of carbon fiber composite materials to low-velocity mechanical impact damage has been studied in numerous works. It has been shown that both matrix, whether thermoset or thermoplastic, and architecture, laminate or woven, have substantial effects on the composite resistance. The stake of the present paper is to investigate how those observations can be transposed to lightning-strike impacts. To that end, several types of carbon fiber composites are submitted to lightning arcs and active infrared thermography is then used as a non-destructive evaluation tool to assess the resulting damage.

1. Introduction

The average frequency of lightning strike for an airliner is estimated to once every 1,500 hours of flight. While composite structures are more and more commonly used in aircrafts, for global weight reduction purposes, their resistance to lightning strikes has then become a major stake for the aeronautic industry. Several solutions are still being under study, such as the introduction of protection layers in aluminium or copper foils.

In the past few years, several ONERA research teams have been working on the improvement of the understanding of the damage generated by lightning arcs in composite materials, both on the generation of such arcs and their interaction with structures [1] and on their non-destructive evaluation [2].

In this paper, several carbon fiber composite coupons are considered in order to study the influence of the resin, whether thermoset (epoxy) or thermoplastic (PEAK) and of the architecture, whether laminated or woven. Similar lightning-strike tests are performed and then non-destructive inspections are carried out by infrared pulse thermography. Conclusions are then drawn as for the nature and extension of the induced damage in every studied configuration.

2. Experimental setup

Composite structures are 400×400 mm² coupons, painted and protected by aluminium foil layers. Their thickness is equal to 2.4 mm, which is either associated with 8 plies for the laminate coupons or with 3 plies for the woven ones. Two different resins are studied: an epoxy thermoset one and a PEAK thermoplastic one.

As illustrated by Fig. 1, two experimental benches are used for this study: the lightning-strike impacts are applied to the composite coupons in the "GRIFON" bench which has been developed in ONERA to deliver lightning D-waveforms of various current levels; the non-destructive evaluations are carried out in the ONERA pulse thermography facility. A mid-wave infrared camera (X6540sc series) is used, with a frame rate of 100 images per second and a recording duration of 60 s, which are standard parameters for carbon fiber composites of such thickness. Raw data is then processed through the Thermographic Signal Reconstruction (TSR) procedure [3].

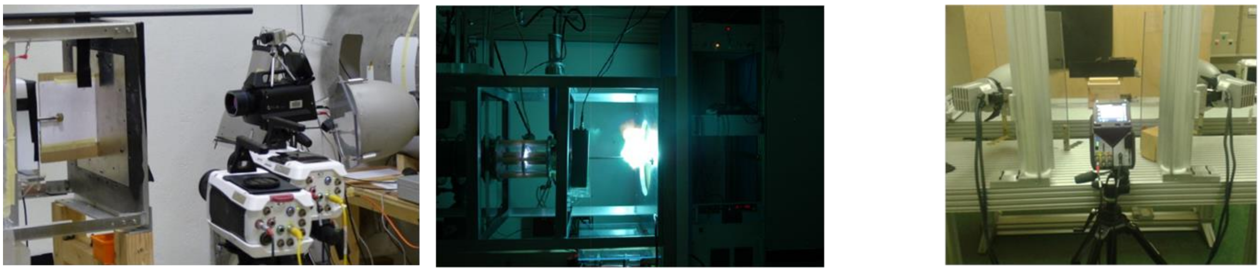

Fig. 1. *ONERA "GRIFON" bench dedicated to the generation of lightning arcs (left) and active IR thermography facility dedicated to non-destructive testing (right).*

3. Damage assessment by pulse thermography non-destructive inspections

Both faces are inspected by pulse thermography: the impacted face and the rear-face. Figure 2 shows that a helical-like damage pattern is observed for the laminate composite whereas a more local damage pattern is observed for the woven composite. In the first configuration, the major damage that occurs is a succession of delaminated areas between plies at different depths; in the second configuration, only one delamination is generated by the lightning strike. Such results are in good agreement with previous works [4] and seem similar to the damage patterns induced by low-velocity mechanical impacts.

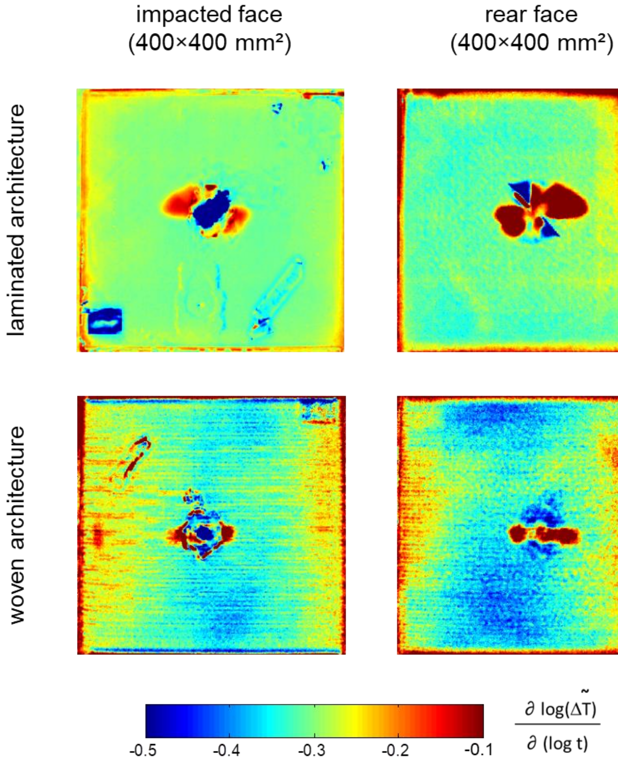

Fig. 2. *Comparison between the damage patterns of 2.4mm-thick laminate (top) and woven (bottom) composite coupons, submitted to the same electric arc. First logarithmic derivative fitted temperature variation for both impacted (left) and rear (right) faces of the coupons.*

In the full paper, further analyses will be detailed and similar damage maps will be provided for thermoplastic composite coupons.

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