iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: XII Month of publication: December 2024

DOI: https://doi.org/10.22214/ijraset.2024.65794

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

Finite Element Analysis of Cracked Beams: A Literature Review

Sandhya Akhand[1], Dr. Raghvendra Singh[2]
[1]*PG Research Scholar,* [2]*Professor, Department of Civil Engineering, Ujjain Engineering College, Ujjain (M.P.) Bharat*

Abstract: Finite Element Analysis (FEA) is a powerful numerical tool for investigating the dynamic behavior of cracked beams, offering detailed insights into the effects of cracks on structural performance. FEA provides the ability to model complex geometries, varying material properties, and diverse boundary conditions with precision, making it an essential method for analyzing cracked beams. Finite Element Analysis (FEA) is a powerful numerical tool for investigating the dynamic behavior of cracked beams, offering detailed insights into the effects of cracks on structural performance. FEA provides the ability to model complex geometries, varying material properties, and diverse boundary conditions with precision, making it an essential method for analyzing cracked beams, and considering these facts, the present research work is devoted to the contributions of researchers in field of FEA of cracked beams. The review focuses finite element analysis used to analyze the cracked beams, and concludes with the investigated gaps in the research and objectives of a proposed research work.
Keywords: Cracks, cracked beams, ANSYS, finite element analysis, literature.

I. INTRODUCTION

Cracks in beams significantly influence their structural performance, introducing localized changes in stiffness, mass distribution, and damping properties. These changes disrupt the natural frequencies and mode shapes, which are critical indicators of a beam's dynamic behavior. Cracks may arise from fatigue, impact, or environmental factors, and their severity and location determine the extent of their impact on structural integrity. Understanding the behavior of cracked beams is crucial for applications in civil, mechanical, and aerospace engineering, where structural reliability is paramount. The interplay between cracks and vibrational characteristics makes them a focal point for structural health monitoring and damage detection strategies.

Modal analysis is a fundamental tool for studying the dynamic behavior of cracked beams, offering insights into their vibrational properties. By identifying natural frequencies, mode shapes, and damping ratios, modal analysis helps engineers predict how cracks alter a beam's response to dynamic loads. Analytical methods based on Euler-Bernoulli and Timoshenko beam theories provide theoretical frameworks, while numerical techniques such as finite element analysis (FEA) allow for detailed modeling of complex scenarios. Considering these facts, the present review is devoted to the contributions of researchers in the field of FEA analysis of cracked beams, and investigates the gaps of the research and objectives of proposed research.

II. CONTRIBUTIONS OF RESEARCHERS IN THE FIELD

The following outlines the research contributions in the field of cracked beams.

1) Tamrakar, A. (2024)

This research proposes a new Notched Cantilever Beam Energy Harvester (NCBEH) incorporating a PZT patch to enhance energy harvesting from low-frequency vibrations.

2) Grechi, R. (2024)

The study presents a simplified, continuum-based numerical modal analysis technique for modeling jointed and fractured rock masses, contributing to the understanding of modal behavior in complex geological structures.

3) Zhu, H. (2024)

This paper discusses an adaptive recursive subspace method for modal parameter estimation of concrete arch dams under seismic loading, enhancing the identification of dynamic characteristics in seismically excited structures.

4) *Ratnika, A. (2024)*
The research combines Operational Modal Analysis (OMA) and Finite Element Model (FEM) updating for structural health monitoring, providing a powerful tool for analyzing complex structures and detecting damage.

5) *Yun, Y. (2024)*
The study presents an LSTM-based method for stable identification of modal damping ratios in building structures, improving the accuracy of modal parameter identification.

6) *Freundlich, J. (2024)*
This paper investigates transient vibrations of a fractional viscoelastic cantilever beam with an eccentric mass element, contributing to the understanding of dynamic behavior in cantilever structures.

7) *Shashank, S. (2024)*
The research explores the effect of cut-outs on modal parameters of FRP composite plates, providing insights into the influence of design choices on dynamic performance.

8) *Kong, L. (2024)*
This study focuses on the vibration modes of shear walls in prefabricated modular construction, addressing the unique challenges posed by modular construction methods.

