International Journal of General Engineering
and Technology (IJGET)
ISSN(P): 2278-9928; ISSN(E): 2278-9936
Vol. 4, Issue 4, Jun - Jul 2015, 9-16

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

ACOUSTIC EMISSION SIGNAL WAVEFORM AND POWER SPECTRA ANALYSIS DURING TENSILE TESTING OF GFRP COMPOSITE

M. SEEMAN

Assistant Professor, Department of Manufacturing Engineering, Annamalai University,
Annamalai Nagar, Tamil Nadu, India

ABSTRACT

In this work, The AE waveform and AE power spectra studied during tensile testing of GFRP (reinforcement: E-glass fiber, matrix: Poly-ester resin) composite studied and compared with conventional materials like Al, Cu, and HCS. The AE waveform of GFRP specimen found more burst type signal compare to homogeneous material like Al, Cu, and HCS. This mainly due to individual fibers breakage produces this type of signal like multi-phase material GFRP laminate. The material having high tensile strength AE signal peak observed at lower frequency range in the AE power spectra. The acoustic emission phenomena in the tensile test were very active in the elastic region, drop significantly when it starts to enter the plastic region and increase rapidly at rupture point during testing a materials Al, Cu, and HCS.

KEYWORDS: Tensile Testing, Acoustic Emission Signal (AE Signal), Glass Fiber Reinforced Polymer (GFRP), AE Waveform, AE Power Spectra

INTRODUCTION TO TENSILE PROPERTIES

Glass fiber reinforced polymer (GFRP) composites are widely used in aircraft, spacecraft, automotive and electronics industry. The typical sudden failure of most GFRP components would considerably benefit of a reliable system for monitoring in real time damage progression and reliably discerning between different damage mechanisms, such as matrix cracking, fiber matrix splitting, delamination and fiber fracture [1-2]. In-service monitoring of acoustic emission (AE) i.e., ultrasonic waves generated in materials under load, can be used for this purpose. A number of studies exist, which are aimed at finding a correlation between AE parameters and damage mechanisms [3-4].

Most studies so far have used AE signal parameters, such as rise time, counts, energy, duration, amplitude and correlated them with the occurrence of some particular damage modes [5]. For example, low-velocity impact damage on natural fiber reinforced laminates are characterized by AE parameters during tensile testing and flexural testing [6]. Acoustic Emission (AE) is the class of phenomena whereby transient elastic waves are generated by the rapid release of energy from a localized source or source within a material or the transient elastic wave so generated". Acoustic emission is just one of a number of methods that can be used to monitor material quality during the tensile testing in order to provide information. An advantage of using AE as a process monitor is that the frequency range of acoustic emission is much higher than that of machine vibrations and ambient acoustic noise [7]. Although the AE technique has been in use for over 50 years or so, effective analysis of data is still a major challenge. Hence, the major scope of this research is focused on the effective analysis of recorded AE data to achieve accurate source identification, effective signal discrimination, and reliable severity assessment. This can be expected to increase the effectiveness of the acoustic emission technique as a health monitoring tool [8].

The objective of this research is to monitor acoustic emission signal during tensile testing of GFRP composite and study the AE waveform and AE power spectra correlate with tensile properties and various failure modes of GFRP composites. The AE signal of GFRP composite compared with AE signal of conventional materials like Al, Cu and High carbon steel (HCS) to find how multiphase material like GFRP composite AE signal varying from homogeneous materials AE signals like Al, Cu, and HCS.

EXPERIMENTAL DETAILS

Materials and Experimental Procedure

The GFRP composite laminate of 4 mm thickness made of E-glass fiber and Poly-ester resin as the matrix manufactured by ECAMS RESINS PVT LTD is used in this study. The mechanical properties of GFRP fiber/resin details E-glass fiber and Poly-ester resin is given in Tables 1 to 3. The un-notched tensile specimens of GFRP, Al, Cu, and HCS were prepared as per the ASTM E8M-04 standard guidelines for monitoring the AE signal. Tensile testing was carried out using 100 kN Electro mechanical controlled universal testing machine (Make: FIE-blue star, India; Model: UNITEK-94100).

