Internal damage investigation of the impacted glass/glass + aramid fiber reinforced composites by micro-computerized tomography

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This paper utilizes the micro-computerized tomography as the non-destructive inspection technique to characterize and compare damage modes of glass and glass + aramid fiber reinforced polyester laminated composites. Main goal of this study is to visualize the internal impact damage variation due to reinforcement type by using micro-computerized tomography scanning. Impact tests were performed on glass fiber reinforced and glass fiber + aramid fiber reinforced polyester composites at the same conditions and both composites were tested at 80 J energy. After low velocity impact tests, micro-computerized tomography scans of both composites were taken from SkyScan 1173 system.

1. Introduction

Fiber reinforced polymer–matrix composites are among the most outstanding engineering materials available nowadays. Glass reinforced and glass + aramid fiber reinforced hybrid composites are commonly used as light-weight materials in a wide variety of marine applications including sporting equipment as well as military structures etc. However, the shortcoming of glass-reinforced plastics along with other fiber-reinforced polymer laminates is that their mechanical properties in the trans-laminar (through thickness) direction are relatively low [1]. Due to the weak bonds between the plies, even small energies imparted by low velocity impacts can result in damage, which, although hardly detectable, causes considerable strength losses in tension and, especially, in compression [2–5].

Composites, nevertheless, also have unique and complex failure characteristics. Fiber and/or matrix breakage, fiber debonding and delaminations are common events not found on monolithic materials, and that can precede the ultimate failure of a composite [6,7].

Micro-computerized tomography (micro-CT) can be used to reconstruct interior structural details with a high resolution on a scale of interest for damage evaluation. It is also gaining popularity as a technique for non-destructive testing (NDT) of materials and components, in many cases through conversion of conventional radiography instrumentation. Most micro-CT studies in the literature have been carried out using specialized one-of-a-kind instruments, often located at synchrotron radiation laboratories. As a consequence, the application of micro-CT has been relatively limited, with measurements largely dependent on scientists with expertise in X-ray techniques and instrumentation. The recent appearance of several commercial micro-CT systems on the market makes micro-CT more accessible for laboratory testing. Such instruments offer the potential for the widespread use of micro-CT by engineers as a tool for characterization of damage in composite materials.

Micro-CT in material science is now becoming a conventional characterization technique which is confirmed by the number of articles published in international journals devoted to materials science [8–10]. In the field of polymer based composites, micro-CT is successfully employed to analyze the micro-structure of multi-axial multi-ply stitched carbon preforms [11] by characterizing the size and shape of resin-rich regions of the composites and 3D microcracks created by hygrothermal fatigue. Researchers use X-ray radiography and micro-CT to understand the behavior and damage of composite materials undergoing fatigue, tensile or impact loading better [12–19], besides analyzing internal structures and complex architectures. Micro-CT has been used by many researchers from various disciplines as listed in Table 1.

Fiber-reinforced composite materials such as glass, aramid and glass + aramid hybrid fiber-reinforced composites are finding increasing use in a wide range of both low and high technology engineering applications. Composites offer a number of distinct advantages over more conventional engineering materials, on