Research on Damage Characteristics of CFRP Based on DFB Fiber Laser

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Introduction

- Carbon fiber reinforced plastic (CFRP) composites have been widely used in aerospace and other fields with the advantages of high specific strength, large specific rigidity, and strong durability. The microscopic damages in this materials has received critical attention.

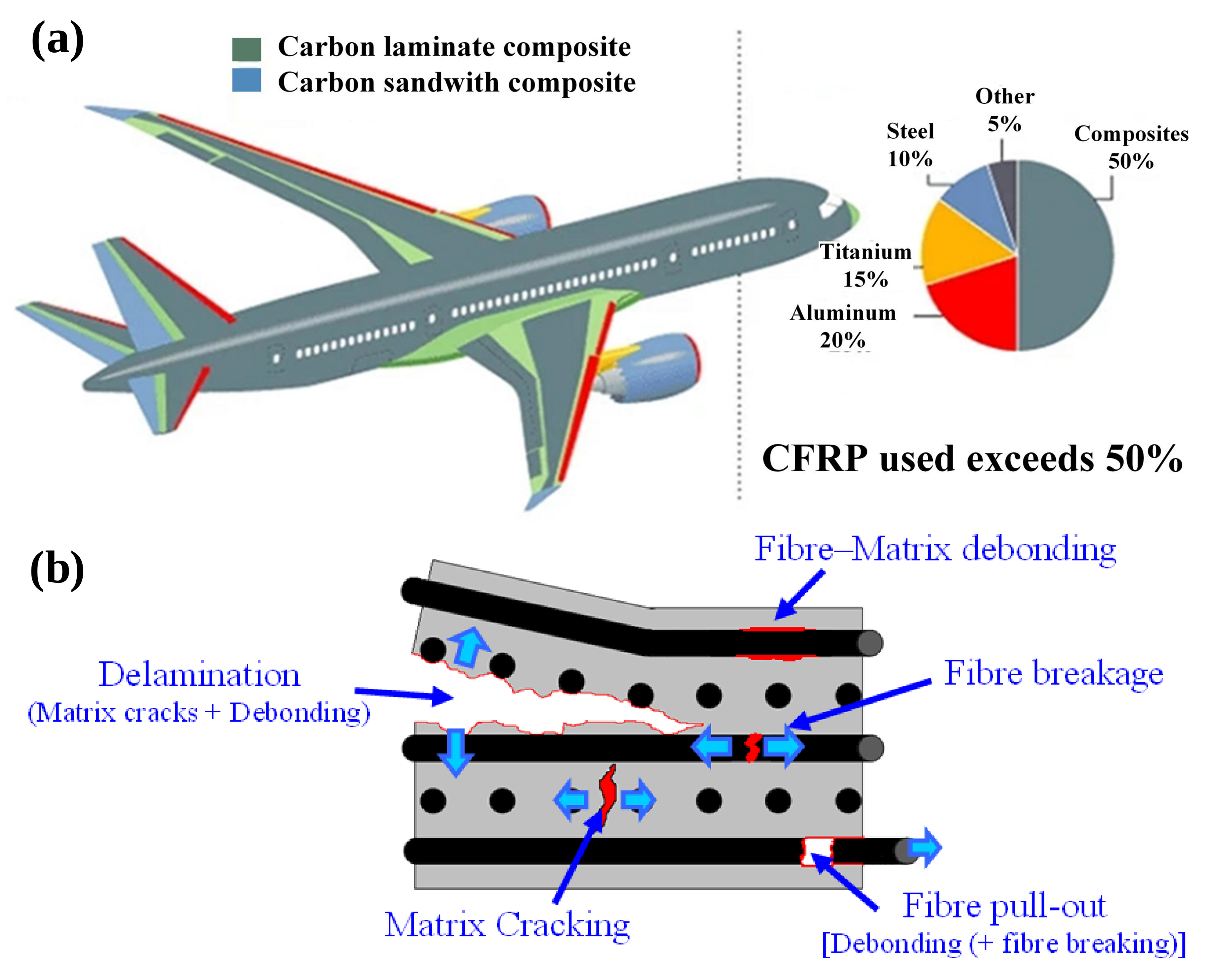

Fig. 1 (a) Materials used for the Boeing 787. (b) Damage modes in CFRP composites.

