ICCES, 2023, vol.27, no.4
Tech Science Press
DOI: 10.32604/icces.2023.09340

PROCEEDINGS

Statistic Structural Damage Detection Of Functionally Graded Euler-Bernoulli Beams Based on Element Modal Strain Energy Sensitivity

Zhongming Hu[1,*], Leilei Chen[1], Delei Yang[1], Jichao Zhang[1] and Youyang Xin[1]

[1] Huanghuai University, Kaiyuan Road, Zhumadian, 463000, China

[*]Corresponding Author: Zhongming Hu. Email: hu-zhongming@huanghuai.edu.cn

ABSTRACT

Functionally graded materials (FGMs), a kind of composite materials, were proposed to satisfy the requirements of thermal barrier materials initially [1-3]. Compared with traditional composites, the microstructure and mechanical characteristics of FGMs change continuously which make them present excellent performance in deformation resistance or toughness under extreme mechanical and thermal loadings [4]. Therefore, FGMs have been paid much attention and experienced rapid developments in the last decade. Nowadays, various structural components manufactured by FGMs have been used in extensive applications, such as aerospace, bioengineering, nuclear industries, civil constructions etc. [5-7]

While, FG Euler-Bernoulli beams maybe suffer damage in practical engineering during application. Therefore, to enhance the safety of structures, study on the damage identification of FG beams is very significance especially when the damage is small [8]. In recent years, the damage detection methods based on vibration characteristics have been fully investigated which served as one of the most effective technologies [9]. Some modal parameters, such as natural frequencies, mode shapes or their combinations included modal strain energy (MSE), are commonly used [10,11]. Among the mentioned damage indexes, owing to the highly sensitive to local damage and excellent noise resistance, MSE has been widely adopted [12-14]. Moreover, it has been demonstrated that the methods based on MSE have satisfactory ability to identify damage location or extent by many researchers.

In terms of practical engineering, there inevitably exist different degrees of "uncertainties" in terms of model employed and measured data. As a consequence, there will be a lot of uncertainties in the damage identification of functional gradient structures which will lead to distortion between the damage identification results and the real damage, resulting in missing judgment and misjudgment. Therefore, damage identification methods are very necessary related to a statistical strategy. It is known that statistical methods can effectively deal with uncertain problems. Currently, researchers have applied it to solve the problem of structural damage identification of homogeneous beam-like structures [15]. Compared with the deterministic damage identification method, it can well present the uncertainties in damage identification which can better solve the impact of these problems on the damage identification results and improve the reliability of the damage identification results.

Despite the statistic structural damage detection method has successfully used for homogeneous materials, whether it works well or not for FG Euler-Bernoulli beams is still unknown and study on this topic should be carried out. In this paper, the statistic structural damage detection of FG Euler-Bernoulli beams based on element modal strain energy sensitivity is proposed. The modal shape and structural parameters (mainly stiffness parameters) are taken as random variables. The probabilities of damage in the beam elements can be obtained by comparing the distributions of the stiffness parameters before and after damage. Furthermore, the damage probability was used to determine whether the structure was damaged and the higher probabilities, the more chance of damage occurrence in the element. Results show that with the increase of damage degree, the damage probability of damage unit increases gradually, and finally tends to 1. The damage probability of most undamaged units gradually decreases, and finally tends to 0.05. Therefore, the higher the damage degree, the more accurate the damage identification result. With the continuous increase of noise level, the probability of damage existence of damaged element decreases gradually, while the probability of damage existence of undamaged element almost remains unchanged.

KEYWORDS

Functionally graded Euler-Bernoulli beam; structural damage detection; modal strain energy; statistical methods

Funding Statement: The author(s) received Key scientific research project of colleges and universities in Henan Province (No. 23A130002) for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References:

1. Kawasaki, A., Watanabe, R. (1997). Concept and P/M fabrication of functionally gradient materials. *Ceramics international, 23*, 73-83.
2. Naebe, M., Shirvanimoghaddam, K. (2016). Functionally graded materials: A review of fabrication and properties. *Applied materials today, 5*, 223-245.
3. Yu, X., Zhou, J., Liang, H., Jiang, Z., Wu, L. (2018). Mechanical metamaterials associated with stiffness, rigidity and compressibility: A brief review. *Progress Materials Science, 94*,114-73.
4. Gupta, A., Talha, M. (2015). Recent development in modeling and analysis of functionally graded materials and structures. *Progress in aerospace sciences*, *79*, 1-14.
5. Zhang, L.W., Song, Z.G., Qiao, P.Z., Liew, K.M. (2017). Modeling of dynamic responses of CNT-reinforced composite cylindrical shells under impact loads. *Computer Methods in Applied Mechanics and Engineering, 313*, 889-903.
6. Ts, C., Pja, B., Iz, C., Xl, C., Rza, B., Nl, C. (2021). Functionally graded materials beams subjected to bilateral constraints: structural instability and material topology. *International Journal of Mechanical Sciences, 194*,106218.
7. Dinachandra, M., Alankar, A. (2022). Static and dynamic modeling of functionally graded Euler-Bernoulli microbeams based on reformulated strain gradient elasticity theory using isogeometric analysis. *Composite structures, 280*, 114923.
8. Zhu, L.F., Ke, L.L., Zhu, X.Q., Xiang, Y., Wang, Y.S. (2019). Crack identification of functionally graded beams using continuous wavelet transform. *Composite Structures, 210*, 473-485.
9. Dang, V.H., Vu, T.C., Nguyen, B.D., Nguyen, Q.H., Nguyen, T.D. (2022). Structural damage detection framework based on graph convolutional network directly using vibration data. *Structures, 38*, 40-51.
10. Avci, O., Abdeljaber, O., Kiranyaz, S., Hussein, M. Inman, D.J. (2021). A review of vibration-based damage detection in civil structures: from traditional methods to machine learning and deep learning applications. *Mechanical Systems and Signal Processing*, *147*, 107077.
11. Pooya, S.M.H., Massumi, A. (2021). A novel and efficient method for damage detection in beam-like structures solely based on damaged structure data and using mode shape curvature estimation. *Applied mathematical modelling, 91*, 670-694.
12. Shi, Z.Y., Law, S.S., Zhang, L.M. (2002). Improved Damage Quantification from Elemental Modal Strain Energy Change. *Journal of Engineering Mechanics, 128*, 521-529.
13. Shi, Z.Y., Law, S.S., Zhang, L.M. (2000). Structural Damage Detection from Modal Strain Energy Change. *Journal of Engineering Mechanics*, *126*, 1216-1223.
14. Pooya, S.M.H., Massumi, A. (2022). A novel damage detection method in beam-like structures based on the relation between modal kinetic energy and modal strain energy and using only damaged structure data. *Journal*

of Sound and Vibration, *530*, 116943.

15. Yan, W.J., Ren, W.X., Huang, T.L. (2012). Statistic structural damage detection based on the closed-form of element modal strain energy sensitivity. Mechanical systems and signal processing, *28*, 183-194.