Vibration analysis of cantilever beam with multiple cracks using natural frequency as basic criterion

M.P.Kolhe[1], Prof .V.D.Wakchaure [2], Prof .A.V.Deokar[3]

[1]PG Student, Department of Mechanical Engineering, A.V.C.O.E. Sangamner Maharashtra, India
[2]Associate Professor, [3]Assistance Professor, Department of Mechanical Engineering, A.V.C.O.E. Sangamner, Sangamner, India

ABSTRACT

Beam type structures are being commonly used in steel construction and machinery industries, in structures and machines, and fatigue cracks are the main cause of beams failure. Crack occurs in beams to change its dynamic behaviour of structure and examining these changes in crack location and crack size are identified. The NDT methods are used for crack detection and which are costly and time consuming. In this paper the beam consider to open transverse cracks. Currently research has focused on using modal parameters i.e. natural frequency used as a basic criterion. In this paper the modal analysis was performed on cracked beams and a healthy beam, to calculate natural frequency. The first three natural frequencies wear considered for vibration analysis of beams. The vibration analysis result to shows the plot the effect of the second crack on the natural frequency and mode frequency ratio in terms of crack depth for various crack positions of the cantilever bar.

Keyword: *- Vibration based detection, crack, crack location and crack depth, natural frequency, mode*

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1. INTRODUCTION

The behaviour of members of structure varies as per damaged or undamaged condition. Most of structures fail due to damage like cracks in member. So, many experiments are done to know the dynamic behaviour of members. The cracks cause the reduction in stiffness and natural frequency. In this paper the objective is to get the natural frequency of cantilever beam with multiple cracks which alert from resonance of structure which leads to fail. And also verify the frequency with the experimental and analytical value. Mechanical structures in service life are subjected to combined or separate effects of the dynamic load, temperature, corrosive medium and other type of damages. Beam is widely used in aircrafts and machinery structures. Because of vibration and cyclic loading action it get cracks on it, that is fatigue cracks are the main cause of beams failure. This leads to the change in natural frequencies of member. This experiment is done to know the effect of crack characteristics (depth, location, number of cracks) on the natural frequencies of beam. The importance of an early detection of cracks appears to be crucial for both safety and economic reasons because fatigue cracks are potential source of catastrophic structural failure.

2. LITERATURE REVIEW

In this chapter, the literature pertaining to various methid of crack detection conducted by earlier researchers is presented. Thatoi et al. [1] have studied the Cascade Forward Back Propagation (CFBP) network for crack detection in Euler Bernoulli beam like structure through the knowledge of changes in the natural frequencies and their measurements. Labib et al.[2] have studied the free vibration analysis of beams and frames with multiple cracks for damage detection. The problem of calculating the natural frequencies of beams with multiple cracks and frames with cracked beams is studied. The natural frequencies are obtained using a new method in which a rotational spring model is used to represent the cracks .The Wittrick–Williams algorithm is used to compute the natural frequencies in the resulting transcendental eigen value problem. Ghadami et al. [3] have studied a new adaptable multiple-crack detection algorithm in beam-like structures. In this article, a simple method for detecting, localizing and quantifying multiple cracks in beams using natural frequencies is presented. We model cracks as rotational springs and demonstrate a relationship among natural frequencies, crack locations and depths. Jassim et al. [4] present an review on the vibration analysis for a damage occurrence of a cantilever beam. Behzad et al .[5] have studied the method for detection of multiple edge cracks in Euler–Bernoulli beams having two different types of cracks is presented based on energy equations. Each crack is modeled as a massless rotational spring using Linear Elastic Fracture Mechanics (LEFM) theory, and a relationship among natural frequencies, crack locations and stiffness of equivalent springs is demonstrated. Lee [6] have studied cracks are modeled as massless rotational springs and the forward problem is solved using the finite element method. The inverse problem is solved iteratively for the crack locations and sizes using the Newton–Raphson method and the singular value decomposition method. Ruotolo and surace [7] have present on natural frequencies of a bar with multiple cracks. In this paper the smooth function method, previously proposed for bending vibrations, is extended to the calculation of longitudinal natural frequencies of a vibrating isotropic bar with an arbitrary finite number of symmetric transverse open cracks. Owolabi et al. [8] have present on crack detection in beams using changes in frequencies and amplitudes of frequency response functions. The work reported in this paper is part of an ongoing research on the experimental investigations of the effects of cracks and damages on the integrity of structures, with a view to detect, quantify, and determine their extents and locations. Patil and Maiti [9] have studied the method for detection of multiple open cracks in a slender Euler–Bernoulli beams is presented based on frequency measurements.