- An acoustic emission (AE) monitoring method based on DFB-FL is proposed. It has the advantages of small dimensions, ultra-narrow linewidth, easy to multiplex, and low noise properties.

Principle

- The configuration of the AE monitoring system of CFRP composites based on DFB fiber laser is shown in Fig. 2. Under the action of the AE events, the fiber laser's wavelength will change with the grating region strain.

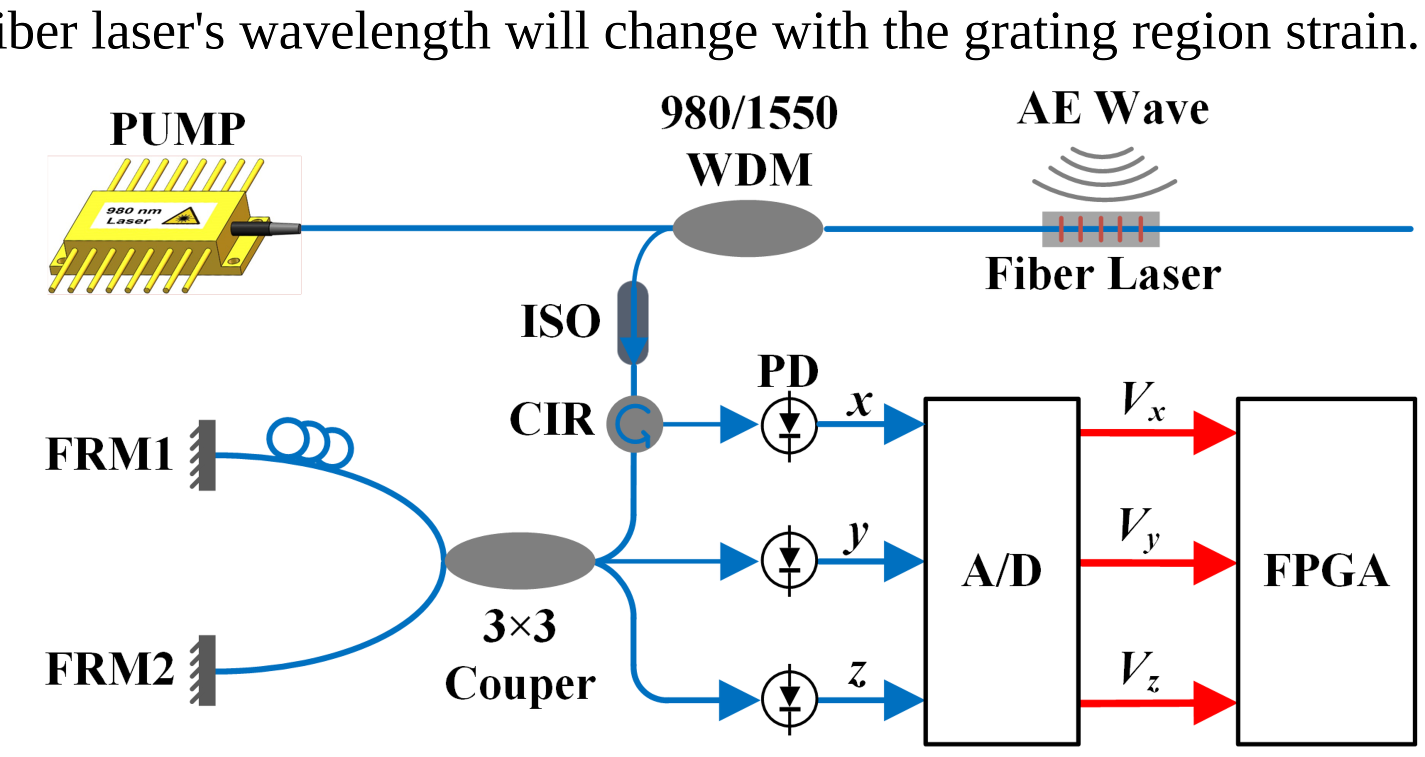

Fig. 2 System configuration of the DFB fiber laser AE sensor interrogation.

