Vibration Analysis of Cracked Overhang Beam Using Experimental Method

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ABSTRACT

The presence of cracks may winds up in damage in structural elements which ends up in in failure of the structure. So that the physical characteristics and dynamic response of a structure also changes. Hence it's vital to check the dynamics of the structures within the current study; vibration analysis of an overhang beam with single open transverse crack for various crack depth and different crack locations is completed using experimental method. To research the vibration characteristics of overhang beam two cases are considered, first is without crack and second case is with crack. For transverse load condition an impact hammer is taken and impacted on five different points at same distance from fixed end of overhang beam from certain height. This analysis is completed to check the response characteristics (i.e. frequency and amplitude) of cracked overhang beam and to search out an effect of crack on these response characteristics. From the results, it's found that, as crack depth increases natural frequency decreases.

Keywords: Overhang beam, crack, crack depth, crack location, natural frequency.

1 Introduction

The occurrence of cracks often leads to damage in structural elements which results in failure of the structure and also changes the physical characteristics and dynamic response of a structure. Crack is one of the foremost common faults that if develops may cause catastrophic damages in structures. That's why, it must be detected in the early stage when it is small. Crack like defects in Mechanical and Engineering structures are a problem that received considerable attention by researchers. Since beam type structures are very common used in steel construction and machinery industries, for the last few decades engineers and scientists are working on various techniques for detection of crack in the beam like structure [19].

The presences of crack not only cause a neighborhood variation in the stiffness but it also affects the mechanical behavior of the whole structure to a considerable extent. Cracks may be caused by fatigue under service condition as a result of the limited fatigue strength. Generally, they are small in sizes. Such small cracks propagate due to the fluctuating stress conditions. If these propagating cracks remain undetected and reach their critical size, then a sudden structural failure occurs [7]. In practice, it is difficult to acknowledge most cracks by using visual inspection techniques. Nowadays, the procedures that are often used for crack detection are those which are called direct procedures, such as Ultrasonic, X-rays, Acoustic emission, Radiography etc. But these methods cannot be used for condition monitoring of structures. So vibration based method is selected for analysis which can be used in condition monitoring of Overhang beam.

For various crack depths, experimental analysis is carried out by using FFT analyzer and numerical analysis is carried out by Finite Element Method by using ANSYS program and first three natural frequencies are obtained. After performing experimentation and considering analytical results, it is observed that natural frequency decreases with increase in relative crack depth. Also, mode shape varies due to

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presence of cracks. By identifying the cracks well in advance, appropriate measures can be taken and damage can be prevented.

A crack or local defect affects the vibration response of structural member. It results in changes of natural frequencies and mode shapes. A crack in a structure introduces a local flexibility that can change the dynamic behavior of the structure and this property used to detect existence of a crack together with its location and depth in the structural member.

2 Experimental Set up and Procedure

Experimental Setup Description

Overhang Beam having material Mild steel beams were used for this experimentation. The 10 beam models with the fixed-free ends are to be considered for experiment. Each beam model was of cross-sectional area 30mm X 20mm with a length of 600 mm from fixed end. It has the below mentioned properties:

Table 1. Geomeric and properties of material

Geometric and material properties	
Material	Mild Steel
Length	0.6 m
Width	0.020 m
Height	0.030 m
Modulus of elasticity	210 Gpa
Density	7850 kg/m3

Fig.1 shows that, two heavy plates are used to clamp the one end of overhang beam with the assistance of fasteners. Accelerometer is kept on beam at a distance of 50mm from open end for both the cases i.e. for no load condition and for loading condition. Accelerometer is connected to FFT analyzer for data acquisition.

3 Experimental Process

The fixed–free beam model was clamped at one end and supported at other end in a fixture. In modal test, the accelerometer is kept at free end.

