

Analysis of Different Cracked on Cantilever Beam Using Ansys Software

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Abstract

A cantilever beam is a rigid structural element supported at one end and unbalanced at the other. Cantilever beams are commonly used in construction to support balconies, roofs, and other overhangs. This investigation focused on analyzing the impact of crack depth and location on the natural frequency of cantilever beams made of mild steel, aluminum, and stainless steel. The study considered beams with a length of 3m, width of 0.25m, and depth of 0.20m, employing modal analysis to examine the first three modes of transverse vibration for cracked beams. Cracks were located at 0.5m, 1.5m, and 2.5m from the fixed end on both the top and bottom surfaces, with a fixed depth and width of 0.002m and 0.1m, respectively. Finite Element Analysis (FEA) simulations using Ansys software revealed that the natural frequency of cracked beams decreased compared to uncracked ones. Mild steel consistently exhibited slightly higher natural frequencies than aluminum and stainless steel, suggesting its superior performance in terms of crack resistance, deformation control, and suitability for fixed-end beam applications.

1. Introduction

A cantilever beam is a rigid structural element that is supported at one end and unbalanced at the other. Cantilever beams are commonly used in construction to support balconies, roofs, and other overhangs. Cantilever beam behaviour has a significant impact on engineering design and analysis. A cantilever beam's stability, deflection, and ability to carry loads are important aspects that must be taken into account during the design process. One of the key considerations in structural engineering and analysis is damage. All constructions are prone to degenerative effects while they are in use, which could start cracks like fractures and eventually cause the structure to collapse or fail catastrophically [1]. A crack in a structural member introduces local flexibility that would affect vibration response of the structure. Cracks can appear in mechanical foundations for a variety of reasons. In structural members like beams, the presence of a crack typically results in a reduction in stiffness, which depends on two factors: the location of the crack and its depth [2,3]. Thus, the appearance of a single crack in a cantilever beam could result in the collapse of a substantial structure. It is challenging to carry out an analytical modal analysis of a cantilever beam when there are discontinuities. Non-destructive testing (NDT) techniques and other conventional fracture detection procedures can be costly and time-consuming. A powerful method for identifying and analyzing cracks in structures, especially cantilever beams, is finite element analysis (FEA) [4]. The previous research investigations delved into the structural analysis of cantilever beams, employing finite element analysis to assess the impact of cracks and crack damage [5-8].

Finite element analysis, a function of the Ansys software, was used in this study to assess the natural frequencies of a crack beam. The purpose of this study is to analyse and simulate the behaviour of a cantilever beam with different types of cracks in order to discover how such flaws affect the beam's structural integrity.

2. Materials and Methods

This chapter explains the methodology and approaches used in the research. The researcher uses two separate software for the generation of the model and simulation, respectively. Before the start of the simulation, the model and geometry need to be generated first using SolidWorks. After that, the models are converted and imported to ANSYS Workbench for meshing. After generating a mesh of the models, the models need to be set up with fixed-end support. Lastly, select the solve option and run the simulation and analysis to obtain the result.

2.1 Model and Geometry

SolidWorks is a popular computer-aided design (CAD) software used by engineers and designers to create and simulate three-dimensional models of products. A three-dimensional cantilever beam made in SolidWorks will be used to do that. The beam dimensions are 3m in length, 0.25m in width, and 0.2m in thickness were taken from the previous studies [9]. The beam's cross-sectional area (A) is 0.05 m². Six models with three transverse cracks at different distances with models were built for simulation and analysis. Cracks were located at 0.5m, 1.5m, and 2.5m from the fixed end on the top and bottom surfaces, with a fixed depth and width of 0.002m and 0.1m, respectively. Fig. 1 shows the model of the uncrack and cracked cantilever beam.