- An interrogation method based on BCESF-3×3 was proposed to improve the resolution of DFB fiber laser AE sensing system. The sensing system achieved a wavelength resolution of 2×10^{-7} pm/√Hz, which was approximately 10 dB higher than the traditional method.

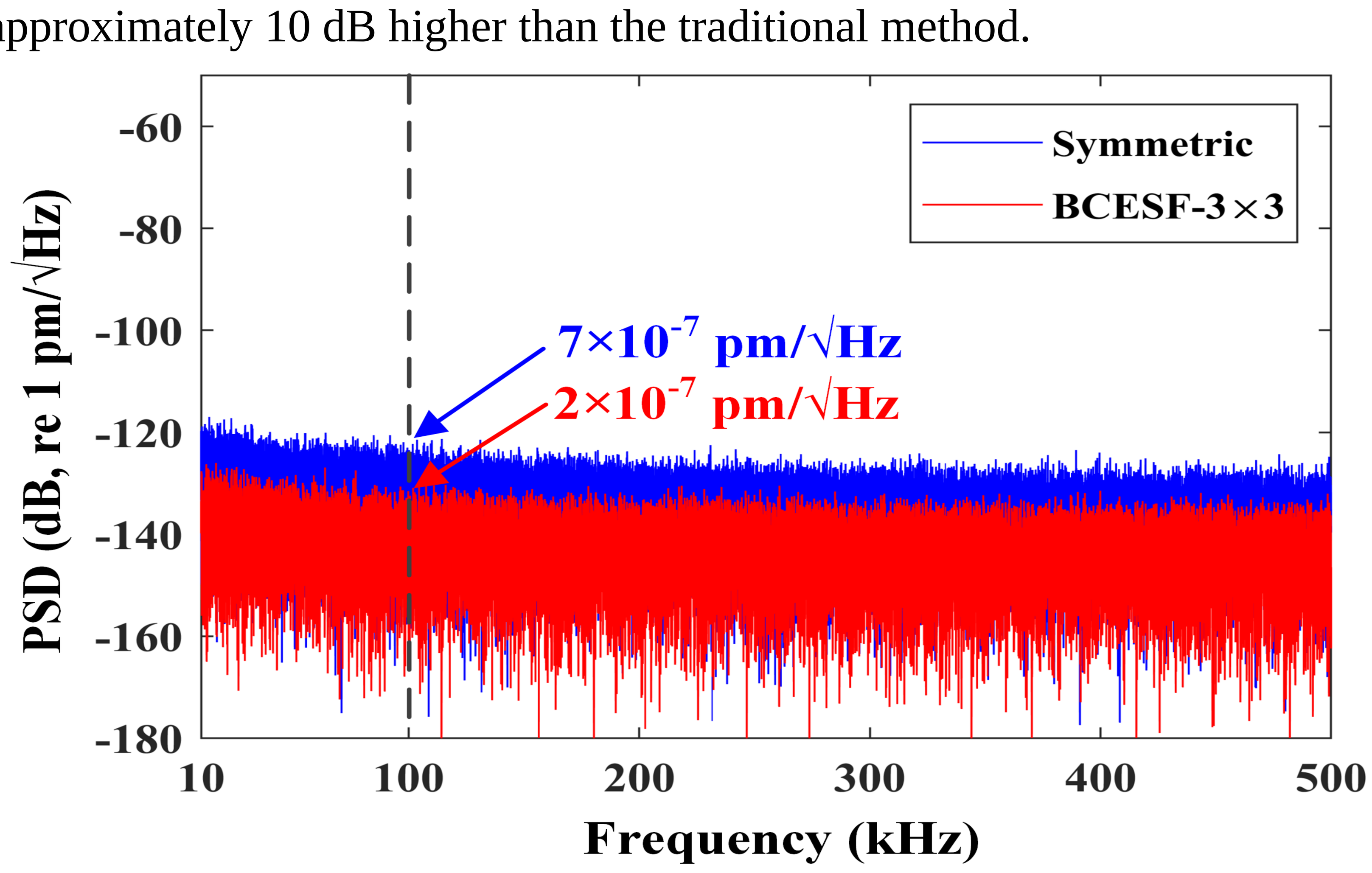

Fig. 3 The system noise floor of the proposed DFB fiber laser AE system.

