International Journal of Engineering Research and General Science Volume 4, Issue 4, July-August, 2016
ISSN 2091-2730

ANALYSIS OF CRACK INFLUENCE ON AN OPEN FRAME L-STRUCTURE USING FEM

Y.P. Mamatha[1], Sujith Kumar S[2], Vivek G[2] , Sumanth D R[2], Vinay N[2].

[1]Assistant Professor, Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysuru.

Email: mamathayp@vvce.ac.in

[2]B.E. Students, Department of Mechanical Engineering, Vidyavardhaka College of Engineering, Mysuru.

Email: sujithskum@gmail.com, vikuuvivek@gmail.com

ABSTRACT: Detection of crack is very important to maintain the safety of the structure. When a crack develops in a structure it leads to changes in its vibration parameters, these affect modal parameters. Based on these changes, it is possible to estimate the crack size and location by measuring the changes in vibration of the structure.

The aim of this project is to carry out modal analysis of In-plane free vibration analysis of two-member open frame with transverse crack. The 3D model of Open frame L-structure is created and analysed with the changes in crack dimensions, crack locations and for with and without concentrated mass (end mass) conditions for both horizontal and vertical members using ANSYS. The results obtained from the vibration analysis of L-frame structure shows that Crack depth is inversely proportional to natural frequency while keeping crack location constant and natural frequency is lower near fixed end region and increases for farther regions.

Keywords- Flexibility, Modal Analysis, Modal Parameters, Mode Shapes, Natural Frequency, Vibration Parameters, ANSYS.

INTRODUCTION

The importance of early detection of cracks is crucial, as it is the most common reason for structural defect. Presence of crack affects the mechanical behaviour of the structure and also reduces the stiffness, the developed crack propagate in size thereby causing failure of the structure in long run. Cracks may develop in a structure due to reduction in fatigue strength, mechanical defects and as a result of improper manufacturing process. Currently research has focused on using modal parameters over other traditional methods. Modal parameters include detection of crack size and location using natural frequency and mode shapes as natural frequencies can easily be obtained and monitored. The main focus of this project is to detect Natural frequency and mode shapes of an open frame L structure using vibrational analysis method for various crack size and location and for with and without mass conditions. The L-frame has vertical and horizontal segment on which the crack is introduced separately, the crack is a transverse crack with uniform width along thickness of frame. The crack introduced causes local flexibility in that region due to strain energy concentration at the tip of the crack, which is a function of crack depth only. So the crack depth is only varied in a particular crack location and results are tabulated.

LITERATURE REVIEW

Structures are usually united to withstand loads with stability, all structures must withstand loads for which they are designed, loads may be dynamic or static loads. When this type of loads are present it leads to fatigue cracks, so the development of cracks lead to many faulty results so the study regarding this has been chosen as area of interest. Many methods and research works have been proposed in order to identify the natural frequency of the structures in which the cracks are developed. The main methods in which the work is done are theoretical, experimental and numerical methods. Theoretically it is usually done by Euler-Bernoulli beam theory, Rayleigh-Ritz theory and Timoshenko beam theory. In experimental method, the crack is induced in the structure, constraints or boundary conditions are applied and using accelerometer equipment the structure is vibrated and the natural frequency is determined.

Numerical methods are done in software packages which help in getting faster results and complex structures can be easily studied. Based on these above mentioned ideas many work has been done in vibration analysis of cantilever beam and other structures, this helps us in understanding their constraints in usage. The vibration analysis of L-frame structure which is used commonly in building structures, trusses is important.

In this work, vibration analysis is carried out in ANSYS WORKBENCH, similar work has been carried out by Y P Mamatha [1], the analysis is carried out theoretically by using Euler-Bernoulli beam theory introducing crack as rotational spring. A comparison has been made with numerical results and theoretical results, a maximum of 5% error occurs for no mass condition and 20 % for other mass conditions. This proves that numerical and theoretical results are in good agreement. H Alper Ozyigit [2] carried out the linear vibrations of frames with circular cross-section where one of the frame is straight and another curved. This research work shows how the natural frequency decreases when a point mass is added at the right tip of the curved beam while the straight beam is fixed. Alejandro R. Ratazzi, Diana V. Bambill and Carlos A. Rossitn [3] have carried out vibration analysis on L-shaped beam theoretically with elastic boundary conditions and a crack in one of the segment which is modelled as rotational spring using Euler-Bernoulli's theorem. P Yamuna, K Sambasivarao [4] carried out the work on vibration analysis of simply supported beam with varying crack location which shows how the natural frequency varies when crack location varies using ANSYS, they used SOLID 186 tetrahedral 20 node brick element. Dr Luay S Al-Ansari [5] did experimental and numerical modal analysis for cracked simply supported solid and hollow beams, in his experiment. It shows that the natural frequency decreases when the crack depth increases in solid beams and the natural frequency increases when crack depth increases in hollow beams, he has used SOLID Tetrahedral 10 node 187 elements in mesh in his analysis in ANSYS. Ranjan K. Behera, Anish Pandey, Dayal R. Parhic [6] performed analysis in-order to find the natural frequency of cantilever beam for inclined cracks.