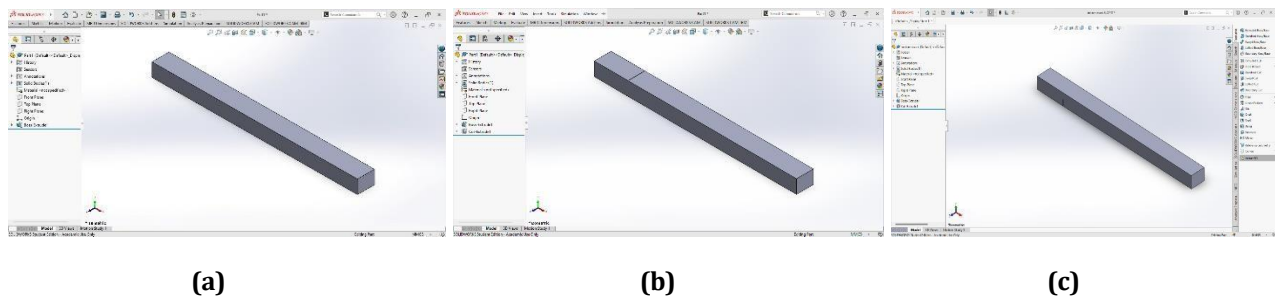


Fig. 1 Uncrack beam(a), Top crack at 0.5m (b), Bottom crack at 0.5m(c)

2.2 ANSYS Software

ANSYS software was used for the simulation of this experiment to obtain the results. ANSYS is software that has a wide range of range from electrical, mechanical, structural, and other functions. In the analysis used ANSYS Workbench, the study began by selecting modal analysis as the analytical framework from the Toolbox panel. Engineering data was input and access to material properties for mild steel, aluminum and stainless steel. Table 1 shows the material properties of each material. In the geometry section of the research, SolidWorks models in IGES format were imported for simulation and analysis using ANSYS software. ANSYS's meshing functions, crucial for optimal geometry meshing, consider project-specific solutions and criteria to achieve the best mesh potential. The minimum Orthogonal Quality value should be larger than 0.14 and the maximum Skewness value should be less than 0.95[10].

Fig. 2 indicates the mesh model of materials. Uniform values for nodes, elements, and skewness across various materials indicate sufficient resources for obtaining reliable and consistent simulation results. Boundary conditions were established for each model, simulating fixed-end support for cantilever beams and applying loading conditions at the free end. These conditions were vital for capturing structural behavior and deformation, providing insights into mechanical performance. The 'Solution' option incorporated solvers to generate data for further analysis, and upon completion, ANSYS presented analysis outcomes, including natural frequency and mode shapes. The entire process was visually illustrated, emphasizing the importance of each step in analyzing a cracked cantilever beam.

Table 1 *Material Properties*

Material	Mild Steel	Aluminium	Stainless Steel
Density	7860kg/m ³	2700kg/m ³	8000kg/m ³
Young's Modulus	210×10 ⁹ N/m ²	70×10 ⁹ N/m ²	200 × 10 ⁹ N/m ²
Poisson's Ratio	0.3	0.3	0.3
Bulk Modulus	1.75×10 ¹¹ N/m ²	5.8333×10 ⁹ N/m ²	1.6667×10 ¹⁰ N/m ²
Shear Modulus	8.0769×10 ¹⁰ N/m ²	2.6923×10 ⁹ N/m ²	7.6923×10 ⁹ N/m ²

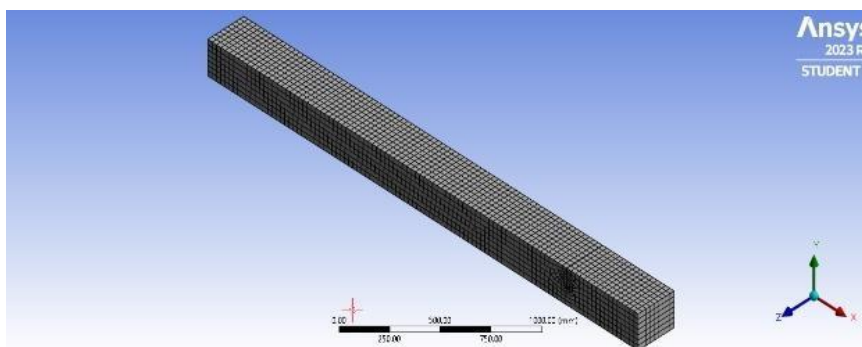


Fig. 2 Mesh model crack beam at 2.5m from fixed end.