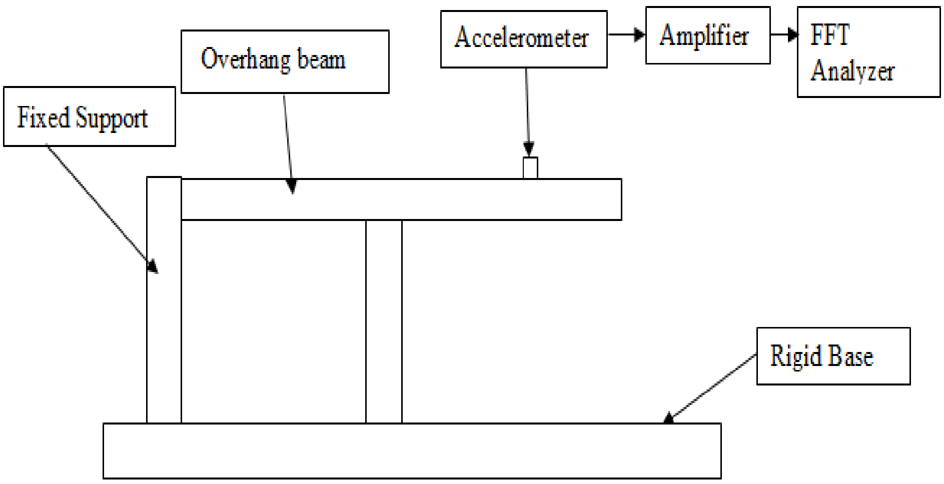

Fig.1 Two heavy plates are used to clamp

To get the natural frequency values beam is vibrated by using impact hammer at different points on beam. By using modal test first three natural frequencies are extracted. Cracks were generated to the specified depth using a wire cut EDM; the crack always remained open during dynamic testing Total 10 beam models were tested with cracks at different locations ranging from a location near to fixed end and 1 beam model was healthy tested without crack. The crack depth varied from 4mm, 8mm and 12mm at each crack position. Each model was excited by an impact hammer. This served as the input to the system. It is to be noted that the model was excited at a point, which was a few millimeters away from the center of the model. This was done to avoid exciting the beam at a nodal point (of a mode), since the beam would not respond for that mode at that point. The dynamic responses of the beam model were measured by using light accelerometer placed on the model as indicated in Fig. 1. The response measurements were acquired, one at a time, using the FFT analyzer.

3.1 Data acquisition is done using accelerometer and FFT analyzer.

Step wise Experimental Procedure

a) Mount the fixture rigidly on beam by using fasteners.
b) Take a bar of rectangular cross section and fix one end of the bar in to fixture.
c) Make all the mandatory connections of FFT analyzer, PC, Vibration exciter and Power Oscillator-amplifier unit.
d) Open the software of vibration analysis i.e. Dewe soft software. Mount accelerometer on Overhang beam at specific distance from free end.
e) Ensure that, all the knob of power oscillator-amplifier unit is at their initial position and then make Power Oscillator-amplifier unit on.
f) Mark the five at same distance points on overhang beam for hammer impact.
g) Excite the beam with the help of Impact Hammer.
h) To find out the frequency at each point impact the hammer three times at first point. It will take average of that and gives frequency response curve for that point.
i) Repeat the procedure for one healthy beam and nine cracked specimen and find out frequency response curve, MIF and phase change curve.

4 Result And Discussions

4.1 For no load condition (Modal test)

Results obtained from Modal test using FFT analyzer are given in following Table II. Results consist of first three natural frequencies for different beam specimens who are made of different crack depth and different crack locations. From following Table 1 it observed that, crack causes decrease in natural frequency of overhang beam. Results obtained from modal test can be use to find the effect of crack depth and crack location on natural frequency.

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Table II: Results of Modal Test

Crack Location from Fixed End (mm)	Crack depth (mm)	Natural frequency (Hz)		
		fn1	fn2	fn3
Uncrack (Healthy Beam)	No	18	78	196.5
100	4	15.969	73.2	192.87
	8	15.869	72.02	190.430
	12	13.428	70801	187.988
200	4	12.207	69.580	185.547
	8	10.986	68.359	183.370
	12	9.766	67.139	181.885
300	4	8.545	63.477	180.664
	8	7.324	59.814	175.781
	12	8.545	50.49	158.806

4.2 Effect of different crack depths on first natural frequency

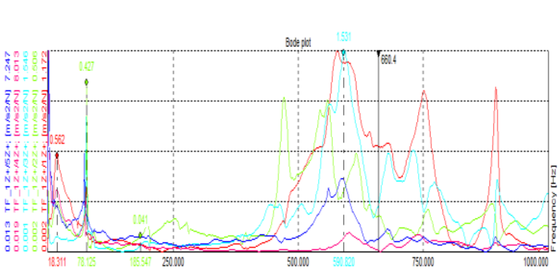


Fig.2 Natural frequency graph of Healthy Beam

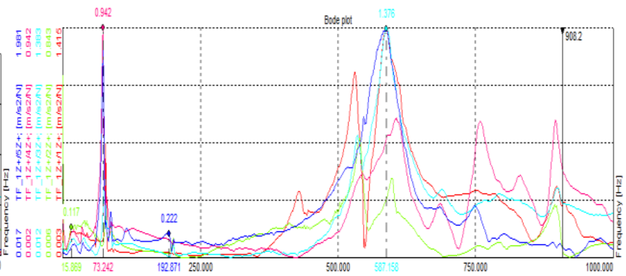


Fig.5 Natural frequency graph of Cracked Beam(CL100mm CD 4mm)