MODELLING OF L-FRAME STRUCTURE

- **GEOMETRIC MODELLING**

The system consist of two flexible members which are arranged as shown in Fig.1.The L-frame with span of L_1=0.9m vertically, L_2=0.6m horizontally and with a cross section of 0.05m x 0.03m (h x w) is modelled using SOLID EDGE v19.The angle between two beams is 90^o.The transverse crack is introduced by cutting out a portion of the structure according to crack size as specified later**.**

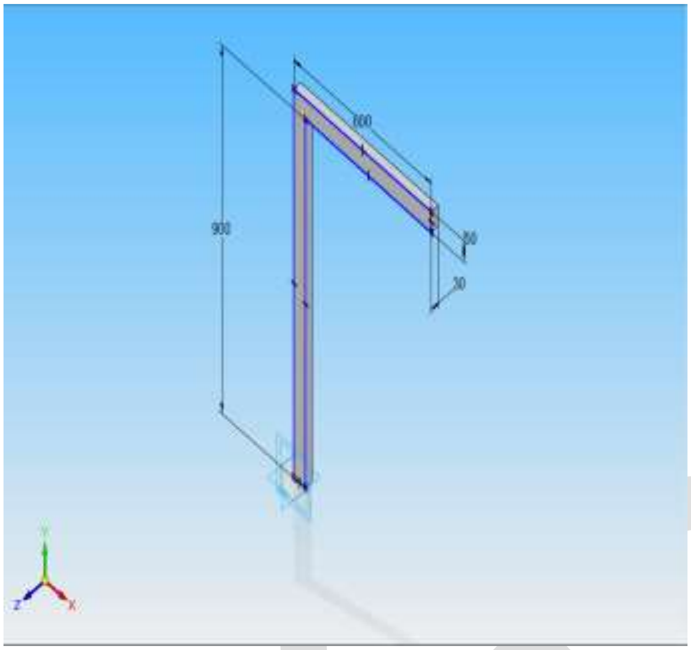


Fig.1. Geometric model of L- frame Developed in SOLID EDGE

- **CRACK MODELLING**

Crack size is introduced as a ratio of **a/h** where ‘a’ is depth of the crack and ‘h’ is the thickness of the beam. The various crack sizes are in ratios of 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6. Crack location for Vertical segment and horizontal segment is introduced as a ratio of L_c/L_1 and L_c/L_2 where L_c is the crack location, L_1 is the length of the vertical segment and L_2 that of horizontal segment as shown in Fig.2 and Fig.3.

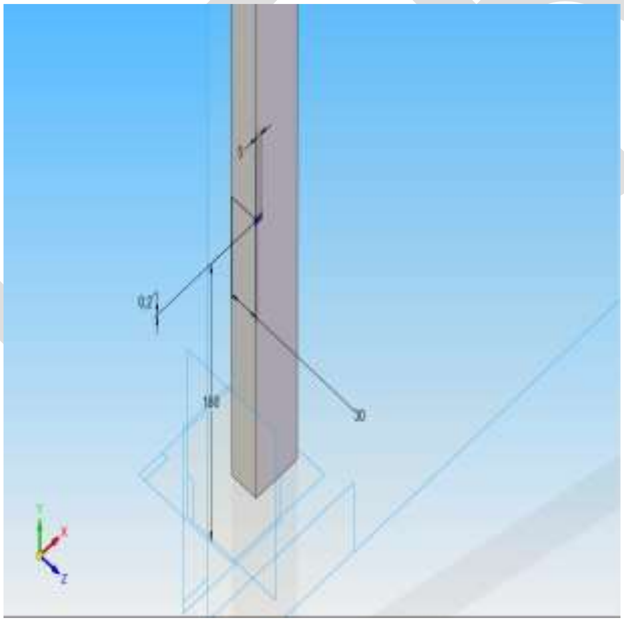


Fig.2.The Crack introduced on the Vertical member of L-frame.