3. Results and Discussion

In this chapter, the result obtained from simulation for natural frequency and maximum deformation will be discussed. As discussed in the previous chapter, ANSYS software was used to simulate and obtain results using different distance cracks on both surfaces with different materials in the Model Solver system. Each model underwent a comprehensive perforation analysis using Ansys software with appropriate configurations to obtain the required outcomes.

The research aimed to provide insights into how crack distance and material composition influence cantilever beams' natural frequencies and mode shapes. The study revealed diverse results in natural frequencies and mode shapes for different material models when cracks were introduced at various positions on the cantilever beam surface.

3.1 Frequency of Crack Beam at Both Surface with Different Material

The natural frequency of a system or structure is its vibration frequency following an initial excitation in the absence of a driving or damping force [4]. The results of the study revealed a consistent trend across different materials: an increase in the depth of surface cracks corresponded to a decrease in natural frequencies. Fig. 3, Fig. 4 and Fig. 5 depicted the graph of natural frequency frequencies of various materials at modes 1, 2, and 3, respectively, illustrating the influence of crack depth on natural frequencies. When cracks are formed in the beam, the natural frequencies are strongly affected. The crack size has a greater effect on the dynamic characteristics than the number of cracks [6]. The location of the crack influenced natural frequencies, with bottom cracks typically resulting in slightly higher natural frequencies at the same depth. Depending on where the crack is, there are differences in the frequency of top and bottom edge cracks [9].

Modal analysis of both top and bottom cracks in mild steel was presented in Fig. 6, Fig. 7, and Fig. 8 for modes 1, 2, and 3, respectively. In the case of mild steel, the study revealed that a top crack at 0.5 mm exhibited a Mode 1 frequency of 15.019 Hz, which decreased to 18.551 Hz at a depth of 2.5 mm, indicating a reduction in stiffness with deeper cracks. Similar trends were observed for the bottom crack in mild steel. For aluminum alloy, renowned for its lightweight properties, natural frequencies consistently decreased with increasing crack depth, illustrated by the top crack at 0.5 mm with frequencies of 14.795 Hz, 110.75 Hz, and 298.86 Hz for Modes 1, 2, and 3, respectively. Stainless steel, known for its corrosion resistance, exhibited comparable trends, with a top crack at 0.5 mm, resulting in Mode 1, Mode 2, and Mode 3 frequencies of 14.529 Hz, 108.75 Hz, and 293.47 Hz. Compared to mild steel, the bottom crack at 2.5 mm in stainless steel showed somewhat lower frequencies,

indicating a more robust response. This comprehensive examination underscored the distinctive behaviors of each material and their susceptibility to structural changes induced by cracks.

