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ASSESSMENT OF CARBON-FIBER-REINFORCED THERMOPLASTICS AFTER IMPACT DAMAGE USING METAMATERIALS SENSOR

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Summary: Carbon fiber reinforced plastics have been started to be used at large scale in aerostructures and automotive industry. Majority of structures have been manufactured using carbon-fiber-reinforced polymers (CFRP), which are thermoset pre-impregnated carbon fibers in the form of unidirectional tape or woven fabric. But, in order to reduce the costs, to increase the production rates and avoid the impact on environment, it requires new manufacturing processes and materials, as for Carbon-fiber-reinforced thermoplastics (CFRTP). Despite the fact that thermoplastic composites are more expensive, they have been preferred, due the advantages of thermoplastic matrix as recyclability, aesthetically finishing, high impact resistance, chemical resistant, hard crystalline or rubbery surface option, eco-friendly manufacturing, making the entire process costless. Woven carbon fiber is most suitable for applications requiring a high strength-to-weight ratio. Polyphenilene sulfide (PPS) has excellent properties, framing into the advantages described above. Woven carbon fibers/PPS laminates are characterized by reduced damages but are susceptible to impacts with low energies, leading to delaminations, desbonding of carbon fibers and/or matrix cracking. The aerospace industry has the requirement for the highest quality control and product release specifications. The raw material standard, prepreg materials, require mechanical property testing (e.g. interlaminar strength and tensile strength) from specimens. Final parts also require Nondestructive Evaluation (NDE) and Structural Health Monitoring (SHM). Alternative techniques based on phenomenological changes on the composite materials were developed during the past several decades, to measure damage due to impacts: ultrasonic techniques, acoustic emissions, infrared imaging, electrical resistance or non-contact techniques such as thermography, digital image correlation and X-ray tomography, but these methods have their limitations.

Under impact, the CFRPT suffer delamination cracking that is usually accompanied by a dent. The dent causes a reduction in the spacing between fibers in the thickness direction and this causes an increase in fiber contact leading to decrease of electrical resistance in the thickness direction. This situation modifies the electrical conductivity local both in the plane of the fibers and perpendicularly on fibers so that electromagnetic NDE methods can be applied.

This paper presents a method and a new electromagnetic transducer with metamaterials lens for testing CFRPT impacted with low energy in order to determine the damage inside the composite and provide more advanced imaging system and image reconstruction. The electromagnetic behavior of composite is first simulated by finite-difference time-domain (FDTD) software, the samples being CAD designed following textiles features, showing a very good concordance with nondestructive evaluation experimental results and destructive tests.

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