Table 1: Mechanical Properties of E-Glass Fiber and Polyester Resin

Fiber/Resin	Tensile Modulus (E) (GPa)	Tensile Strength (σ) (MPa)	Density (ρ) (g/cm^3)	Shear Modulus	Ultimate Elongation (%)
E-Glass	69	2400	2.6	27	-
Polyester	3000	50	1.10	-	2%

Table 2: Details of E-Glass Fiber

Fiber, E-Glass (M123 300-130 1B)	
Manufacturer	OCV^{TM} Reinforcements
M123	Chopped Strand Mat(CSM)
300	Roll weight(g/m^2)
130	Roll width(cm)
1B	Number of trimmed edges(zero,one or two)

Table 3: Details of Poly-Ester Resin

Resin, Poly-Ester	
Manufacturer	ECAMS RESINS PVT LTD.
Product	Ecamalon 8811(Isothalic based resin)
Hardner	MEKP(Methyl Ethyl Ketone Peroxide)

Acoustic Emission Signal Monitoring

The AE data Acquisition setup, AE sensor with preamplifier as shown in Figure 1 and 2, piezoelectric AE transducer was fixed on the tensile specimen using couplant (shown in Figure 3) made of Physical acoustic corporation Ltd (PAC) frequency range of 0-1000 kHz, before each test, the calibration of the acquisition parameter was achieved by performing a pencil lead break procedure [9]. Electric signal produced by the transducer was of very low amplitude and high-frequency contentand was initially amplified with a low noise pre-amplifier. Most pre-amplifier had a gain of 40-60 dB. In this study 40 dB, pre-amplified gain is used [10]. The pre- amplified signal was passed through a band pass filter with a threshold set greater than background noise; the conditioned signal was stored in the computer (shown Figure 4) and analyzed using AE Win software. The acoustic emission monitored for the entire testing of all the specimens and tensile properties correlated with AE parameter.

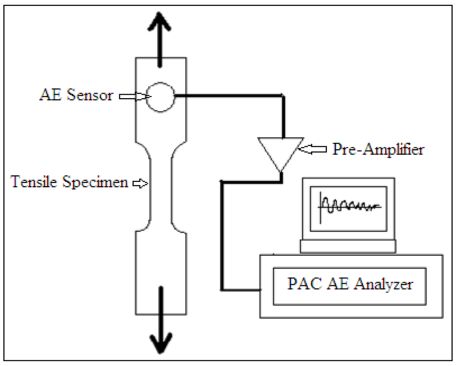

Figure 1 AE Data Acquisition Setup

Figure 2: PAC AE Sensor with Preamplifier

Figure 3: Details of AE Sensor Mounting

Figure 4: AE Monitoring System

RESULTS AND DISCUSSIONS

Tensile Properties

The transverse tensile properties such as yield strength, tensile strength, and percentage of elongation of GFRP material were evaluated along the conventional materials of Al, Cu and HCS. The tensile test specimens are shown in Figure 5, three specimens were tested, and the best one selected and load vs. displacement curves as shown in Figures 6 results are presented in Table 4. The same tensile specimen acoustic emission signal also captured for further analyzes. The yield strength and tensile strength of GFRP material 235, 268 MPa respectively. From table observed that yield strength of and tensile strength of GFRP higher than Al and Cu by 46% and 12% respectively. This indicates that GFRP has superior mechanical properties compared to Al and Cu.

Figure 5: Un-Notched Tensile Specimens of GFRP, Al, Cu and HCS (Before and After Testing)

Table 4 Transverse Tensile Properties of Materials GFRP, Al, Cu and HCS

Material	Yield Strength(MPa)	Ultimate Tensile Strength (MPa)	Elongation In 50 mm Gauge Length (%)
GFRP	235	268	13.92
Al	125	144	10.20
Cu	205	229	38.58
HCS	690	723	20.24