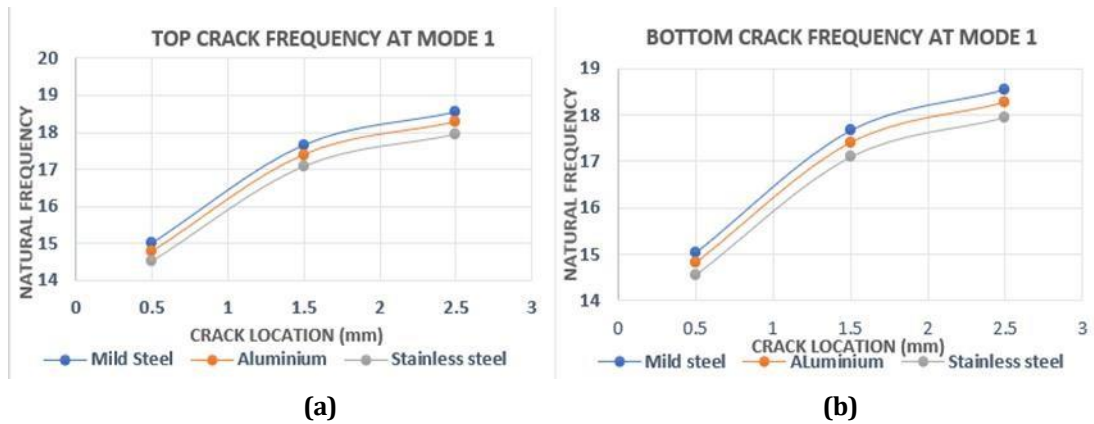


Fig. 3 Graph of top crack frequency(a), Graph of bottom crack frequency at mode 1(b)

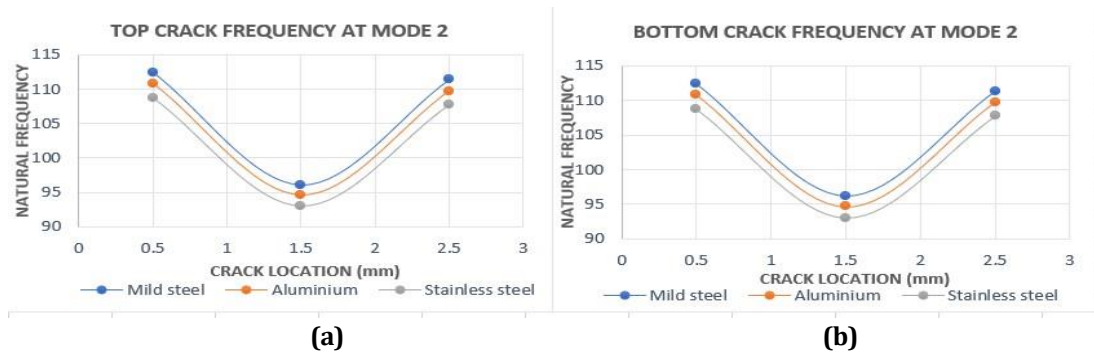


Fig. 4 Graph of top crack frequency(a), Graph of bottom crack frequency at mode 2(b)

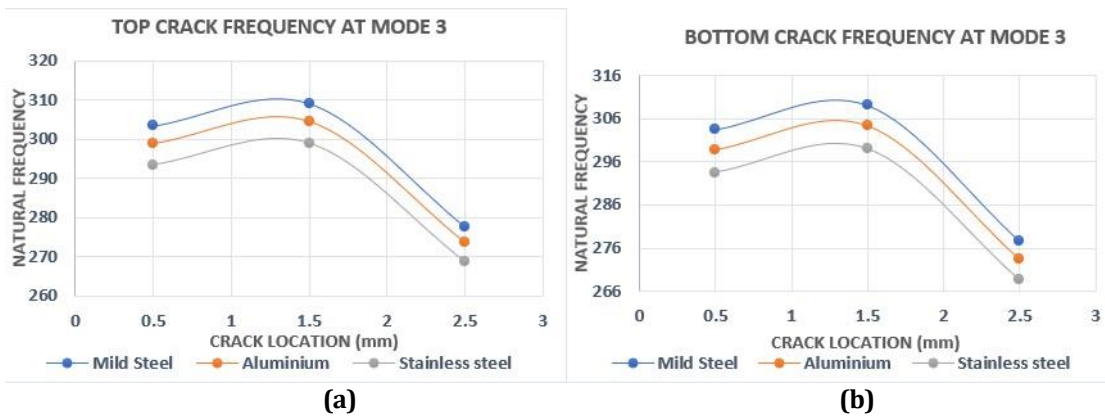


Fig. 5 Graph of top crack frequency(a), Graph of bottom crack frequency at mode 3(b)