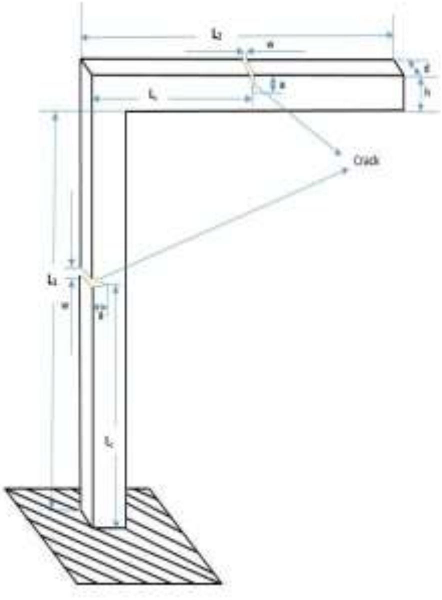


Fig.3. L-frame structure with crack

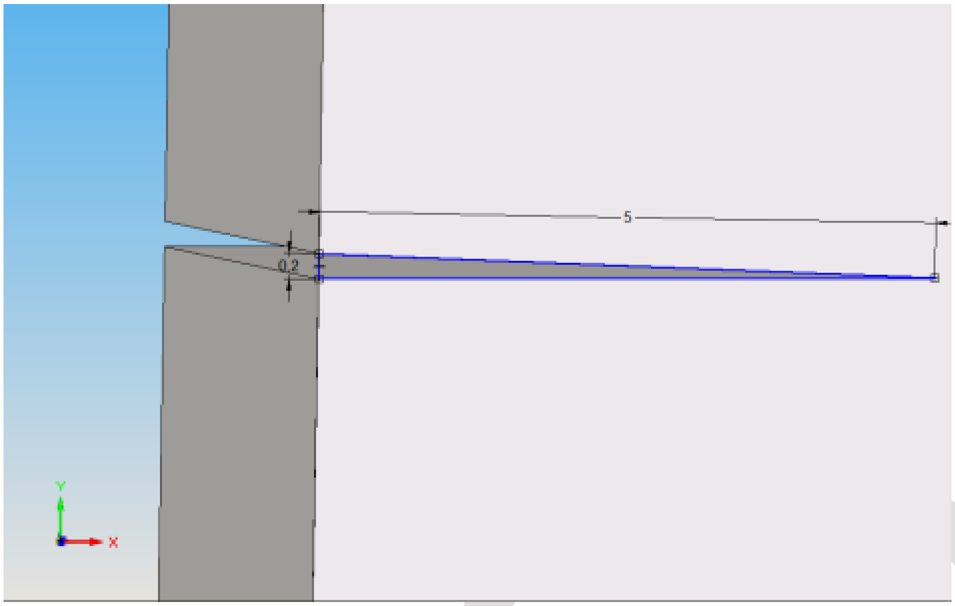


Fig.4. Crack of 5 mm depth and uniform width along thickness on L- frame.

- **FEM-ANALYSIS**

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. In this project modal analysis method, which is the study of the dynamic properties of structures under vibration excitation is used. Modal analysis is the field of measuring and analyzing the dynamic response of structures during excitation.

STEPS INVOLVED IN ANSYS WORKBENCH 15

1. **Selecting analysis type**

   Modal analysis

2. **Material properties**

   Material-Aluminum

   Young's Modulus (E) = 70Gpa

   Density (ρ) = 2600 Kg/m^3

   Poisson's ratio (υ) = 0.33

3. **Importing geometry**

   The geometry created in SOLID EDGE is imported in .igs format.

4. **Selecting element type and MESHING**

In this analysis, **Tetrahedral 10 node SOLID 187** mesh element with **3 cycles of refinement** is used because of its quadratic displacement behavior which is more suitable for irregular meshing and to obtain fine mesh. This helps in dividing the solid structure into small elements and meshing the crack location clearly. The SOLID 187 is as shown in Fig.5 it has three degrees of freedom at all the 10 nodes.

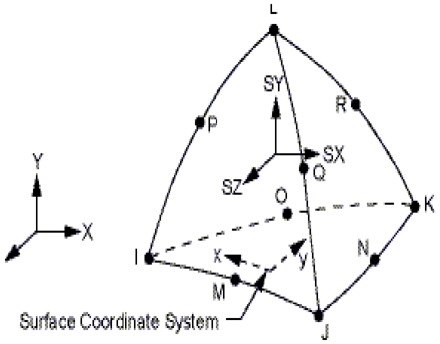


Fig.5. Tetrahedral 10 node SOLID 187 element of meshing

The Fig.6 shows meshing which is done in **ANSYS WORKBENCH 15** using SOLID 187 element for triangular crack on vertical segment.