Experiment and Results

- DFB fiber laser AE sensor's entire active area is coupled to the surface of CFRP specimen using an epoxy resin adhesive. The tensile load and displacement of the specimen were recorded by the testing machine. A commercial AE PZT sensor was used for comparison.

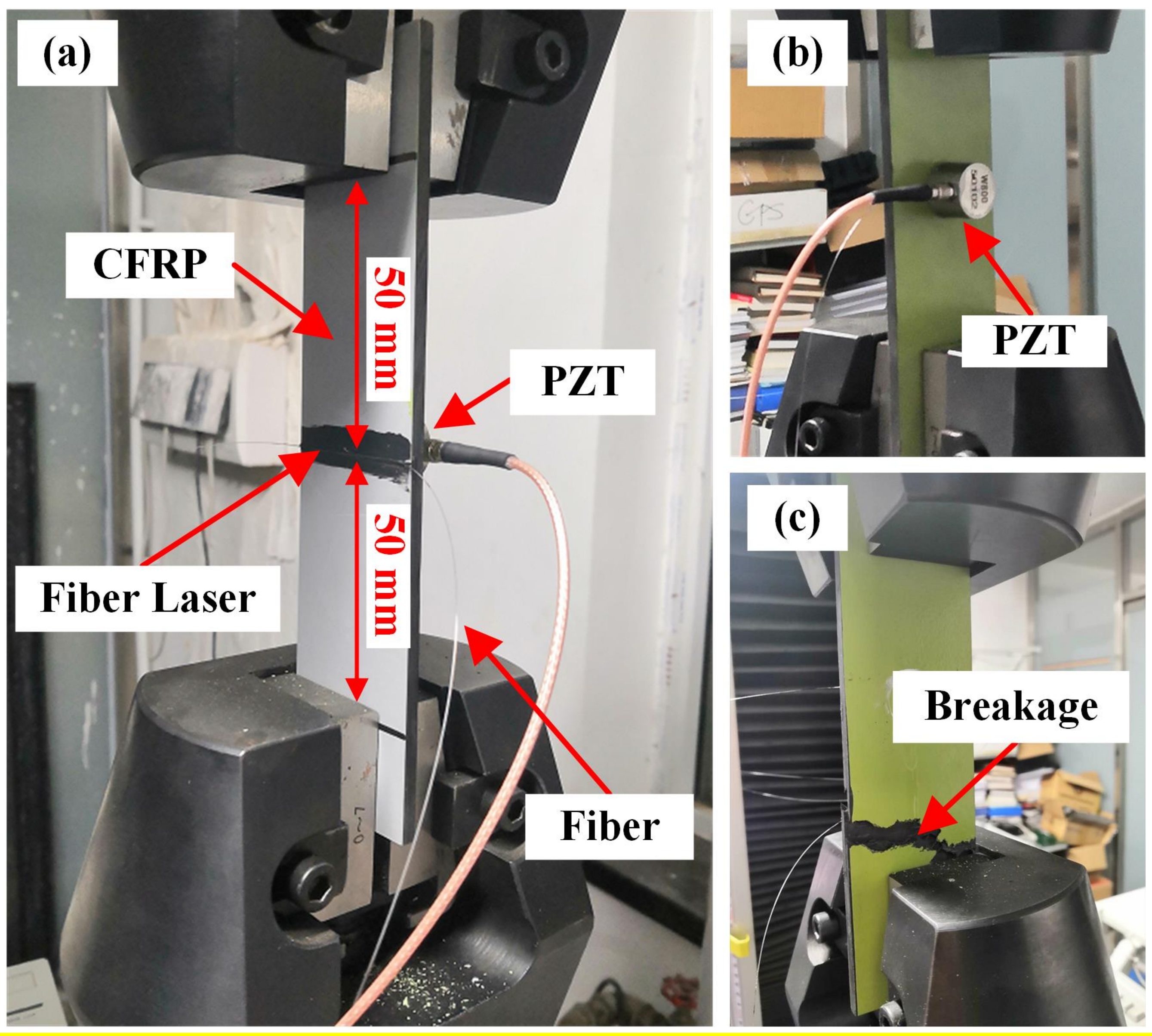

Fig. 4 Experimental setup employed in the AE detection of the CFRP specimen.