Chinchalkar [10] present on determination of crack location in beams using natural frequencies. In the present topic, a number of papers published so far have been surveyed, reviewed and analysed. A substantial amount of work has been conducted on natural frequency and mode shape based damage detection methods in the past. Frequency response functions, on the other hand, are used only to detect the damage by searching for the nonlinear features of frequency response functions. Some of the approaches use finite element method as a tool for analysis and they are iterative and require an initial guess. As a result the error in the solution is remarkably influenced by the initial guess. Most of the researchers studied the effect of a single and multiple crack on the dynamics of structures. A lot of studies using natural frequency as a damage detection tool are being carried out in the vibration based damage detection field. Recently, a new vibration based damage detection technique that utilizes a shift in natural frequencies has been the focus in this thesis. Results obtained from these studies seem more promising in terms of damage identification when compared to modal analysis results. The signals obtained in defect-cantilever cracked beams were compared in the frequency domain. Simulations are obtained by the FEA software such as Ansys.In this topic, a new method to analysis of vibration of cantilever beams. In this method to shows the plot the effect of the second crack on the natural and mode frequency ratio in terms of crack depth for various crack positions and crack location for various crack depth of the cantilever bar. The method proposed is an extension of a recently developed technique for identification of damage in cantilever beams.

3. MODAL ANALYSIS USING FEM

3.1 .NUMERICAL MODELLING OF BEAM

To create a numerical model of laboratory specimen beams, the commercial finite element (FE) analysis package ANSYS14.5 is used. The dimensions of the numerical model are based on the measurements of the laboratory beams: 260mm, long, 20 mm X 20 mm, cross section. If values are close it reflects the excellent quality of finite element models prepared with the help of ANSYS14.5. The element type used is SOLID PLANE 183. This element is chosen as it is recommended by ANSYS documentation for three dimensional modelling of solid structures and because wire cut damage can easily modelled for this element. According to manufacturer's specifications of the laboratory steel beams, the modulus of elasticity is set to be 210Gpa, the poissons ratio to 0.3 and density to 7860kg/m3.

Material properties of numerical analysis of beam: Material of Beam: Mild Steel, Length, L = 240 mm, Height, H =20 mm, Width, W=20 mm, Poissons ratio=0.3, Density=7860 kg/m3, Elasticity=210 Gpa.

4. RESULT AND DISCUSSIONS

4.1 Results

The effects of a crack, present at different locations, on the first three modal frequencies have been determined by FEA. Table I- III show the variation of frequency ratio (wc/w) (ratio of natural frequency of the cracked beam to the uncracked beam), as a function of crack location and crack depth for cantilever beams.

B. Change In Natural Frequencies

Fig. 1 to 3 shows that the effect of the second cracks on the natural frequency ratio in terms of crack depth for various crack positions of the cantilever bar. Fig. 4 to 6 shows that the effect of the second crack on the second mode frequency ratio in terms of crack location for various crack depth of the cantilever bar.

Form Fig.1 shows that the first natural frequency was least affected at 220 mm crack location form cantilever beam. The crack was mostly affected at 40 mm crack location form cantilever beam. For bending moment is greatest for a crack located that effect the decrease in frequencies is greatest.

Form Fig.2 shows that the second natural frequency was least affected at 220 mm crack location form cantilever beam. The crack was mostly affected when the crack was located at the center for all crack depths of a beam due to the fact that at that location the bending moment is having large value

Form Fig.3 shows that the third natural frequency changed rapidly for a crack located at 180 mm. The third natural frequency was almost unaffected for a crack located at the center of a cantilever beam because this zero influence was that the nodal point for the third mode was located at the center of beam.

From Fig.4 shows that the first natural frequency was least affected at that the crack depth was 2 mm. The crack was mostly affected at that the crack depth 8 mm. Hence for a cantilever beam it could be inferred that the fundamental frequency decreases significantly as the crack depth increase to 40% of beam depth. The decrease in frequencies is greatest for a more crack depth because the more material gets removed, the stiffness of the beam decrease and hence the natural frequency.

From Fig.5 show that the second natural frequency was mostly affected at the crack depth of 8 mm at the crack location 175 mm. The second natural frequency was least affected at that the crack depth was 2mm. For all crack depths when crack was located at 60mm, the frequencies remain unchanged due to the presence of node point at that position.