9) *Wang, Y. (2024)*
The paper discusses dynamic characteristics analysis methods for rotary drilling rig masts, utilizing ANSYS for theoretical modal analysis and experimental validation of results.

10) *Islam, M. (2023)*
This study proposes equations relating normalized frequency with varying crack depth and location, contributing to the understanding of damage detection in structural beams.

11) *Sahoo, S., & Jena, S. (2023)*
The research investigates the combined effects of lamina orientation and crack severity on the dynamic behavior of hybrid composite cantilever beams, providing insights into modal characteristics.

12) *Gautam, A. (2023)*
This work conducts harmonic analysis of a cantilever steel beam under various scenarios, including cracks, using ANSYS software to visualize changes in modal frequencies and deformation patterns.

13) *Francese, A., et al. (2023)*
The study investigates the dynamic response of 3D-printed beams with cracks, utilizing experimental modal analysis to quantify and localize defects.

14) *Choi, J., et al. (2023)*
This research analyzes changes to the dynamic characteristics of concrete sleepers using modal testing techniques, contributing to the assessment of structural integrity in concrete components.

15) *Aman, M. (2023)*
The paper discusses analytical methods for detecting damage in beams subjected to external factors, including cracks, emphasizing the use of squared normalized modal curvature as an indicator.

16) *Azhar, M., et al. (2023)*
This study compares modal parameters obtained from finite element methods and operational modal analysis, establishing a research database for modal parameters in plated structures.

17) *Deng, Y., et al. (2023)*
The paper discusses the application of characteristic modes in various engineering problems, providing insights that can be applied to modal analysis in structural contexts.

18) *Pirrotta, A., & Russotto, G. (2023)*
This research presents a new operational modal analysis method, validated through numerical simulations and experimental tests, relevant for structural health monitoring.

19) *Mironov, A., et al. (2023)*
The study explores vibration-based fault detection methods for structures, emphasizing the role of modal analysis techniques in structural health monitoring.

20) *Gärtner et al. (2022).*
This paper offers a specific proposal for implementing principles of responsible research assessment in practice, advocating for a broader range of relevant research contributions and proposing concrete quality criteria for published research articles, data sets, and research software.

21) *Schönbrodt et al. (2022).*
This study presents four principles of responsible research assessment in hiring and promotion, suggesting a two-phase assessment procedure that combines objective indicators with qualitative assessments of shortlisted candidates.

22) *Zheng et al. (2022).*
This study discovered the significant role of self-efficacy on emotion regulation, with implications for fostering effective teaching in higher education, particularly during the COVID-19 pandemic.

23) *Fraysier, A., & Reschly, A. (2022).*
This study examines the extent to which various demographic, academic, financial, and engagement factors contribute to postsecondary enrollment, supporting student engagement as an important factor in both secondary and postsecondary completion.

24) *Eaton, S., & Hughes, R. (2022).*
The authors conclude with a call to action for enhanced support for academic integrity scholarship to advance advocacy, policy, and practice.

25) *Estrada, M., et al. (2022).*
This study explores the relationship between emotions and students' academic performance during the pandemic, highlighting the importance of emotional intelligence and resilience.

26) *Zalazar-Jaime, M., et al. (2022).*
The results highlight the contribution of positive affect on academic satisfaction and its impact on life satisfaction.

27) *Lee, J. et al. (2022)*
The proposed token system aims to expand recognition metrics, promote efficiencies, and improve the robustness of professional assessments in academia.

28) *Elliott, K., et al. (2022).*
This paper presents a survey on the perceptions of the global research community regarding predatory journals and conferences, contributing to the understanding of this important issue.

29) *Motta, M. (2022).*
This editorial categorizes articles published in leading practitioner-focused journals into different types, providing insights into the nature of technological articles in business contexts.

30) *Wang & Zhou (2021)*
This study presents a comprehensive approach to solving the static deflection mode shape function of cantilever beams subjected to transverse flow

31) *Li et al. (2021)*
The authors introduce a novel low-frequency FBG (Fiber Bragg Grating) acceleration sensor utilizing a multi-cantilever beam design.).

32) *Uyar (2021)*
This article discusses the use of the finite element method (FEM) for dynamic modeling of flexible structures, specifically cantilever beams.