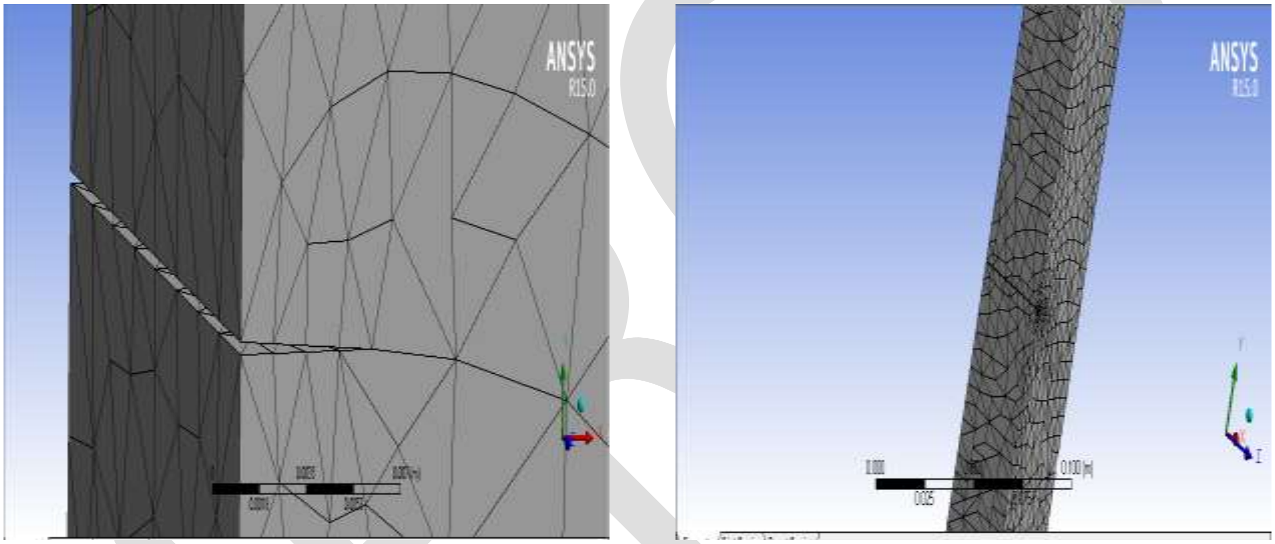


Fig.6. Meshing of the structure at the Crack

5. Applying boundary conditions

Using fixed support option the bottom end of the vertical segment is constrained in all DOF as shown in Fig.7.

6. Adding end mass

Different mass conditions are considered here. The various mass conditions are **No Mass**, **0.4kg** and **0.8kg**, which are applied to the free end face of the horizontal beam individually for corresponding crack size and location to study the changes in modal parameters of the structure by using point mass option as shown in Fig.8.

Fig.7.The Bottom end is fixed using fixed support

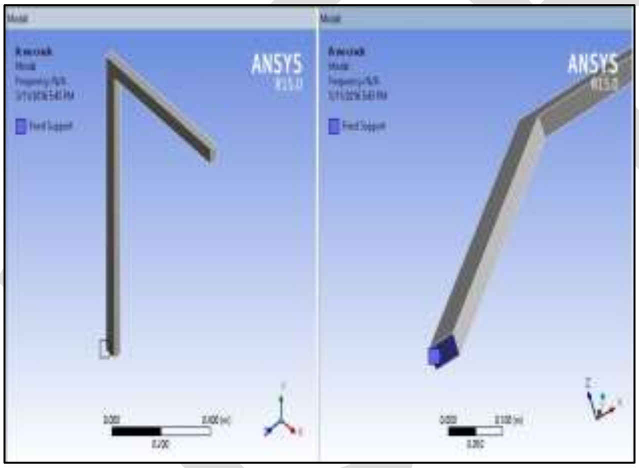
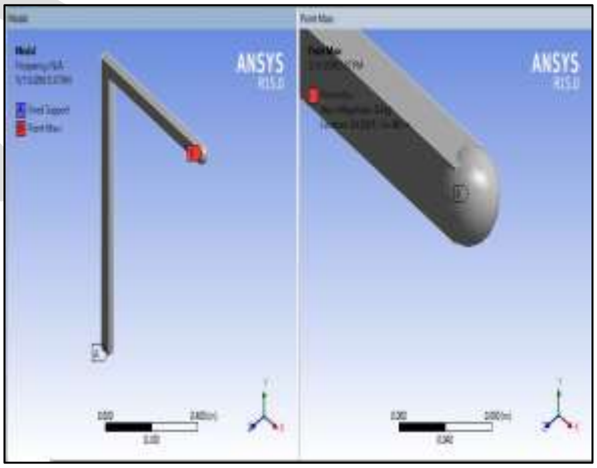


Fig.8.L-frame with 0.4 kg End mass at face of free end



7. Solution

The modal analysis solution is done using **BLOCK LANCZOS** mode extraction method.