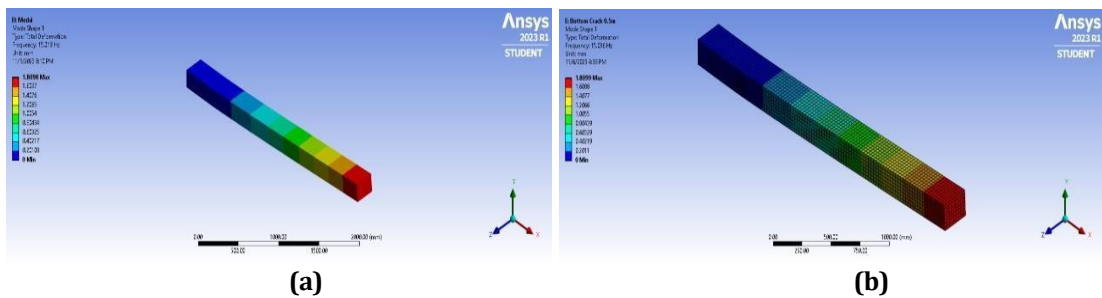


Fig. 6 Modal analysis top crack at 0.5m(a), Modal analysis bottom crack at 0.5m(b)

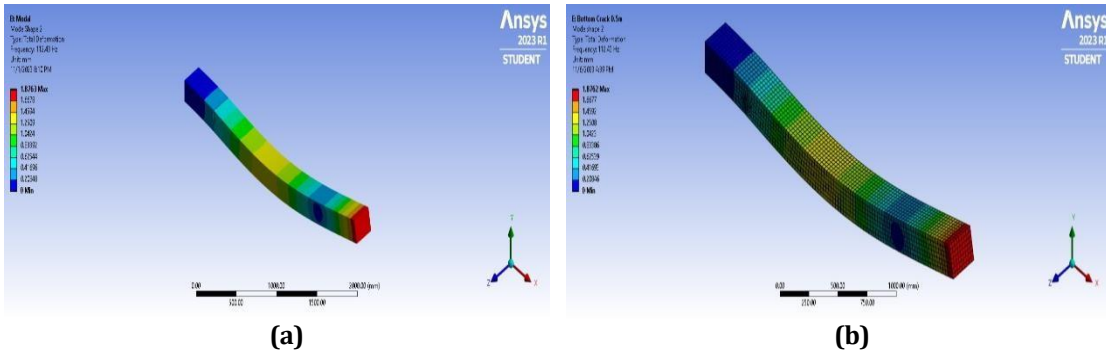


Fig. 7 Modal analysis top crack at 1.5m(a), Modal analysis bottom crack at 1.5m(b)

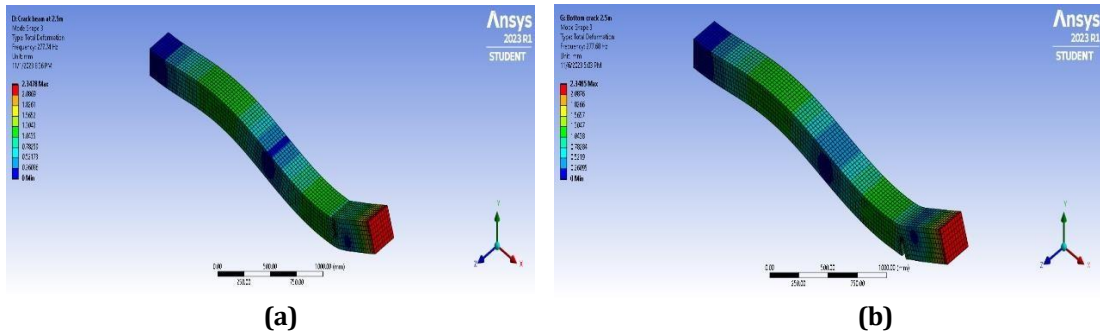


Fig. 8 Modal analysis top crack at 2.5m(a), Modal analysis bottom crack at 2.5m(b)