33) *Zhang et al., (2021)*
The authors explore the application of dynamic adaptive technology to identify modal parameters in cantilever structures, particularly in chip manufacturing. This research is crucial for understanding the vibrational behavior of cantilever beams under high-frequency conditions, which can be directly related to modal analysis techniques used in assessing cracked beams.

34) *Heydari et al. (2021)*
This study investigates the fluid-structure interaction of a flexible cantilever cylinder in low Reynolds number flows. The research provides valuable insights into the dynamic behavior of cantilever structures under fluid forces, which can be critical for modal analysis, especially when assessing the impact of cracks on structural integrity in fluid environments.

35) *Fan et al. (2021)*
The authors present a design and optimization study of an electromagnetic-piezoelectric composite vibration generator. This research highlights the relationship between cantilever beam dimensions and their vibration characteristics, providing a basis for understanding how modifications in beam design can influence modal properties, particularly in cracked structures.

36) *Khalid et al. (2021)*
This paper addresses the limitations of single-degree-of-freedom models in describing the motion of low-frequency cantilever fiber Bragg grating accelerometers. By introducing a modal model that considers multiple vibration modes, the authors enhance the understanding of vibrational behavior, which is essential for accurate modal analysis of cracked cantilever beams.

37) *Jiang et al. (2021)*
The research focuses on vibration monitoring using buckypaper sensors in composite structures. The findings emphasize the importance of monitoring vibration in cantilever beams, especially under dynamic loading conditions, which is critical for assessing the impact of cracks on modal behavior.

38) *Ansari (2021)*
This review discusses various aspects of vibration analysis in cracked cantilever beams, emphasizing the unique properties of fiber-reinforced composite materials. The paper provides a comprehensive overview of how cracks affect dynamic performance, which is vital for modal analysis applications in engineering.

39) Rincón et al. (2021)
The study presents an active vibration absorber model for continuous structures, which can be applied to cantilever beams. The research contributes to the field by exploring methods to mitigate vibrations, thereby enhancing the understanding of modal behavior in cracked cantilever structures.

40) Baitharu, S., & Kumar, A. (2020)
The authors present a numerical approach to analyze non-Darcy mixed convective flow over vertical surfaces, which is relevant for understanding the effects of fluid interactions on the dynamic behavior of cantilever beams in various thermal conditions.

41) Dey, S., & Ghosh, P. (2020)
The study examines the oscillatory behavior of cantilevered micro beams driven by viscoelastic flow instabilities, providing valuable data on the dynamic response of cantilever beams under complex fluid conditions.

42) Rosali, A., & Kadir, M. (2020)
This paper discusses unsteady boundary layer flows in porous media, offering insights into how such conditions can affect the vibrational characteristics and stability of cantilever beams.

43) Adewusi, S. (2020)
The research focuses on the performance of double-cantilever dynamic vibration absorbers, highlighting their effectiveness in mitigating vibrations in cantilever structures, which is crucial for enhancing structural performance.

44) Gherieb, M., & El-Sayed, M. (2020)
The authors introduce a new generalized decomposition method for analyzing hydromagnetic flows, providing a framework that can be applied to study the effects of magnetic fields on the dynamics of cantilever beams.

45) Ravve, A., & Koren, Z. (2020)
This study presents a method for ray tracing in heterogeneous media, which can enhance the modeling of wave propagation in cantilever structures, contributing to the understanding of their dynamic behavior.

46) Hao, Y., & Zhang, L. (2020)
The research investigates the dynamic response of PVDF cantilevers subjected to droplet impacts, providing insights into the electromechanical behavior of cantilever sensors and their potential applications in energy harvesting.

47) Farokhi, S., & Ghayesh, M. (2020)
This study examines the dynamics of cantilevers under coupled base excitation, contributing to the understanding of resonance phenomena and the impact of external excitations on the modal properties of cantilever structures.

III. GAPS IN THE RESEARCH AND OBJECTIVES OF PROPOSED RESEARCH

The survey of available literature revealed the following observations:

a) Very few research papers focused on cracked metallic beams with varying lengths.
b) Almost no research papers addressed the deformation of cracked beams.

Following points represent the objectives of the research work:

a) Determination and comparison of natural frequency parameters at different mode shapes for cracked beams of different lengths; and
b) Determination and comparison of total deformation values at different mode shapes for cracked beams of different length.