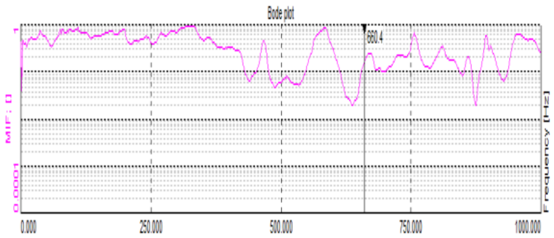


Fig.3 MIF graph of Healthy Beam

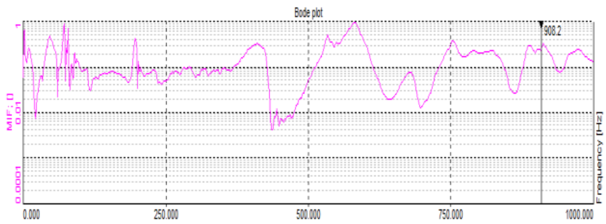


Fig.6 MIF graph of Cracked Beam(CL100mm CD 4mm)

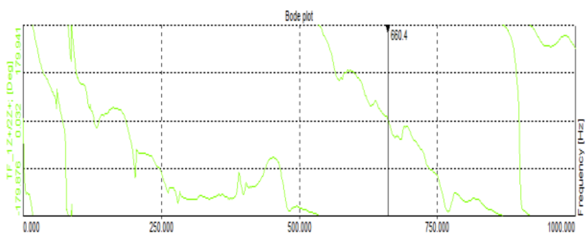


Fig.4 Phase Change graph of Healthy Beam

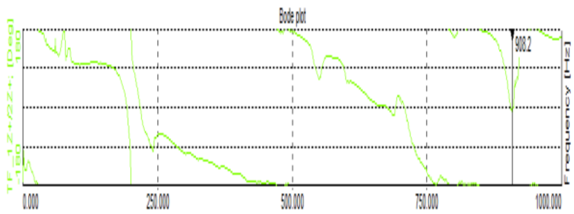
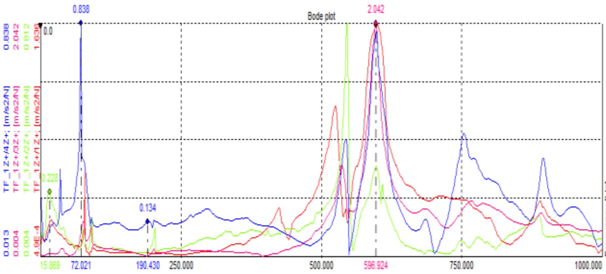


Fig.7Phase Change graph of Cracked Beam(CL100mm CD 4mm)

Inferences from above result

From Fig. 2-7, it is observed that, natural frequency decreases as crack depth increases for all Crack Locations (CL).

4.3 Effect of different crack depths on first natural frequency



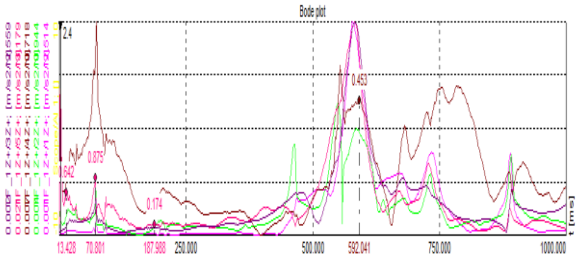
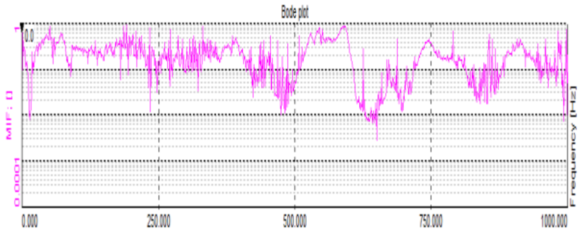


Fig.8 Natural frequency graph of Cracked Beam(CL100mm CD 8mm) Fig.11 Natural frequency graph of Cracked Beam(CL100mm CD 12mm)