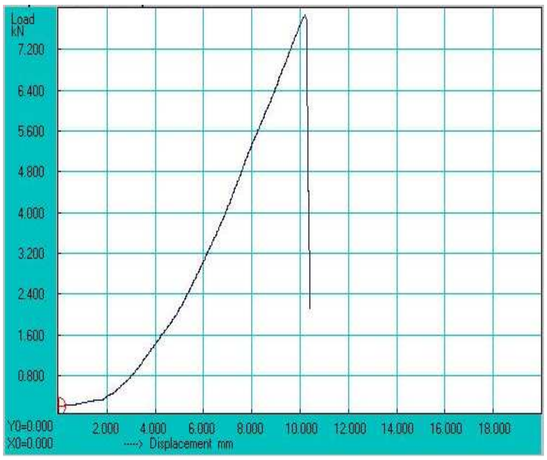

Figure 6 (a): GFRP Laminate

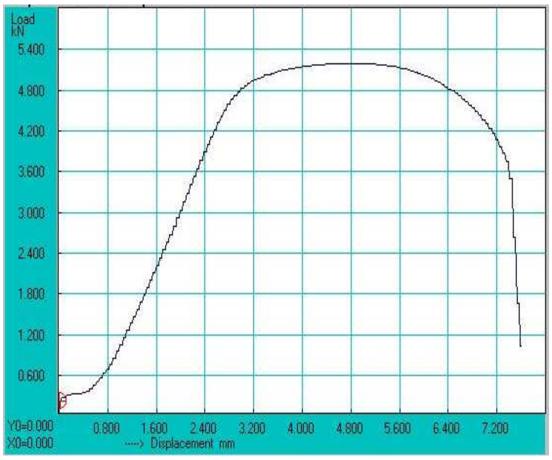

Figure 6 (b): Al Specimen

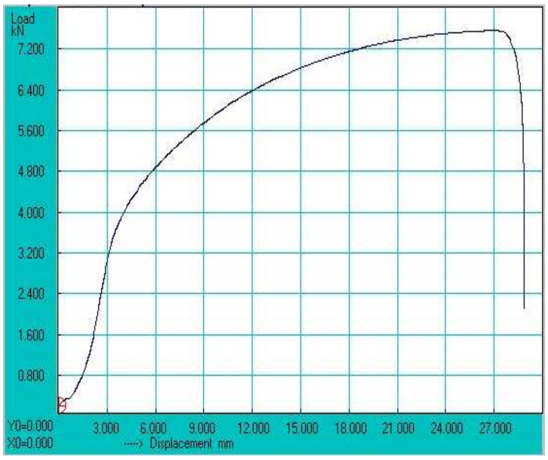

Figure 6 (c): Cu Specimen

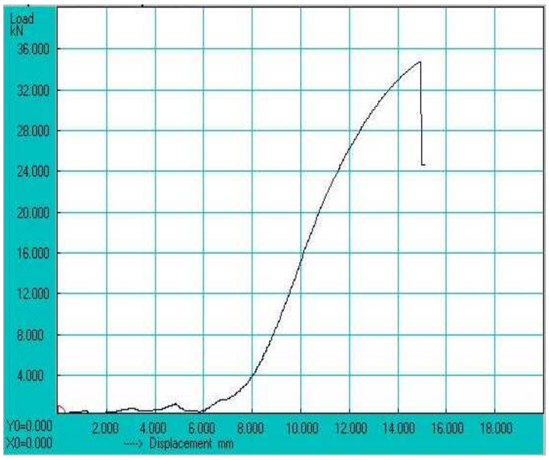

Figure 6 (d): HCS Specimen

Figure 6: Load VS Displacement Curve

Acoustic Emission Signal Monitoring

AE Waveform Analysis

Typical AE waveforms pertaining to hit data and possibly related to the failure modes during tensile test monitoring are identified from the parametric analysis. Waveforms for GFRP, Al, Cu and HCS specimen are shown in Figure 7. From Figure observed that different materials having a different pattern of AE waveform especially GFRP specimen waveform seen more burst type signal compare to homogeneous material like Al, Cu, and HCS. This mainly due to individual fibers breakage produces this type of signal like multi-phase material like GFRP [11].