From Fig.6 show that the third natural frequency of beam changed rapidly at the crack depth of 8mm.Third natural frequency was remained unaffected when crack depth was 2mm. Third natural frequency was remained unchanged at crack locations 40mm, 120mm, and 220mm due to the presence of node point at that position.

TABLE –I: FIRST NATURAL FREQUENCY RATIO (Wc/W) OF DIFFERENT CRACK LOCATION, (X) AND CRACK DEPTH, (a).

X	a=2	a=4	a=6	a=8
40	0.9755	0.9281	0.8420	0.7103
60	0.9783	0.9427	0.8747	0.7616
80	0.9805	0.9554	0.9047	0.8134
100	0.9825	0.9825	0.9309	0.8627
120	0.9838	0.9738	0.9521	0.9065
140	0.9848	0.9795	0.9676	0.9415
160	0.9854	0.9832	0.9777	0.9655
180	0.9857	0.9851	0.9834	0.9792

200	0.9859	0.9860	0.9858	0.9852
220	0.9860	0.9864	0.9866	0.9869

TABLE- II: SECOND NATURAL FREQUENCY RATIO (Wc/W) OF DIFFERENT CRACK LOCATION, (X) AND CRACK DEPTH, (a)

X	a=2	a=4	a=6	a=8
40	0.9935	0.9906	0.9855	0.9776
60	0.9937	0.9916	0.9875	0.9803
80	0.9908	0.9753	0.9461	0.8995
100	0.9873	0.9873	0.8988	0.8138
120	0.9853	0.9446	0.8719	0.7641
140	0.9856	0.9464	0.8728	0.7575
160	0.9881	0.9589	0.8999	0.7946
180	0.9910	0.9758	0.9422	0.8707
200	0.9932	0.9887	0.9781	0.9528
220	0.9941	0.9938	0.9930	0.9907

TABLE- III: THIRD NATURAL FREQUENCY RATIO (Wc/W) OF DIFFERENT CRACK LOCATION (X) AND CRACK DEPTH (a)

X	a=2	a=4	a=6	a=8
40	0.9974	0.9921	0.9754	0.9148
60	0.9927	0.9643	0.9038	0.8056
80	0.9920	0.9615	0.9031	0.8171
100	0.9961	0.9961	0.9598	0.9086
120	0.9983	0.9977	0.9960	0.9897
140	0.9945	0.9763	0.9423	0.8902
160	0.9894	0.9493	0.8827	0.7983
180	0.9895	0.9475	0.8696	0.7582
200	0.9942	0.9731	0.9236	0.8186
220	0.9979	0.9953	0.9885	0.9693

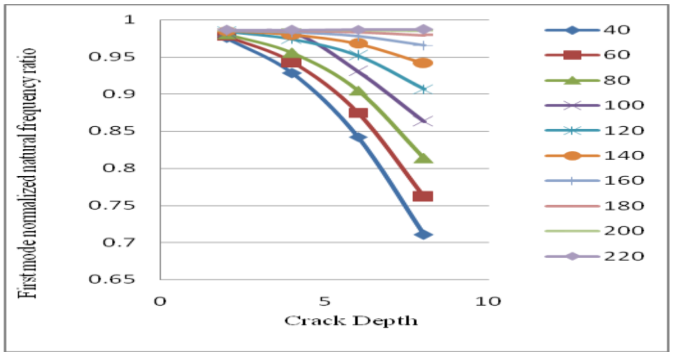

Fig-1: Effect of the second crack on the first natural frequency ratio in terms of crack depth for various crack positions of the cantilever bar.

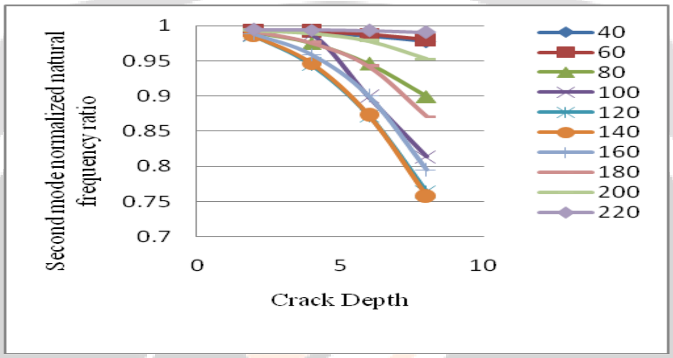

Fig-2: Effect of the second crack on the second natural frequency ratio in terms of crack depth for various crack positions of the cantilever bar.