8. Results

The modal analysis solution is done for ***total deformation*** of the structure and ***mode shapes*** are extracted for in-plane and out-plane vibrations of the structure. The natural frequencies for the first four modes are tabulated for various conditions considered. Natural frequencies for various crack size and location is obtained and the frequency ratio in percentage is calculated using the formula. $\boldsymbol{\omega}_{uncracked}$ is considered as reference frequency.

FREQUENCY RATIO

$$\% \, Diff = \frac{\omega_{cracked} - \omega_{uncracked}}{\omega_{uncracked}} \, x \, 100$$

TABULAR RESULTS

1	**In- Plane Natural Frequencies for Crack on Vertical Segment (L1) without End Mass**								
Crack Location (L_c/L_1)	**Crack Size (a/h)**	**Natural Frequencies (Hz)**							
		ω_1	**%Diff**	**ω_2**	**%Diff**	**ω_3**	**%Diff**	**ω_4**	**%Diff**
No Crack		23.5498		81.5947		290.8431		596.6108	
0.2	**0.1**	23.4532	-0.4101	81.5303	-0.0789	290.7937	-0.0170	596.3694	-0.0405
0.2	**0.2**	23.1443	-1.7218	81.3589	-0.2890	290.6903	-0.0525	595.7983	-0.1362
0.2	**0.3**	22.6219	-3.9400	81.0679	-0.6456	290.5122	-0.1138	594.6185	-0.3339
0.2	**0.4**	21.7894	-7.4754	80.6060	-1.2117	290.2142	-0.2162	592.4379	-0.6994
0.2	**0.5**	20.5901	-12.5680	79.9893	-1.9675	289.8333	-0.3472	588.8811	-1.2956
0.2	**0.6**	18.7725	-20.2858	79.1347	-3.0149	289.3058	-0.5286	582.6287	-2.3436
0.6	**0.1**	23.5202	-0.1258	81.5165	-0.0958	290.0258	-0.2810	596.5763	-0.0058
0.6	**0.2**	23.4288	-0.5138	81.2858	-0.3786	287.5711	-1.1250	596.4448	-0.0278
0.6	**0.3**	23.2574	-1.2415	80.9064	-0.8436	283.2572	-2.6082	596.2304	-0.0638
0.6	**0.4**	22.9720	-2.4535	80.2841	-1.6062	276.5983	-4.8977	595.7159	-0.1500
0.6	**0.5**	22.5240	-4.3558	79.3429	-2.7598	267.3159	-8.0893	594.7421	-0.3132
0.6	**0.6**	21.7575	-7.6105	77.8736	-4.5605	254.1809	-12.6055	592.7568	-0.6460

2	**In- Plane Natural Frequencies for Crack on Vertical Segment (L1) with End Mass=0.4Kg**								
Crack Location (L_c/L_1)	**Crack Size (a/h)**	**Natural Frequencies (Hz)**							
		ω_1	**%Diff**	**ω_2**	**%Diff**	**ω_3**	**%Diff**	**ω_4**	**%Diff**
No Crack		21.3818		67.8189		278.6443		522.3525	
0.2	**0.1**	21.2974	-0.3950	67.7572	-0.0909	278.5938	-0.0181	522.2040	-0.0284
0.2	**0.2**	21.0276	-1.6568	67.5888	-0.3392	278.4487	-0.0702	521.9427	-0.0784
0.2	**0.3**	20.5701	-3.7965	67.3048	-0.7581	278.2095	-0.1560	521.3538	-0.1912
0.2	**0.4**	19.8382	-7.2195	66.8577	-1.4173	277.8228	-0.2948	520.2103	-0.4101
0.2	**0.5**	18.7786	-12.1751	66.2622	-2.2953	277.3051	-0.4806	518.3499	-0.7663
0.2	**0.6**	17.1615	-19.7382	65.4425	-3.5040	276.5777	-0.7417	515.0334	-1.4012
0.6	**0.1**	21.3529	-0.1355	67.7679	-0.0752	277.8580	-0.2822	522.2402	-0.0215
0.6	**0.2**	21.2637	-0.5525	67.6184	-0.2957	275.4961	-1.1298	521.8746	-0.0915
0.6	**0.3**	21.0968	-1.3329	67.3803	-0.6466	271.3241	-2.6271	521.2789	-0.2055
0.6	**0.4**	20.8196	-2.6295	66.9868	-1.2269	264.8904	-4.9360	520.1359	-0.4243
0.6	**0.5**	20.3861	-4.6569	66.3885	-2.1092	255.9089	-8.1593	518.2688	-0.7818
0.6	**0.6**	19.6492	-8.1035	65.4572	-3.4824	243.1433	-12.7406	515.1115	-1.3862

