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Thermography of ballistically impacted curved thermoplastic composite laminate

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Abstract

The purpose of this project seeks to characterize by thermography the damage caused to curved sheets of laminates made with a thermoplastic matrix of PPS reinforced by carbon fibers, which were previously subjected to repeated thermal shocks and subsequently ballistic impact, simulating the conditions encountered by vehicles if travelling in low Earth orbit.

Keywords: Composite laminate; thermoplastic composite; ballistic impact; thermal cycles; thermography.

Introduction

Polymeric matrix composite laminates reinforced with continuous carbon fibers are widely used in the space, aeronautics, automobile and wind industries, among others, mainly due to their high specific mechanical properties (per unit of mass) and great design flexibility. Aerospace structure components, including satellites (SMAP/NASA, https://smap.jpl.nasa.gov/), employ today composite laminates with carbon fibers reinforcing thermoplastic matrices (eg, polyphenylene sulphide - PPS/FC), which exhibit advantages over traditional thermoset resins (eg, epoxies), such as greater resistance and tolerance to damage, particularly those resulting from impacts, greater ease of fabrication, infinite storage time, weldability and repairability.

Experimental Procedure

The performance of thermal shock and impact tests on curved specimens were designed to represent the conditions that most closely approximate the Earth's orbit environment. In thermal shock cycles, the specimens will be immersed alternately in liquid nitrogen (-200°C) and in boiling water (+100°C). For the transverse ballistic impact, the specimens will be manufactured via a cylindrical projectile with a kinetic energy of 50 J to simulate the impact of micrometeoroids.

Results and Discussion

In a previously performed thermographic analysis, the damage caused to curved sheets of carbon fiber laminates and PPS thermoplastic matrix indicated that by keeping the number of thermal cycles constant, but varying their radius of curvature, the damage to the laminates increases considerably as the radius of curvature decreases, with less average depth of damage and more damaged zones. The increase in tension is proportional to the increase in effort during buckling, causing more damage to occur during the bending of the laminates, and they propagate during thermal shocks, as shown in figure 1.

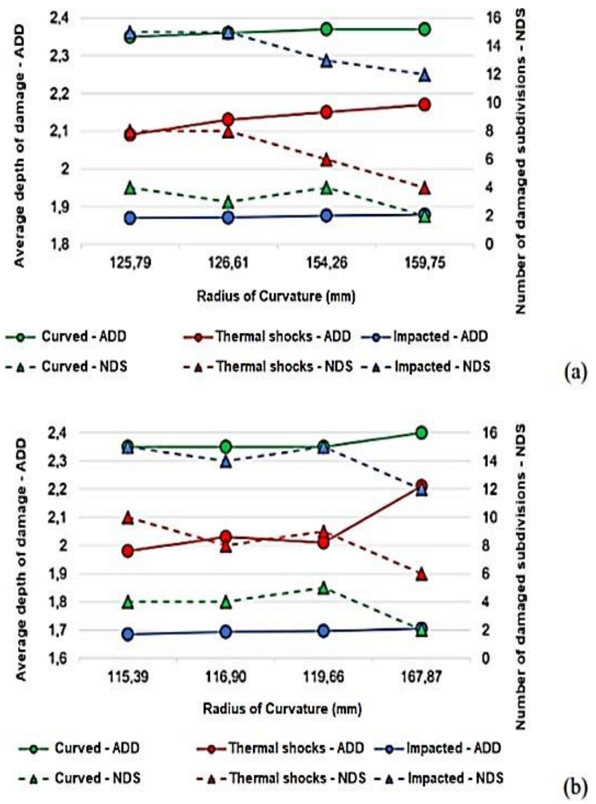

Figure 1 – Average damage depth and number of damaged subdivisions of specimens with (a) 300 cycles, and (b) 500 cycles as a function of their radius of curvature.

Figure 2 shows the results obtained with PT (Pulsed thermography) after image processing by PCT (Principal component thermography). Note that the specimen with 150 thermal shock cycles (Fig.2a) has small cracks spread and delamination; note that these features have intensified as the number of thermal cycles has increased, as shown in Figs. 2(c) and 2(e), respectively.

Conclusions

In this work, specimens were prepared to mimic the conditions found in geostationary satellites were inspected by infrared thermography. Specimens were curved, submitted to different shock cycles (0, 300 and 500), and then impacted. NDT (non-destructive test) results shown with higher number of thermal shocks had more damage after the impact.

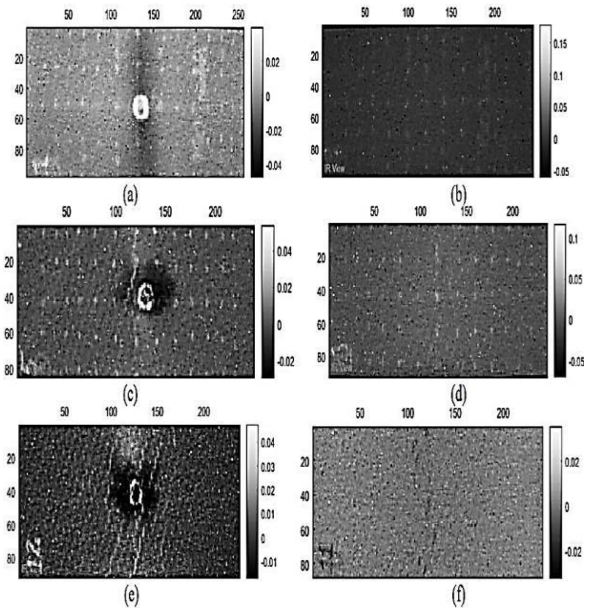

Figure 2 - Qualitative PCT results: (a) sample subjected to 150 thermal cycles and impact, (b) to 150 thermal cycles, (c) to 300 thermal cycles and impact, (d) to 300 thermal cycles, (e) to 500 thermal and impact cycles, (f) to 500 thermal cycles.

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