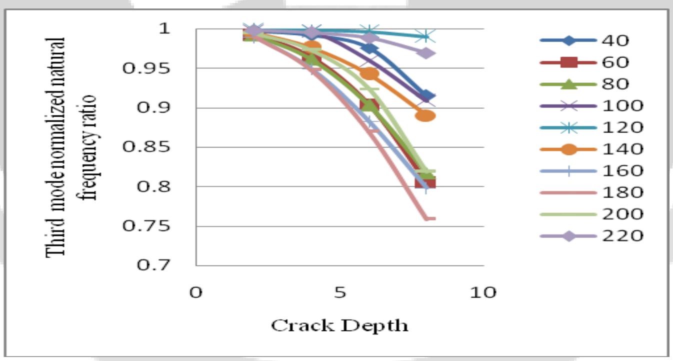

Fig-3: Effect of the second crack on the third natural frequency ratio in terms of crack depth for various crack positions of the cantilever bar.

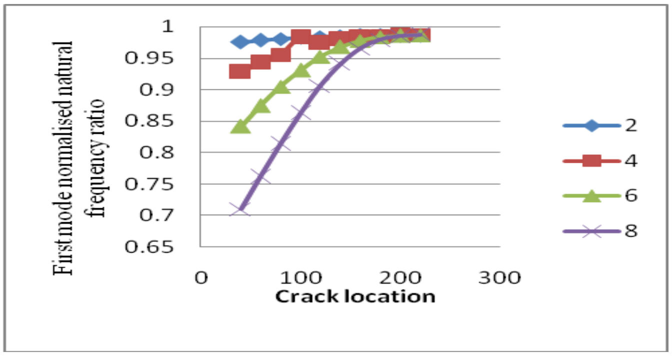

Fig-4: Effect of the second crack on the first mode frequency ratio in terms of crack location for various crack depth, (a=2, 4, 6, 8) of the cantilever bar.

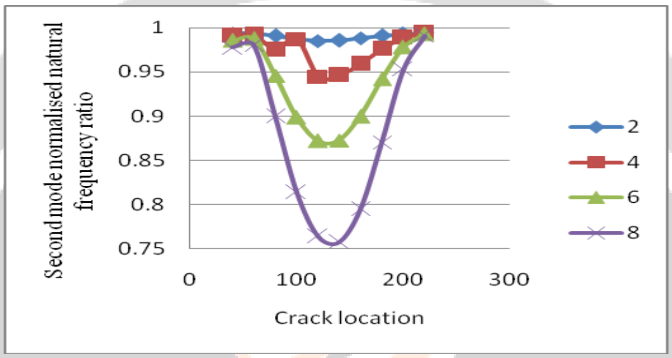

Fig-5: Effect of the second crack on the second mode frequency ratio in terms of crack location for various crack depth, (a=2, 4, 6, 8) of the cantilever bar.

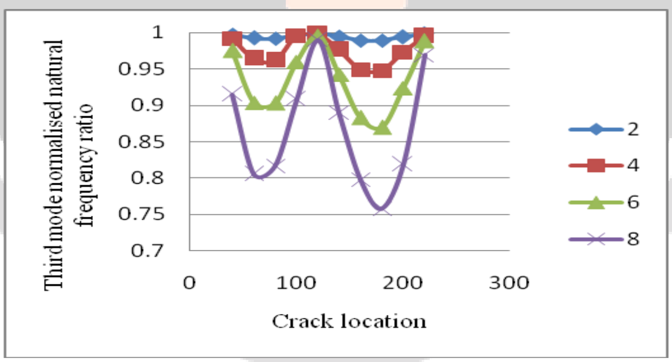

Fig-6: Effect of the second crack on the third mode frequency ratio in terms of crack location for various crack depth, (a=2, 4, 6, 8) of the cantilever bar.

5. CONCLUSION:

Crack changes the dynamic behavior of the structure and by examining this change, crack size and position can be identified. Non destructive testing (NDT) methods are used for detection of crack which are very costly and time consuming. Currently research has focused on using modal parameters like natural frequency, mode shape to analysis of vibration. In this paper a method for detection of two transverse cracks in a slender Euler–Bernoulli beam is presented. To show the effect of second crack on natural and mode frequency ratio to first crack, to show the crack depth for various crack positions and crack location for various crack depth of the cantilever bar presented in this paper. Form this results it is evident that the vibrations behavior of the beams is very sensitive to the crack depth, crack location and mode number.

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