- The DFB fiber laser AE sensor records more AE signals than the PZT sensor over the same period due to its higher detection resolution of weak AE signals and better coupling with the specimen.

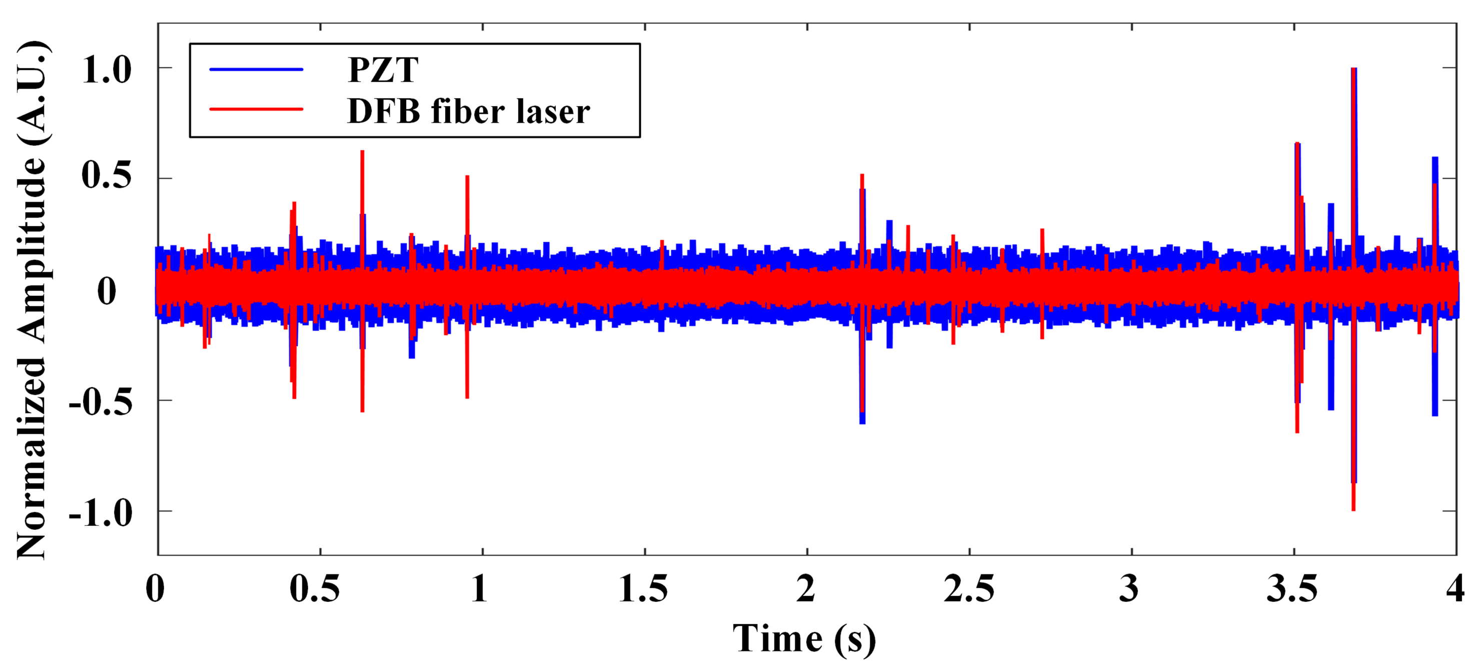

Fig. 5 Waveforms recorded within 4 s by the DFB fiber laser and PZT sensor

- AE hits per second used as the characteristic parameters of damage. The results shown that the severity of damage inside the CFRP specimen and the development of damage during the entire tensile failure be divided into 3 phases: ***A***. Initiation phase of damage; ***B***. Spread phase of damage; ***C***. Instability stage of damage.

