IDENTIFICATION OF COMPOSITE DEFORMATION BY ACOUSTIC EMISSION METHOD

Alexander Pysarenko
associate professor, PhD, Odessa State Academy
of Civil Engineering and Architecture
ORCID: 0000-0001-5938-4107

Internet address of the article on web-site:
https://www.economy-confer.com.ua/full-article/5721/

Rapidly growing demand from industries for high-performance, lightweight structures has driven strong and expanding development of reinforced polymer composites [1]. Composite materials can be used as replacements for metals and alloys in terms of high specific strength, high corrosion resistance, and weight savings. Due to manufacturing considerations and the high degree of complexity in component design for assembly, composite materials may be susceptible to deformation during the assembly stage. The industrial processing mechanism of reinforced composites is a process different from the process of homogeneous and isotropic metal removal from conventional materials. Moreover, several undesirable forms of damage (such as matrix cracking, delamination and fiber breakage) caused by industrial deformations dramatically reduce the fatigue strength, thereby deteriorating the long-term performance of composite laminates [2].

The study of mechanical properties of damaged reinforced composites is often performed using acoustic emission, as one of the most suitable methods in the field of composite materials processing. Acoustic emission is the occurrence and propagation of transient ultrasonic waves generated by sudden movement in a material under stress. Mechanical loading in composites, as well as ruptures in the volume of the material, can release acoustic emission energy. This energy propagates in the form of high-frequency stress waves. The propagation of waves occurs throughout the volume of the sample, in which the conversion into electrical signals is detected using piezoelectric transducers. Subsequently, the amplification and additional processing of the acoustic emission signal parameters occurs.

One of the main objectives of the acoustic emission method is to identify different damage mechanisms in a composite material. The most common technique is to use time descriptors such as signal amplitude and energy to characterize the damage development [3]. Clustering is a general methodology and an exceptionally rich conceptual and algorithmic framework for the analysis and interpretation of mechanical damage data. In this paper, unsupervised analysis of local areas of mechanical deformation (clustering) is used as the final tool for analyzing acoustic wave characteristics.

The problem of visualizing data containing many variables is one of the difficulties inherent in multivariate statistics. The solution to this problem is to reduce the dimensionality of the data. The method generates a new set of variables called principal components. All principal components are orthogonal to each other, so there is no redundant information. Mathematically, the entire procedure for detailing mechanical damage in the volume of a composite is described by a packet wavelet transform. The result of acoustic signal processing must be sampled at a frequency twice as high as the highest frequency contained in the signal. Therefore, in this case, the sampling frequency is set to 1 MHz, and the frequency of the converted signals must be up to 500 kHz. Since the number of levels is three, then, accordingly, the number of components will be eight (i = 23). The frequency ranges for these components are: C1 [0 – 62.5], C2 [62.5 – 125], C3 [125 – 187.5], C4 [187.5 – 250], C5 [250 – 312.5], C6 [312.5 – 375], C7 [375 – 437.5] and C8 [437.5 – 500] kHz. The frequency range and energy percentage for the clustered stages of the third level (L3) are given in Table 1.

According to this table, components 1, 2, 4 and 6 correspond to a higher energy value than the other components. The components with a fixed frequency range can be assigned to one of the four main mechanisms of mechanical damage in a reinforced composite. The elastic acoustic velocities and natural frequencies are related to the density and elastic modulus according to the dependence f ~ (E/ρ)0.5, which is the basis for the different distribution in the dominant frequency range for heterogeneous local deformations.

Table 1. Frequency range and energy percentage for eight components of L3

Phase	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$	$C7$	$C8$
beginning	4.4	26.5	8.8	46.2	4.2	6.6	3.1	1.4
middle	5.6	21.0	5.9	3.7	3.1	50.8	4.6	2.2
exit	12.8	7.4	4.7	26.3	3.0	41.3	2.4	1.1

The most prominent mechanical damage mechanisms are matrix cracking and fiber breakage, the former of which is associated with component C2. According to Table 2, fiber breakage appears to be associated with component C6. This conclusion is supported by the fact that fiber breakage produces a higher frequency range compared to other damage mechanisms. Therefore, component C6 with a frequency distribution of [312.5 – 375] kHz is associated with fiber breakage.

References:

1. Goh G. D. et al. Recent progress in additive manufacturing of fiber reinforced polymer composite. Advanced Materials Technologies. 2019. Vol. 4(1). P. 1800271. https://doi.org/ 10.1002/admt.201800271

2. Kumar D. et al. Numerical modeling of combined matrix cracking and delamination in composite laminates using cohesive elements. Applied Composite Materials. 2016. Vol. 23. Pp. 397-419. https://doi.org/10.1007/s10443-015-9465-0
3. Saeedifar M., Zarouchas D. Damage characterization of laminated composites using acoustic emission: A review. Composites Part B: Engineering. 2020. Vol. 195. P. 108039. https://doi.org/10.1016/j.compositesb.2020.108039
4. Jolliffe I. T., Cadima J. Principal component analysis: a review and recent developments. Philosophical transactions of the royal society A: Mathematical, Physical and Engineering Sciences. 2016. Vol. 374 (2065). P. 20150202. https://doi.org/10.1098/rsta.2015.0202

DESIGNING MINIMALISTIC POWERED ARM ORTHOSIS FOR BRACHIAL PLEXUS INJURIES

Anton Kotsiubailo
PhD Student, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»

Anton Popov
Associate Professor, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukrainian Catholic University, Lviv, Ukraine

Oleksandr Lysenko
Professor, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»

Internet address of the article on web-site:
https://www.economy-confer.com.ua/full-article/5740/

Elbow paresis, frequently caused by brachial plexus injuries, poses a significant challenge in rehabilitation. To tackle this issue, we have developed a prototype powered orthosis that employs non-invasive surface electromyography (EMG) signals from neck muscles, such as the sternocleidomastoid, for intuitive control. This EMG-driven system enables precise manipulation of the elbow joint, covering the full physiological range of motion. The prototype integrates an EMG signal processor with an orthosis action operator, creating a seamless interface between human intent and mechanical action. Healthy participants successfully used neck muscle contractions to control elbow rotation, demonstrating the system's potential for real-world application. For the proposed basic prototype, we implemented the following functionality: an extension from 0 to 90 degrees at a constant speed upon neck muscle contraction detected using single-channel EMG. We have developed a mechanical design, EMG measurement system, and a basic algorithm for contraction detection.