3.2 Compared of Natural Frequency with Top and Bottom Surface Crack

The top and bottom surfaces of the different materials utilized in the cantilever beam all had similar crack dimensions (0.5, 1.5, and 2.5 m) and depths (1.0 m). The investigation showed that the related frequencies of the cantilever beam's top and bottom surfaces differed slightly by 0.1, respectively, with all materials. Fig. 9, Fig.10 and Fig. 11 display the graphs illustrating the natural frequency of both surface cracks for different materials. This suggests that the dynamic features of the beam were influenced by the positioning of cracks at various points along its length [10].

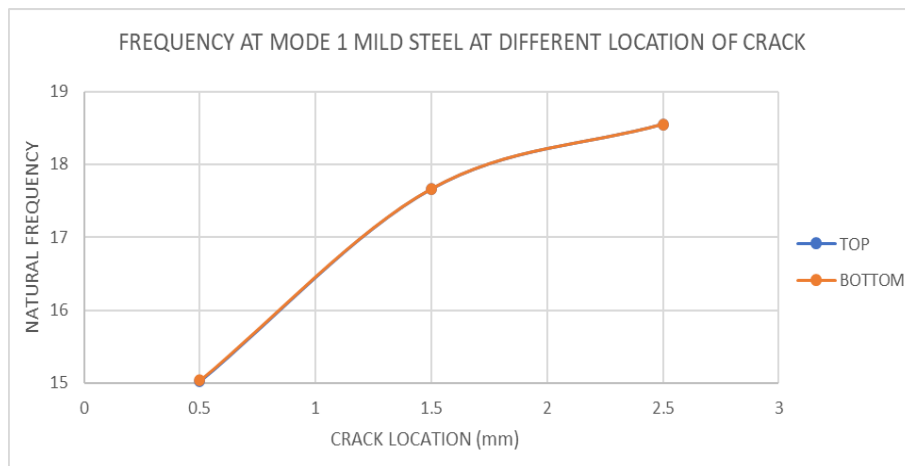


Fig. 9 Natural frequency of both surfaces in mild steel.