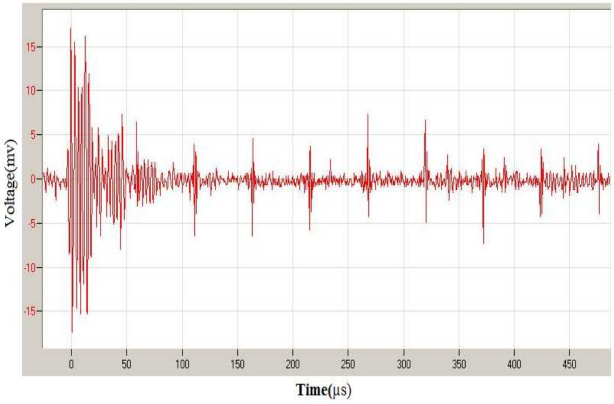

Figure 7 (a): GFRP Laminate

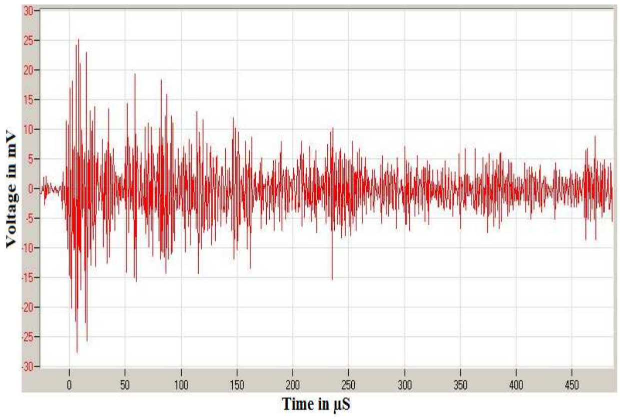

Figure 7 (b): Al Specimen

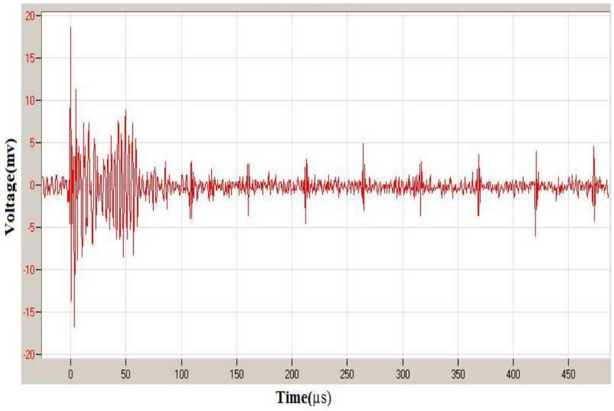

Figure 7 (c): Cu specimen

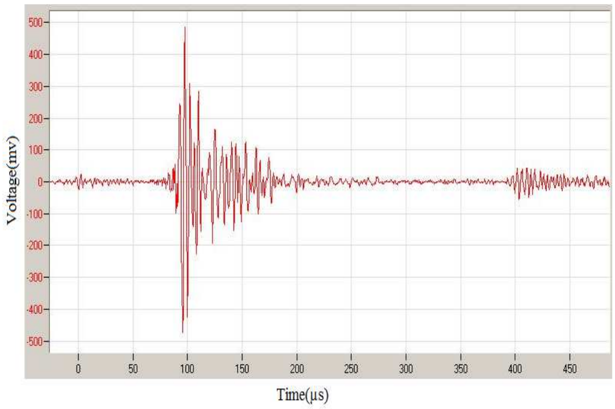

Figure 7 (d): HCS specimen

Figure 7: AE Waveform

AE Power Spectra Analysis

Typical AE power spectra pertaining to hit data and possibly related to the failure modes during tensile test monitoring are identified from the parametric analysis. AE power spectra for GFRP, Al, Cu and HCS specimen are shown in Figure 8. From Figure observed that different materials having a different pattern of AE power spectra. From the figures, the peak frequencies of 590, 320, 310 and 180 kHz observed for Al, Cu, GFRP and HCS respectively. The peak frequency of AE spectra for four different materials compared with tensile strength (shown Table 4); found that material having higher tensile strength peak at lower frequency range i.e 180 kHz for HCS followed by 310, 320 and 590 kHz for GFRP, Cu, and Al respectively. The AE power spectra of GFRP having more sharp fluctuations compare to other materials this mainly due to fiber breakage during tensile test [12].

