Abstract

Journal of Mechanical Engineering Advancements - Volume 1 (Issue 2) October, 2024

Pages: 14-28

Detection of Crack in a Composite Beam by Using Continuous Wavelet Transform

Author: Ritik Roshan, Bhupal Kumar, Bimal Kumar, Ramnivas Kumar and Ravi Nigam

Category: Machine Design

[Download PDF]

Abstract:

Composite beams play a critical role in modern engineering and construction, offering a unique combination of strength, light weight, and flexibility that makes them ideal for use in structures ranging from bridges to aerospace components. Their ability to withstand various loads while maintaining structural integrity is paramount to ensuring safety and durability. However, the presence of cracks in composite beams poses significant challenges, as these defects can compromise the beam's loadbearing capacity and lead to catastrophic failures if undetected. Cracks, often caused by factors such as fatigue, environmental conditions, or manufacturing defects, can propagate over time, weakening the material and reducing the overall lifespan of the structure. Therefore, early detection and accurate assessment of cracks in composite beams are essential to maintaining the safety and longevity of structures that rely on these advanced materials.

In this study, the Continuous Wavelet Transform (CWT) is utilized to identify the presence and location of cracks in composite beams. To evaluate the algorithm's robustness against noise, white Gaussian noise is introduced into the simulated beam deflection data. The findings reveal that the CWT-based algorithm effectively identifies the crack even with significant noise interference. Additionally, the algorithm's performance is assessed for detecting cracks with varying depths. The results demonstrate that the algorithm can accurately locate cracks with depths as small as 10% of the beam thickness, maintaining its effectiveness up to a Signal-to-Noise Ratio (SNR) of 60. Furthermore, the study explores the algorithm's reliability in detecting cracks positioned at different locations along the beam length. The CWT-based algorithm consistently locates the crack regardless of its position along the length of the beam, indicating its noise robustness and versatility in different scenarios.

Keywords: Continuous Wavelet Transform, Composite Beam, Crack Detection, Finite Element Analysis

Cite this article:

Ritik Roshan, Bhupal Kumar, Bimal Kumar, Ramnivas Kumar and Ravi Nigam, Detection of Crack in a Composite Beam by Using Continuous Wavelet Transform, Journal of Mechanical Engineering Advancements. Vol 1 (Issue 2: May-August, 2024), pp 14-28.

References:

1. Wang B, Zhong S, Lee TL, Fancey KS, Mi J. Non-destructive testing and evaluation of composite materials/structures: A state-of-the-art review. Advances in mechanical engineering. 2020 Apr;12(4):1687814020913761.

2. Saha N, Roy P, Topdar P. Damage detection in composites using non-destructive testing aided by ANN technique: A review. Journal of Thermoplastic Composite Materials. 2023 Dec;36(12):4997-5033.

3. Duchene P, Chaki S, Ayadi A, Krawczak P. A review of non-destructive techniques used for mechanical damage assessment in polymer composites. Journal of materials science. 2018 Jun;53(11):7915-38.

4. Katunin A, Dragan K, Dziendzikowski M. Damage identification in aircraft composite structures: A case study using various non-destructive testing techniques. Composite structures. 2015 Sep 1;127:1-9.

5. Mayes JS, Hansen AC. Composite laminate failure analysis using multicontinuum theory. Composites Science and Technology. 2004 Mar 1;64(3-4):379-94.

6. Schuecker C, Pettermann HE. Fiber reinforced laminates: progressive damage modeling based on failure mechanisms. Archives of Computational Methods in Engineering. 2008 Jun;15:163-84.

7. Raju K. Modelling of Composites with Direct FE2-A Multi-Level FEM (Doctoral dissertation, National University of Singapore (Singapore)).

8. Linde P, Pleitner J, de Boer H, Carmone C. Modelling and simulation of fibre metal laminates. InABAQUS Users' conference 2004 May 19 (Vol. 421).

9. Monticeli FM, Fuga FR, Arbelo MA, Donadon MV. The effect of fibre orientation on fatigue crack propagation in CFRP: Finite fracture mechanics modelling for open-hole configuration. Engineering Failure Analysis. 2024 Jul 1;161:108278.

10. Bennett JA. Fibre/crack interaction in polymer matrix composites. The University of Manchester (United Kingdom); 1998.

11. Abdel Wahab Ly. Structural Behaviour Of Reinforced Concrete Beams Strengthened For Shear Using Cfrp Laminates Subjected To Cyclic Loading (Doctoral Dissertation, University Technology Petronas).