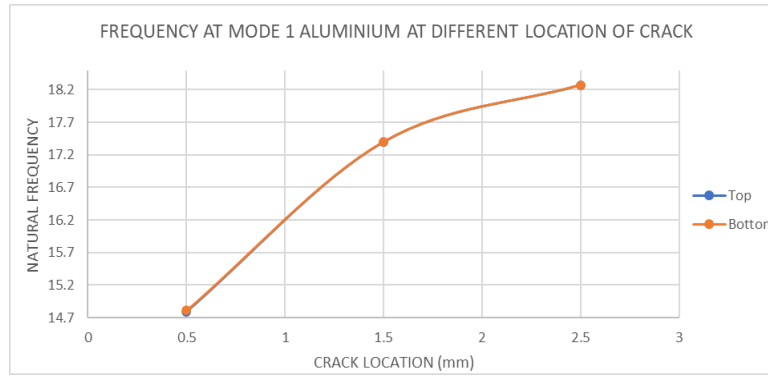


Fig. 10 Natural frequency of both surfaces in aluminum

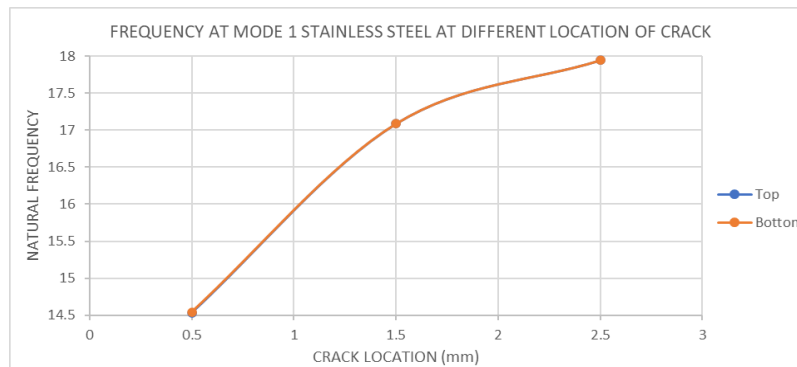


Fig. 11 Natural frequency of both surfaces in stainless steel

3.3 Maximum Deformation of Crack Beam of Different Material

The structural deflection responses of stainless steel, aluminum alloy, and mild steel were investigated under various surface crack depths. Fig. 12, Fig. 13 and Fig. 14 show the maximum deformation of different materials at mode 1, mode 2, and mode 3. The deflection analysis revealed notable patterns for mild steel, where deflections resulting from a top crack at 0.5 mm were 1.809 mm, 1.876 mm, and 1.773 mm for Mode 1, Mode 2, and Mode 3, respectively. As the crack deepened to 2.5 mm, deflections increased, with Mode 1 peaking at 1.85 mm and Mode 3 at 2.348 mm. Similar trends were observed for the bottom crack, underscoring mild steel's vulnerability to crack propagation and its impact on structural deflections.

Aluminum alloy, known for its lightweight properties, exhibited significant deflection changes with increasing crack depth, particularly at 2.5 mm where Mode 1, Mode 2, and Mode 3 deflections reached 3.157 mm, 3.201 mm, and 4.005 mm, respectively. Corrosion-resistant stainless steel displayed a resilient response, consistently showing lower deflections compared to mild steel, with Mode 1, Mode 2, and Mode 3 deflections at the top crack location of 0.5 mm measuring 1.794 mm, 1.859 mm, and 1.758 mm, and slightly greater deflections at the bottom crack of 2.5 mm. The analysis emphasized the need for preventive maintenance in mild steel due to its susceptibility to crack propagation, cautious design considerations for aluminum alloy in weight-sensitive situations, and the enduring response of stainless steel to rising crack depths.