3 In- Plane Natural Frequencies for Crack on Vertical Segment (L1) with End Mass=0.8Kg

Crack Location (L_c/L_1)	Crack Size (a/h)	Natural Frequencies (Hz)							
		ω_1	%Diff	ω_2	%Diff	ω_3	%Diff	ω_4	%Diff
No Crack		19.6933		59.8975		272.0090		497.2525	
0.2	**0.1**	19.6179	-0.3832	59.8371	-0.1009	271.9566	-0.0192	497.1220	-0.0262
0.2	**0.2**	19.3770	-1.6062	59.6692	-0.3813	271.7892	-0.0808	496.9305	-0.0648
0.2	**0.3**	18.9678	-3.6843	59.3869	-0.8525	271.5163	-0.1811	496.4737	-0.1566
0.2	**0.4**	18.3111	-7.0187	58.9447	-1.5907	271.0797	-0.3416	495.5637	-0.3396
0.2	**0.5**	17.3567	-11.8653	58.3558	-2.5739	270.4871	-0.5595	494.0935	-0.6353
0.2	**0.6**	15.8918	-19.3038	57.5475	-3.9235	269.6505	-0.8671	491.4628	-1.1643
0.6	**0.1**	19.6653	-0.1422	59.8596	-0.0634	271.2413	-0.2822	497.1095	-0.0288
0.6	**0.2**	19.5793	-0.5792	59.7488	-0.2482	268.9347	-1.1302	496.6534	-0.1205
0.6	**0.3**	19.4185	-1.3958	59.5775	-0.5343	264.8506	-2.6317	495.9146	-0.2691
0.6	**0.4**	19.1518	-2.7500	59.2924	-1.0102	258.5532	-4.9468	494.5534	-0.5428
0.6	**0.5**	18.7359	-4.8618	58.8571	-1.7370	249.7531	-8.1820	492.4014	-0.9756
0.6	**0.6**	18.0321	-8.4356	58.1815	-2.8649	237.2160	-12.7911	488.9131	-1.6771

4 In- Plane Natural Frequencies for Crack on Horizontal Segment (L2) without End Mass

Crack Location (L_c/L_2)	Crack Size (a/h)	Natural Frequencies (Hz)							
		ω_1	%Diff	ω_2	%Diff	ω_3	%Diff	ω_4	%Diff
No Crack		23.5520		81.6253		290.9321		596.6835	
0.2	**0.1**	23.5482	-0.0161	81.3684	-0.3147	290.2343	-0.2398	596.2835	-0.0670
0.2	**0.2**	23.5431	-0.0378	80.6708	-1.1694	288.4241	-0.8621	595.3094	-0.2303
0.2	**0.3**	23.5343	-0.0752	79.4583	-2.6548	285.4237	-1.8934	593.7079	-0.4987
0.2	**0.4**	23.5191	-0.1397	77.6028	-4.9280	281.1838	-3.3507	591.3899	-0.8872
0.2	**0.5**	23.4894	-0.2658	74.4321	-8.8125	274.6877	-5.5836	587.8572	-1.4792
0.2	**0.6**	23.4371	-0.4879	69.8449	-14.4323	266.7055	-8.3272	583.5182	-2.2064
0.6	**0.1**	23.5495	-0.0106	81.5597	-0.0804	290.6953	-0.0814	594.1593	-0.4230
0.6	**0.2**	23.5492	-0.0119	81.4983	-0.1556	290.3392	-0.2038	586.5906	-1.6915
0.6	**0.3**	23.5486	-0.0144	81.3888	-0.2897	289.7054	-0.4216	573.5862	-3.8709
0.6	**0.4**	23.5473	-0.0200	81.1785	-0.5474	288.5387	-0.8227	552.0742	-7.4762
0.6	**0.5**	23.5448	-0.0306	80.8319	-0.9720	286.5098	-1.5200	520.1715	-12.8229
0.6	**0.6**	23.5401	-0.0505	80.2682	-1.6626	282.7255	-2.8208	475.8786	-20.2461

