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# Nondestructive testing and evaluation techniques of defects in fiber-reinforced polymer composites: A review

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Fiber-reinforced polymer composites have excellent mechanical properties and outstanding development potential and are cost-effective. They have increasingly been used in numerous advanced and engineering applications as materials for wind turbine blades, helicopter rotors, high-pressure pipelines, and medical equipment. Understanding and assessing structural failure promptly in the whole lifecycle of a composite is essential to mitigating safety concerns and reducing maintenance costs. Various nondestructive testing and evaluation (NDT&E) technologies based on different evaluation principles have been established to inspect defects under different conditions. This paper reviews the established types of NDT&E techniques: acoustic emission, ultrasonic testing, eddy current testing, infrared thermography, terahertz testing, digital image correlation, shearography, and X-ray computed tomography, which is divided into three categories based on the operation frequency and data processing means of the output signal that is directly under analysis. We listed four types of defects/damage that are currently of great interest, namely, voids and porosity, fiber waviness and wrinkling, delamination and debonding, as well as impact damage. To identify a suitable method for different defects/damage, we performed characterization and evaluation by using these NDT&E techniques for typical defects/damage. Then, the cost, inspection speed, benefits and limitations, etc. were compared and discussed. Finally, a brief overview of the development of the technologies and their applications in the field of composite fabrication was discussed.

## KEYWORDS

non-destructive evaluation, fiber-reinforced polymer composites, ultrasonic testing, laminates, defects

## 1 Introduction

Fiber-reinforced polymer composites (FRPCs) are defined as composite materials consisting of a polymer matrix reinforced with fibers, and its structures are in the form of laminated components. Due to its low weight to modulus and stiffness ratio, corrosion resistance, tailored performance, and cost-effectiveness (Li et al., 2017b; Jawaid et al.,

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