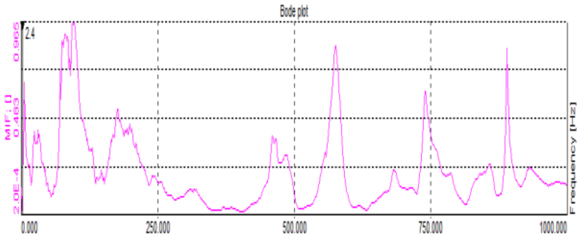
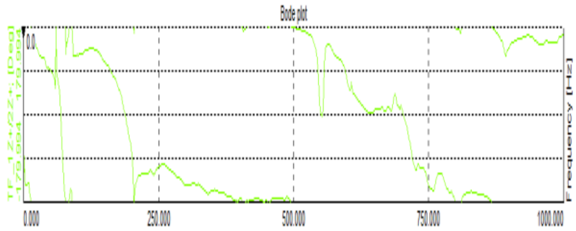


Fig.9 MIF graph of Cracked Beam(CL100mm CD mm) Fig.12 MIF graph of Cracked Beam(CL100mm CD 12mm)



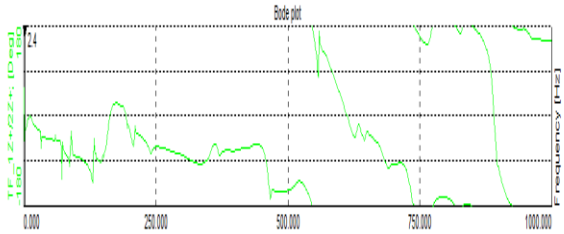
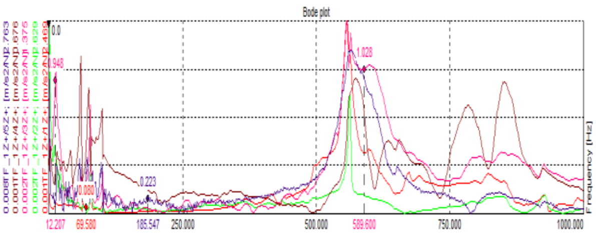


Fig.10 Phase Change graph of Cracked Beam(CL100mm CD 8mm) Fig.13 Phase Change graph of Cracked Beam(CL100mm CD 12mm)

4.4 Effect of different crack depths on first natural frequency



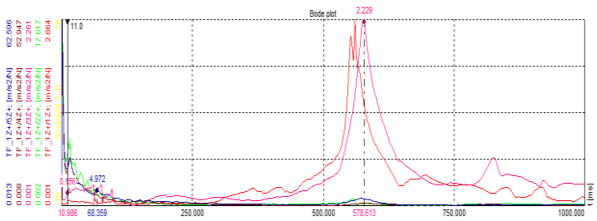
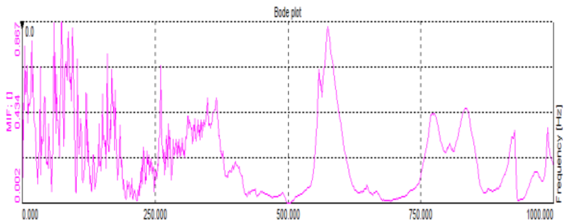


Fig.14 Natural frequency graph of Cracked Beam(CL200mm CD 4mm) Fig.17 Natural frequency graph of Cracked Beam(CL200mm CD 8mm)



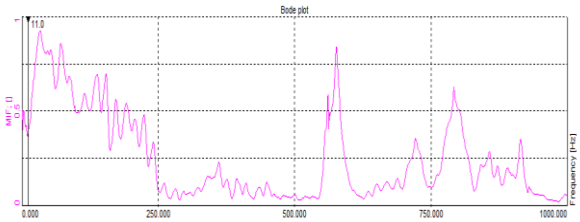


Fig.15 MIF graph of Cracked Beam(CL200mm CD 4mm) Fig.18 MIF graph of Cracked Beam(CL200mm CD 8mm)

Phase Change Phase Change

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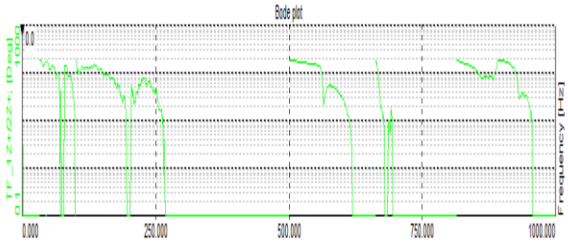