5 In- Plane Natural Frequencies for Crack on Horizontal Segment (L2) with End Mass=0.4Kg

Crack Location (L_c/L_2)	Crack Size (a/h)	Natural Frequencies (Hz)							
		ω_1	%Diff	ω_2	%Diff	ω_3	%Diff	ω_4	%Diff
No Crack		21.3818		67.8189		278.6443		522.3525	
0.2	**0.1**	21.3793	-0.0120	67.6194	-0.2942	278.1201	-0.1881	522.3020	-0.0097
0.2	**0.2**	21.3712	-0.0499	67.0062	-1.1983	276.5676	-0.7453	522.1258	-0.0434
0.2	**0.3**	21.3567	-0.1175	65.9442	-2.7643	273.9944	-1.6688	521.8897	-0.0886
0.2	**0.4**	21.3323	-0.2317	64.3328	-5.1402	270.3803	-2.9658	521.3911	-0.1840
0.2	**0.5**	21.2850	-0.4530	61.6060	-9.1610	264.8493	-4.9508	520.7043	-0.3155
0.2	**0.6**	21.2017	-0.8420	57.7211	-14.8892	258.0783	-7.3807	519.7540	-0.4974
0.6	**0.1**	21.3813	-0.0024	67.7785	-0.0596	278.4274	-0.0779	519.7598	-0.4963
0.6	**0.2**	21.3803	-0.0073	67.6917	-0.1876	277.8217	-0.2952	511.9532	-1.9909
0.6	**0.3**	21.3784	-0.0161	67.5383	-0.4138	276.7408	-0.6831	499.0162	-4.4675
0.6	**0.4**	21.3748	-0.0329	67.2565	-0.8292	274.7807	-1.3866	478.7243	-8.3523

0.6	**0.5**	21.3684	-0.0631	66.7940	-1.5112	271.3561	-2.6156	463.1178	-11.3400
0.6	**0.6**	21.3569	-0.1168	66.0313	-2.6359	264.9377	-4.9190	461.4804	-11.6534

6	**In- Plane Natural Frequencies for Crack on Horizontal Segment (L2) with End Mass=0.8Kg**								
Crack Location (L_c/L_2)	**Crack Size (a/h)**	**Natural Frequencies (Hz)**							
		ω_1	**%Diff**	**ω_2**	**%Diff**	**ω_3**	**%Diff**	**ω_4**	**%Diff**
No Crack		19.6933		59.8975		272.0090		497.2525	
0.2	**0.1**	19.6901	-0.0167	59.7178	-0.3000	271.5326	-0.1751	497.2401	-0.0025
0.2	**0.2**	19.6797	-0.0692	59.1667	-1.2202	270.1242	-0.6929	497.1722	-0.0161
0.2	**0.3**	19.6611	-0.1636	58.2138	-2.8110	267.7896	-1.5512	497.1307	-0.0245
0.2	**0.4**	19.6300	-0.3215	56.7745	-5.2140	264.5175	-2.7541	496.8892	-0.0731
0.2	**0.5**	19.5699	-0.6267	54.3513	-9.2596	259.5082	-4.5957	496.6304	-0.1251
0.2	**0.6**	19.4645	-1.1623	50.9268	-14.9768	253.3783	-6.8493	496.2097	-0.2097
0.6	**0.1**	19.6926	-0.0038	59.8567	-0.0682	271.7637	-0.0902	494.7518	-0.5029
0.6	**0.2**	19.6909	-0.0123	59.7638	-0.2232	271.0561	-0.3503	487.2766	-2.0062
0.6	**0.3**	19.6879	-0.0274	59.6002	-0.4963	269.7962	-0.8135	474.9910	-4.4769
0.6	**0.4**	19.6824	-0.0558	59.3040	-0.9909	267.5290	-1.6470	461.0758	-7.2753
0.6	**0.5**	19.6726	-0.1054	58.8201	-1.7988	263.5961	-3.0929	459.9908	-7.4935
0.6	**0.6**	19.6553	-0.1934	58.0236	-3.1286	256.3394	-5.7607	458.6754	-7.7581

IN-PLANE MODE SHAPES

The below Fig.9 shows various mode shapes for In-plane free vibration at no mass and no crack condition for the first four modes. By looking at the mode shapes one can say that deformation has occurred in the same plane for all the modes with variation in knee angle.