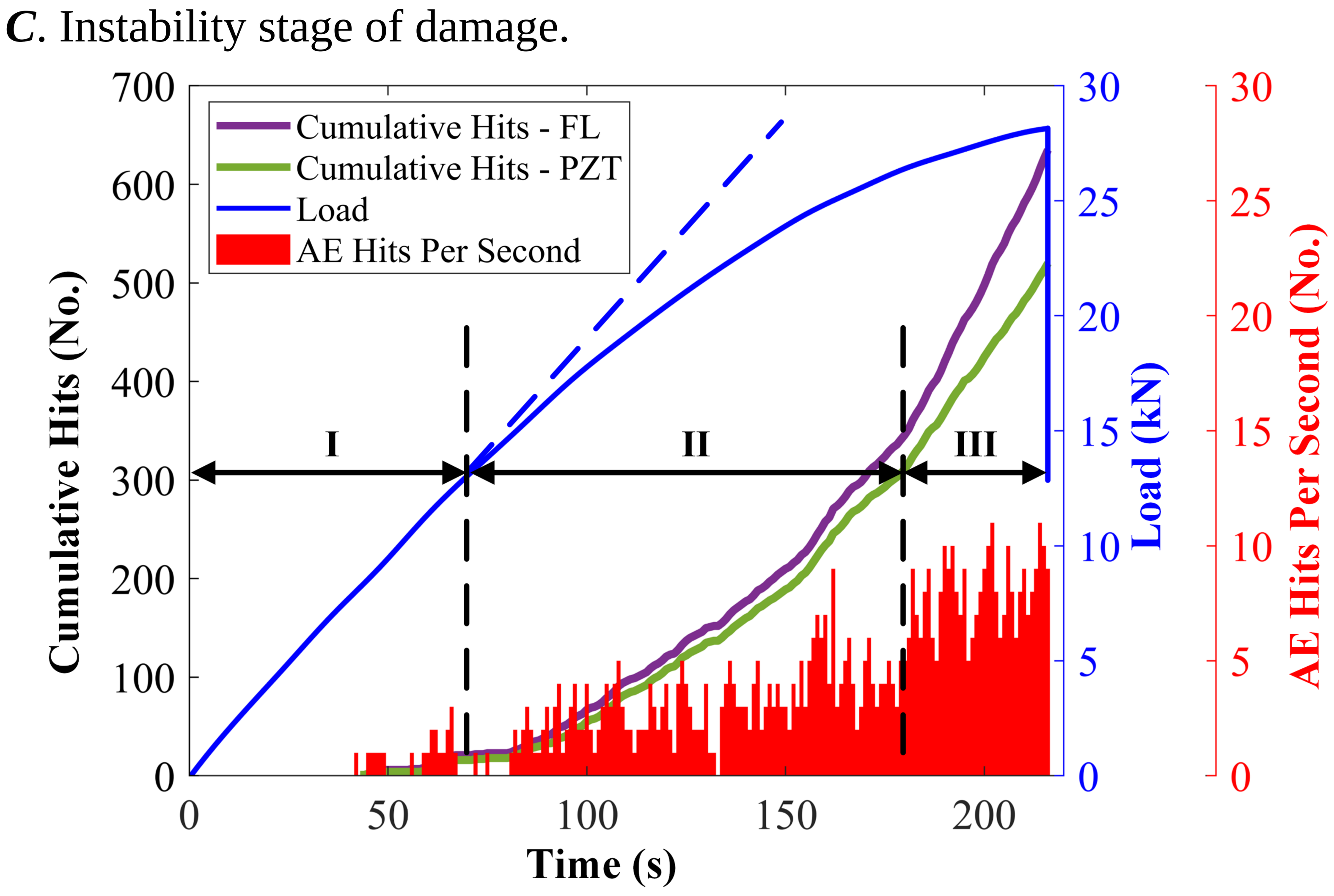

Fig. 6 The load, cumulative AE hits, and AE hits per second versus time curves of whole tensile process of the specimen.

Summary

- DFB fiber laser AE monitoring system reliably detects AE signals and recognizes damage characteristics of CFRP laminates during initiation, spread, and instability stages.

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