Fig.16 Phase Change graph of Cracked Beam(CL200mm CD 4mm)

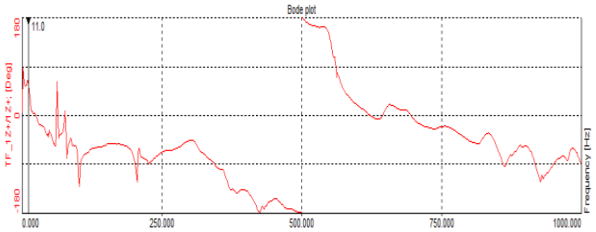

Fig.19 Phase Change graph of Cracked Beam(CL200mm CD 8mm)

4.5 Effect of different crack depths on first natural frequency

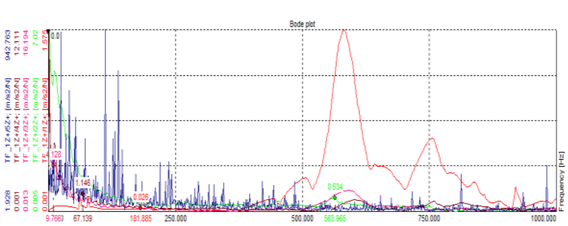

Fig.20 Natural frequency graph of Cracked Beam(CL200mm CD 12mm)

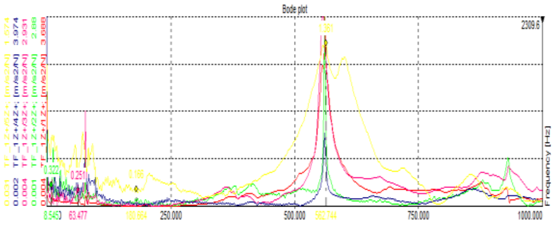

Fig.23 Natural frequency graph of Cracked Beam(CL200mm CD 12mm)

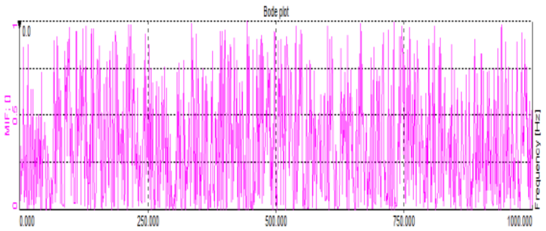

Fig.21 MIF graph of Cracked Beam(CL200mm CD 12mm)

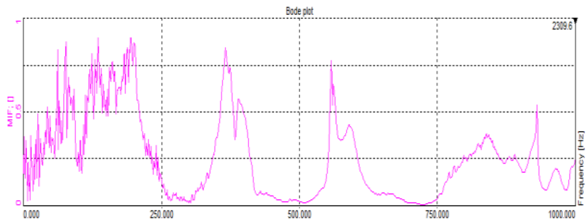

Fig.24 MIF graph of Cracked Beam(CL300mm CD 4mm)

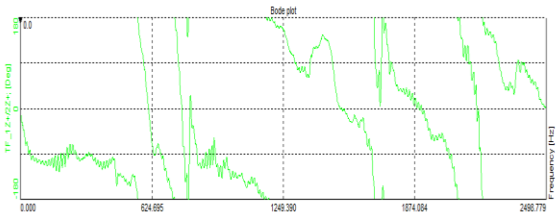

Fig.22 Phase Change graph of Cracked Beam(CL200mm CD 12mm)

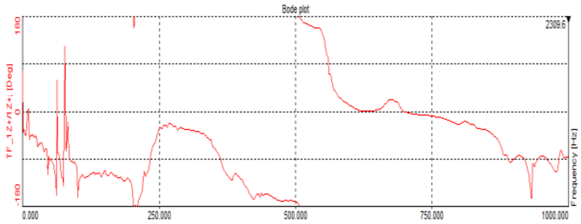

Fig.25 Phase Change graph of Cracked Beam(CL300mm CD 4mm)

4.6 Effect of different crack depths on first natural frequency

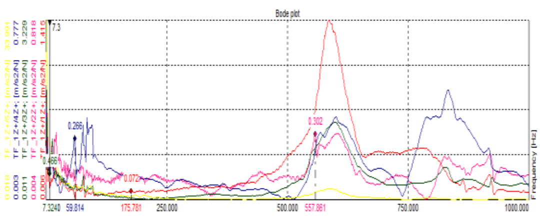

Fig.26 Natural frequency graph of Cracked Beam(CL300mm CD 8mm)

