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Damage Detection using Infrared Thermography in a Carbon-Flax Fiber Hybrid Composite

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Abstract

Hybrid polymer composites are used in many secondary load carrying structures and use of natural fibers for hybridization is one of the options. However, in view of the higher levels of mismatch in strength between synthetic fibers and natural fibers, the failure modes of hybrid natural fiber composites are different. Advanced non-destructive test methods such as infra-red thermography are employed for damage detection. The present paper discusses the detection of damage in hybrid natural fiber composite laminates using active thermography method. Carbon and Flax fiber reinforcements are considered for this study. Specimens of hybrid composites prepared by hand lay-up technique were subjected to impact loading and post-impact fatigue loading to study damage progression through infra-red thermography. The laminates are tested for cooling response under transmission mode and reflection mode of thermal imaging for the test conditions of pristine specimen, impact damaged specimen, and fatigue cycled specimen after impact damage. It is observed that there is a secondary heating of specimens near the impact damaged zone when the active thermography is done in the transmission mode; the de-lamination defect can be more easily detected when the heating is from the damaged side and the measurement is from the opposite side using transmission mode.

Keywords: Infrared Thermography; Damage detection; Cooling response; Hybrid Polymer Composites

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1. Introduction

Up-front detection and consequent prevention of component failure is a crucial demand in the transportation and power sectors. Non-destructive testing (NDT) has emerged as one of the most widely used methods across the industries to detect damage in components without affecting the maintainability or serviceability of the components. Various NDT technologies have been developed to characterize damage and predict failure in components built out of several advanced materials that include polymer composites. Conventionally polymer matrix composites use synthetic fibers, such as, Glass fibers, Carbon fibers, Kevlar fibers; these have high strength and are used in safety critical primary structures such as aircraft structures. However, from the view point of bio-degradability, natural fibers are being considered these days for polymer composite systems. The disadvantage with natural fibers is the lower strength compared to synthetic fibers as well as variability in properties based on the geographical location of sourcing. As recourse, hybridization of fibers is considered as the viable option and the resultant hybrid composite is utilized in many secondary structures. The mechanical properties play an important role while one uses these composite systems. The general failure mechanisms can still be classified as under: fiber failure, matrix failure, de-lamination, de-bonding etc. The hybrid composites are inhomogeneous by nature and are susceptible to inherit defects induced during the processing; hence, exhaustive experimental validation needs to be done on these materials to prevent catastrophic failures. Many of the mechanical property tests are conducted under static conditions, but, they do not reflect the real-time behavior under service conditions, such as fatigue loading, mild impact loading. To overcome this, it is essential to have NDT technologies that can be used to understand the behavior of the materials when they are subjected to in-service loading. Infrared (IR) Thermography technique is one of the most widely used NDT methods to detect failure in materials (Wong et al (1999), Maldague (2001) and Bagavathiappan et al (2013)); the IR technique is in-situ and can be used for online condition monitoring. Infrared thermography works on two basic principles: a) active thermography where the test specimen is heated up (or) thermally activated using an external source and the cooling response is monitored and b) using passive thermal imaging where the heat emitted by a specimen in response to a mechanical loading is monitored.

It is reported in the literature that composites exhibit thermo-mechanical behavior – i.e., application of an external load induces heat in the specimen. Muneer et al (2009) have utilized this to measure the temperature response during tensile loading in a glass fiber reinforced plastic (GFRP) by passive thermography technique and indicated that the temperature response is sensitive to prior damage. Chrysafi et al (2017) have suggested that active thermography is more suited compared to passive thermography for polymer composite specimens. Active thermography using halogen lamp heating has been used to detect the appearance of defects in adhesively bonded joints in a study conducted by Carosena and Giovanni (2010). Harizi et al (2014) have used active thermography and cooling response as a tool to detect the presence of damage in a polymer matrix composite.

For the purpose of active thermography, two types of specimen heating and resultant temperature response are considered: i) heating of the specimen and the temperature measurements are done on the same surface, also referred to as reflection mode, and ii) temperature measurements are carried out on the surface that is opposite to the heating surface, also referred to as transmission mode. Figure 1 presents schematic of the reflection and transmission mode for pristine and impacted specimen respectively.

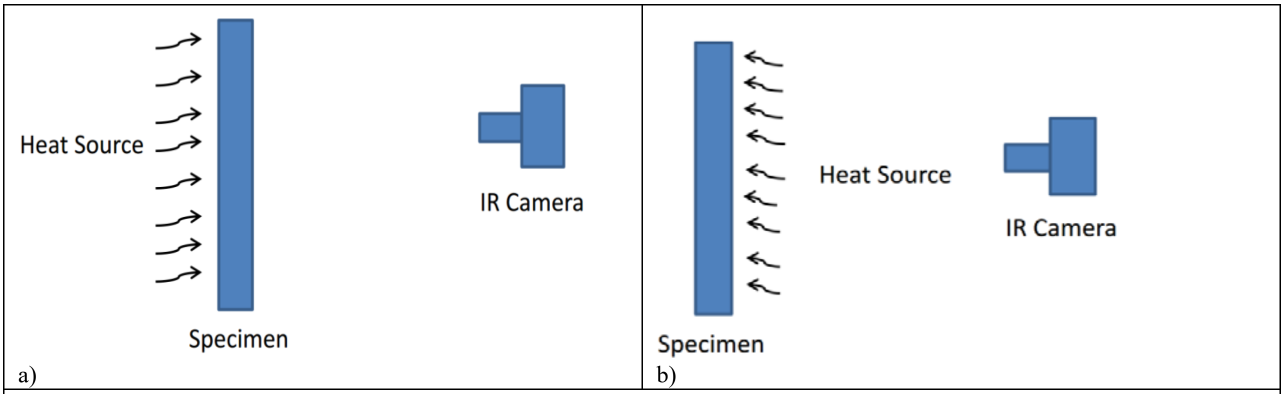

Fig. 1 – Schematic of a) Transmission mode of active thermography and b) reflection mode of active thermography.