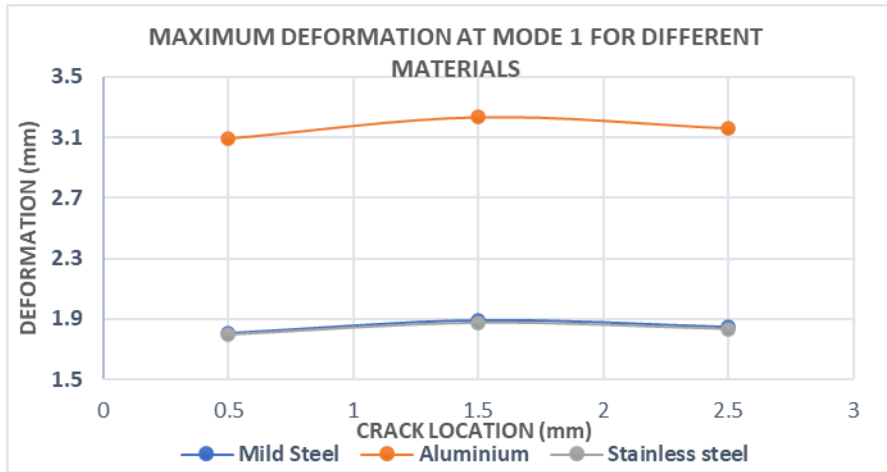


Fig. 12 Maximum deformation of different materials at mode 1

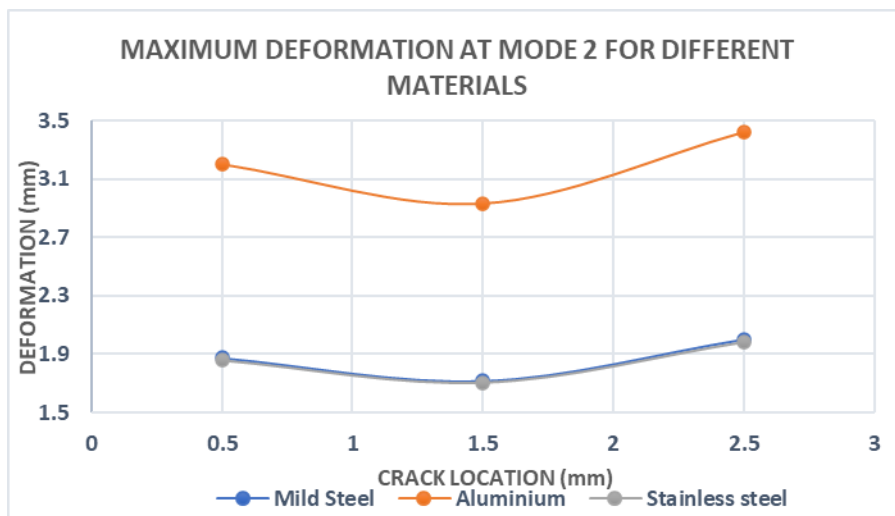


Fig. 13 Maximum deformation of different materials at mode 2

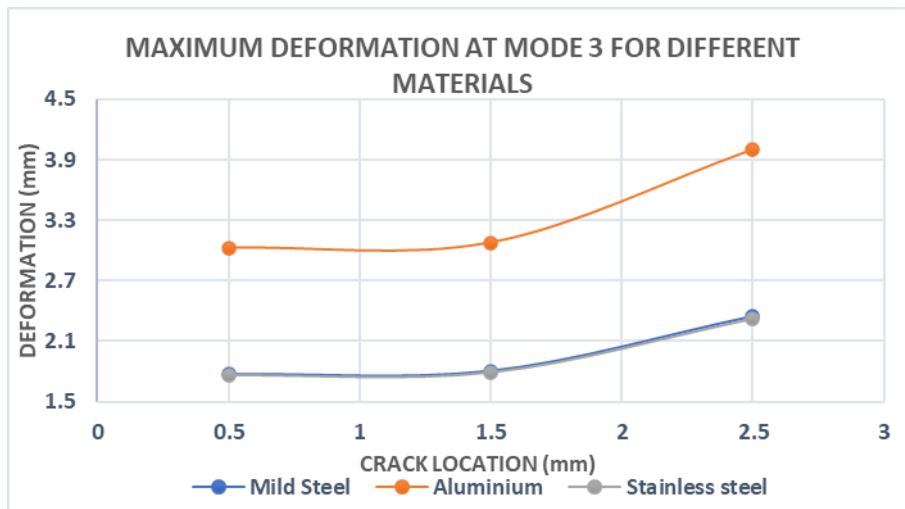


Fig. 14 Maximum deformation of different materials at mode 3

4. Conclusion

In conclusion, the modal analysis of mild steel, aluminum alloy, and stainless steel under varying surface crack depths has provided insightful observations into their dynamic behaviors, considering different crack depths and locations. The study aimed to assess the influence of crack depth and position on frequency, determining natural frequencies and mode shapes of cantilever beams with cracks. The consistent correlation between deeper cracks and reduced natural frequencies across all materials indicates a decrease in structural rigidity. Variations in natural frequencies between top and bottom crack scenarios highlight the significance of crack location.

Mild steel demonstrates susceptibility to crack propagation, emphasizing the need for preventive maintenance. Aluminum alloy exhibits notable deflection changes with deeper cracks, underlining the importance of careful design in weight-sensitive applications. Stainless steel consistently displays lower deflections compared to mild steel, showcasing its endurance and suitability for applications demanding improved structural integrity despite surface defects. Mild steel consistently exhibits slightly higher natural frequencies than aluminum and stainless steel across all modes, suggesting greater stiffness and improved structural stability. This study advocates for the use of mild steel in fixed-end beam applications due to its superior performance in natural frequencies, crack resistance, and deformation control.

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