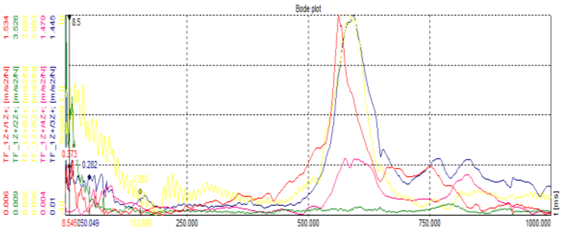

Fig.29 Natural frequency graph of Cracked Beam(CL 300mm CD 12mm)

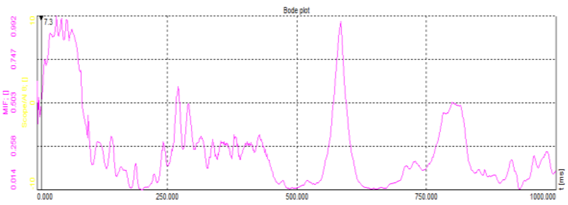

Fig.27 MIF graph of Cracked Beam(CL300mm CD 8mm)

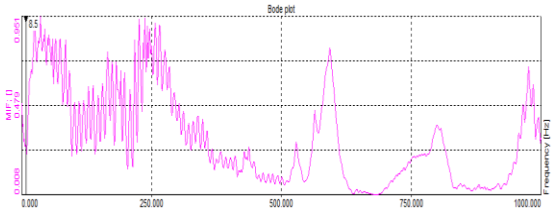

Fig.30 MIF graph of Cracked Beam(CL300mm CD 12mm)

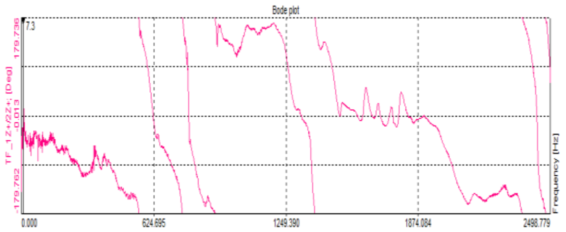

Fig.28 Phase Change graph of Cracked Beam(CL300mm CD 8mm)

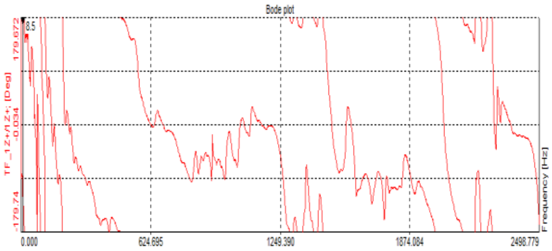

Fig.31 Phase Change graph of Cracked Beam(CL300mm CD 12mm)

From Fig., it is observed that, natural frequency decreases as crack depth increases for all Crack Locations (CL).

5 Conclusion

1. The first, second and third natural frequency of intact Overhang beam is 18 Hz, 78 Hz and 196.5 Hz respectively and that of all cracked specimen is less than above values of intact Overhang beam. Hence, presence of crack in Overhang beam results in decrease in natural frequency.
2. Crack located at 0.1m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of first natural frequency as 15.969Hz, 15.869Hz and 13.428Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
3. Crack located at 0.1m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of second natural frequency as 73.2Hz, 72.02Hz and 70.801Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
4. Crack located at 0.1m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of third natural frequency as 192.87Hz, 190.43Hz and 187.988Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
5. Crack located at 0.2m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of first natural frequency as 12.207Hz, 10.986Hz and 9.766Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
6. Crack located at 0.2m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of second natural frequency as 69.580Hz, 68.359Hz and 183.370Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
7. Crack located at 0.2m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of third natural frequency as 185.547Hz, 183.370Hz and 181.885Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
8. Crack located at 0.3m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of first natural frequency as 8.545Hz, 7.324Hz and 8.454Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.
9. Crack located at 0.3m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of second natural frequency as 63.477Hz, 59.814Hz and 50.49Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.

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10. Crack located at 0.3m from fixed end with crack depth 0.004m, 0.008m and 0.012m has values of third natural frequency as 180.664Hz, 175.781Hz and 158.806Hz respectively. Hence, as crack depth increases at constant crack location, natural frequency decreases.

The change in first second and third natural frequency with variation in crack location and crack depth is uniform i.e. as crack location increases from fixed end to free end, values of both frequencies increases. Hence, first, second and third natural frequency can be used for effective prediction of presence of crack.

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