12. Shen YL, Needleman A, Suresh S. Coefficients of thermal expansion of metal-matrix composites for electronic packaging. Metallurgical and Materials Transactions A. 1994 Apr;25:839-50.

13. Gomes GF, Mendéz YA, Alexandrino PD, da Cunha Jr SS, Ancelotti Jr AC. The use of intelligent computational tools for damage detection and identification with an emphasis on composites–A review. Composite Structures. 2018 Jul 15;196:44-54.

14. Gomes GF, Mendéz YA, Alexandrino PD, da Cunha Jr SS, Ancelotti Jr AC. The use of intelligent computational tools for damage detection and identification with an emphasis on composites–A review. Composite Structures. 2018 Jul 15;196:44-54.

15. Raut NP, Kolekar AB, Gombi SL. Optimization techniques for damage detection of composite structure: A review. Materials Today: Proceedings. 2021 Jan 1;45:4830-4.

16. Ghoneam, S.M., Dynamic analysis of open cracked laminated composite beams, Composite Structures, Vol.32, No. 1, 1995, pp. 3-11

17. Shu, D. and Della, C.N., Vibrations of multiple delaminated beams, Composite Structures, Vol.64, No. 3–4, 2004, pp. 467-477.

18. Parhi, P., Bhattacharyya, S., and Sinha, P., Finite element dynamic analysis of laminated composite plates with multiple delaminations, Journal of reinforced plastics and composites, Vol.19, No. 11, 2000, pp. 863-882.

19. Mujumdar, P.M. and Suryanarayan, S., Flexural vibrations of beams with delaminations, Journal of Sound and Vibration, Vol.125, No. 3, 1988, pp. 441-461.

20. Sharma, A., Kumar, V., and Raghav, A.K., Vibrational frequency of circular tapered square plate, Romanian Journal of Acoustics and Vibration, Vol.14, No. 1, 2017, pp. 21.

21. Lestari, W. and Hanagud, S. Health monitoring of structures-Multiple delamination dynamics in composite beams. in 40th Structures, Structural Dynamics, and Materials Conference and Exhibit. 1999.

22. Shen, M.-H. and Grady, J., Free vibrations of delaminated beams, AIAA journal, Vol.30, No. 5, 1992, pp. 1361-1370.

23. Saravanan K, Sekhar AS. Crack detection in a rotor by operational deflection shape and kurtosis using laser vibrometer measurements. Journal of Vibration and Control. 2013 Jun;19(8):1227-39.

24. Hadjileontiadis LJ, Douka E, Trochidis A. Crack detection in beams using kurtosis. Computers & structures. 2005 May 1;83(12-13):909-19.

25. Kumar R, Singh SK. A variance-based approach fo the detection and localization of cracks in a beam. In Structures 2022 Oct 1 (Vol. 44, pp. 1261-1277). Elsevier.

26. Rezaifar O, Gholhaki M, Khanahmadi M, Amiri Y. A review of structural health monitoring and damage detection using wavelet transform: The case study of damage detection in cantilever beams. Journal of Vibration and Sound. 2022 Oct 20;11(21):157-71.

27. Kumar R, Nigam R, Singh SK. Selection of suitable mother wavelet along with vanishing moment for the effective detection of crack in a beam. Mechanical Systems and Signal Processing. 2022 Jan 15;163:108136.

28. Katunin A. Nondestructive Damage Assessment of Composite Structures Based on Wavelet Analysis of Modal Curvatures: State-of-the-Art Review and Description of Wavelet-Based Damage Assessment Benchmark. Shock and Vibration. 2015;2015(1):735219.

29. Rezaifar O, Gholhaki M, Khanahmadi M, Amiri Y. A review of structural health monitoring and damage detection using wavelet transform: The case study of damage detection in cantilever beams. Journal of Vibration and Sound. 2022 Oct 20;11(21):157-71.

30. Rezaifar O, Gholhaki M, Khanahmadi M, Amiri Y. A review of structural health monitoring and damage detection using wavelet transform: The case study of damage detection in cantilever beams. Journal of Vibration and Sound. 2022 Oct 20;11(21):157-71.

31. Chasalevris AC, Papadopoulos CA. Identification of multiple cracks in beams under bending. Mechanical systems and signal processing. 2006 Oct 1;20(7):1631-73.

32. Kumar R, Singh SK. Crack detection near the ends of a beam using wavelet transform and high resolution beam deflection measurement. European Journal of Mechanics-A/Solids. 2021 Jul 1;88:104259.