IV. CONCLUSION

The present research work was focused on the contributions of researchers in the field of cracked beams and modal analysis, which, ultimately lead to the gaps in the research and objectives for a upcoming research, which might be useful for upcoming researches.

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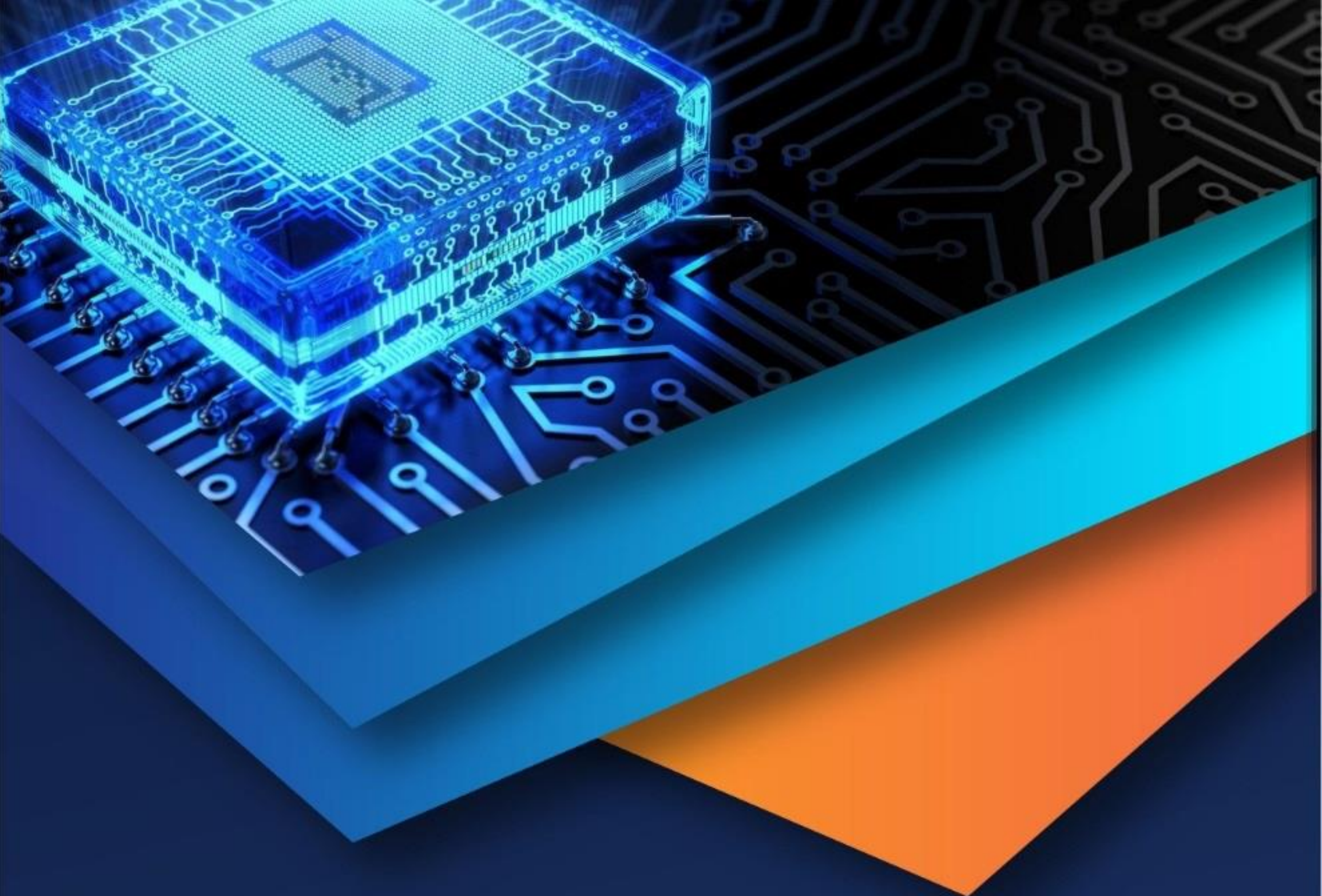

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