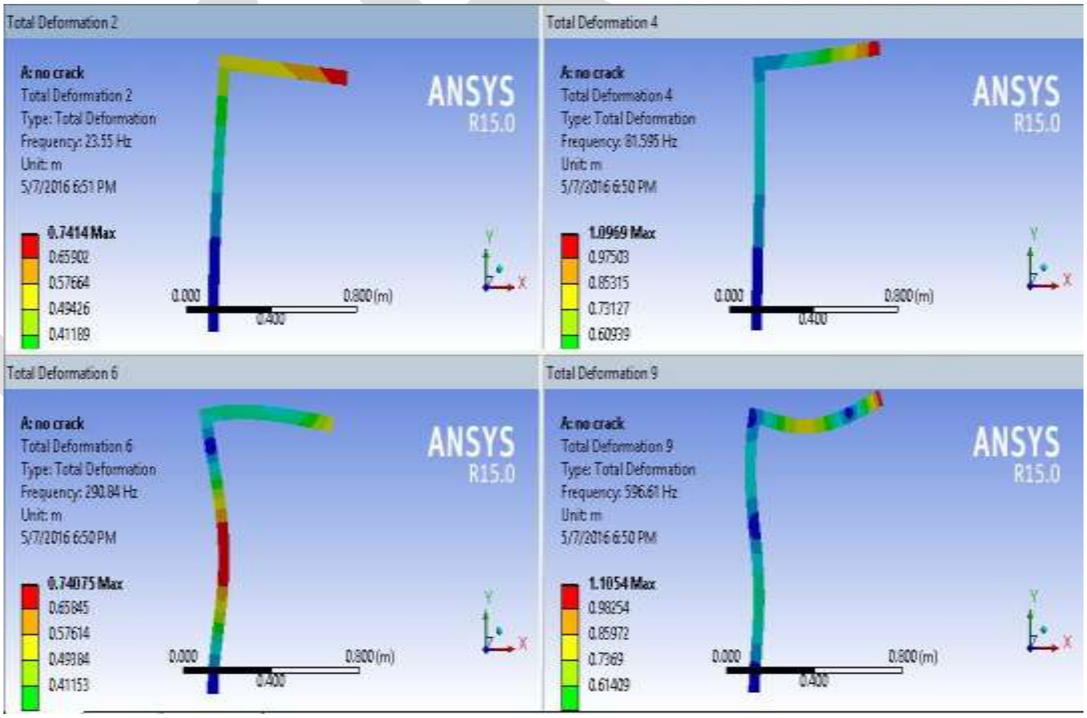


Fig.9. Mode shapes of In-plane vibration

CONCLUSION

In this paper, it can be observed that the crack depth is inversely proportional to natural frequency while keeping crack location constant. When mass is applied on the structure, natural frequency decreases. Natural frequency is lower near fixed end region and increases for farther regions. From the obtained results it can be stated that natural frequency is affected by mode number. Natural frequency at certain cracked condition tends to increase rather than decreasing because of clapping effect.

REFERENCES:

[1] Y.P. Mamatha, “In-plane free vibration of two member open frame with transverse crack”, M.Tech report, Dept. ME., BMSCE, Bengaluru, Karnataka, IN., Jul. 2008.

[2] H. Alper Ozyiğit, “Linear vibrations of frames carrying a concentrated mass”, Mathematical and Computational Applications, Vol. 14, No. 3, pp. 197-206, 2009.

[3] Alejandro R. Ratazzi, Diana V. Bambill, Carlos A. Rossit, “Free Vibrations of Beam System Structures with Elastic Boundary Conditions and an Internal Elastic Hinge”, Hindawi Publishing Corporation, Chinese Journal of Engineering Volume 2013, Article ID 624658.

[4] P.Yamuna, K.Sambasivarao, “Vibration analysis of beam with varying crack location”, International Journal of Engineering Research and General Science Volume 2, Issue 6, October-November, 2014, ISSN: 2091-2730.

[5] Dr. Luay S. Al-Ansari, “Experimental and Numerical Comparison between the Natural Frequency of Cracked Simply Supported Hollow and Solid Beams”, Volume: 3, Issue: 9, Sept 2013, ISSN: 2249-555X.

[6] Ranjan K. Behera, Anish Pandey, Dayal R. Parhic, “Numerical and Experimental Verification of a Method for Prognosis of Inclined Edge Crack in Cantilever Beam Based on Synthesis of Mode Shapes”, 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014.