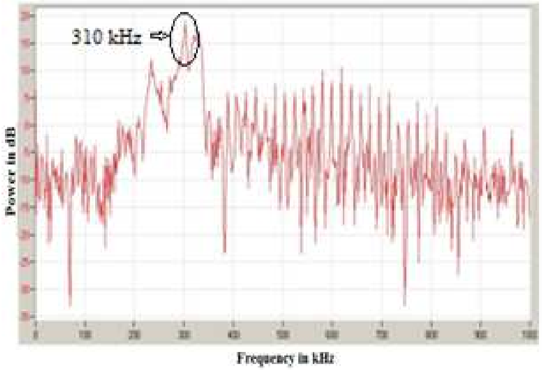

Figure 8(a): GFRP Laminate

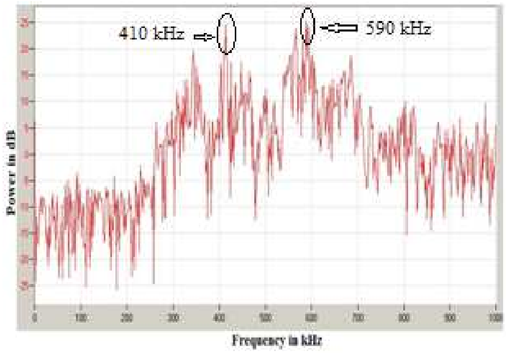

Figure 8(b): Al Specimen

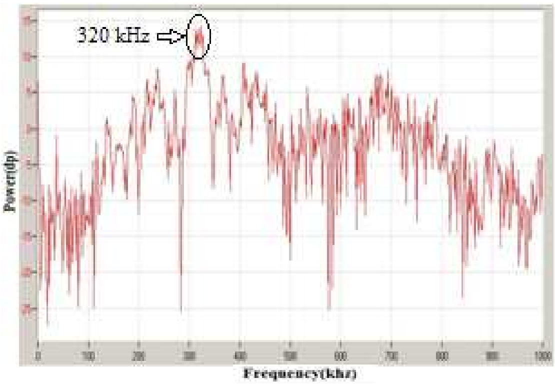

Figure 8(c): Cu Specimen

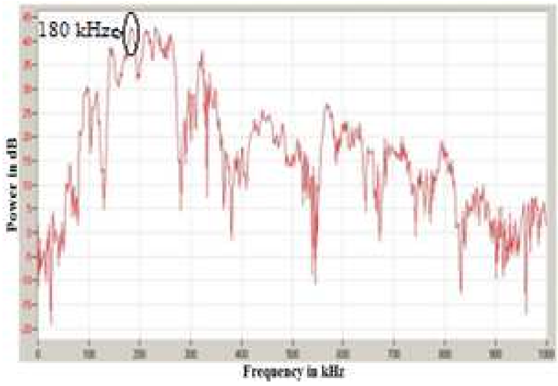

Figure 8(c): HCS Specimen

Figure 8: AE Power Spectra

CONCLUSIONS

From the Acoustic emission signal monitoring during tensile test of GFRP laminate and other materials of Al, Cu and HCS the following conclusions can be drawn.

- The acoustic emission phenomena in the tensile test of multi-phase material like GFRP laminate varying from conventional materials like Al, Cu, and HCS due to its heterogeneity.
- The AE waveform of GFRP specimen found more burst type signal compare to homogeneous material like Al, Cu, and HCS. This mainly due to individual fibers breakage produces this type of signal like multi-phase material like GFRP.
- The material having high tensile strength AE signal peak observed at lower frequency range in the AE power spectra.

REFERENCES

1. De Oliveira R, Marques AT: Health monitoring of FRP using Acoustic Emission and Artificial neural network. Computers and Structures, 86, (2008), 367-373.
2. Godin N, Huguet S, Gaertner R: Integration of the Kohonen's self organizing map and K-means algorithms for the segmentation of the AE data collected during tensile tests on cross ply composites. NDT & E International, 38, (2005), 299-309.

3. Dornfeld D, Liang S: Tool wear detection using time series analysis of acoustic emission. Transactions of ASME Journal of Engineering for Industry, 111 (19893), 99–205.
4. Philippidis TP, Nikolaidis VN, Anastassopoulos AA: Damage characterization of carbon/carbon laminates using neural network techniques on AE signals. NDT & E International, 31, (1998), 329-340.
5. Barre S, Benzeggagh ML: On the use of Acoustic Emission to investigate damage mechanism in Glass-Fiber-Reinforced polypropylene. Composites Science and Technology, 52, (1994), 369-376.
6. Bar HN, Bhat MR, Murthy CRL: Parametric analysis of acoustic emission signals for evaluating damage in composites using PVDF film sensors. NDT & E International, 24, (2005), 121-134.
7. Dzenis YA, Qian J: Analysis of micro damage evolution histories in composites. International Journal of Solids and Structures, 38, (2001), 1831-1854.
8. Santulli C: Post-impact damage characterization on natural fiber reinforced composites using Acoustic Emission. NDT & E International, 34, (2001), 531-536.
9. Beattie A G: Acoustic emission principle and instrumentation. J of Acoustic Emission, 2, (1983), 95-128.
10. Bussiba A, Piat R, Kupiec M, Carmi R, Alon I, Bohlke.T : Threshold parameters and Damage accumulation profile in C/C composites monitored by Acoustic Emission Response: progress in Acoustic Emission XIV, the Japanese society for NDI, 2008.
11. Raja, R., & Jannet, S. Experimental Investigation Of High Speed Drilling Of Glass Fiber Reinforced Plastic (Gfrp) Composite Laminates Made Up Of Different Polymer Matrices.
12. Agresti EM, Caneva C, De Rosa IM, Sarasini F, Valente M: Effect of jute fibers on post-impact behavior of E-glass reinforced composites assessed through Acoustic Emission, International Journal of Materials and Product Technology 36, (2009), 3046.
13. Bussiba A, Kupiec M, Ifergane S, Piat R, Bohlke T: Damage evolution and fracture events sequence in various composites by acoustic emission technique, Composites Science and Technology, 68, (2008), 1144-1155.