Vibration analysis of cracked steel beams

A Project Submitted

In Partial Fulfillment of the Requirements

For the Degree of

Bachelor of Technology

In Civil Engineering

By

Sameer Naik

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DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

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Under the Guidance of

Prof. Shishir Kumar Sahu

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National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled, "VIBRATION ANALYSIS OF CRACKED STEEL BEAMS"submitted by Shri Sameer Naik in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

Dr. Shishir Kumar Sahu
Dept. of Civil Engineering
National Institute of Technology
Rourkela - 769008

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Sameer Naik Dt::

Roll No :: 10501013

NIT Rourkela

Contents

Abstract

Defects influence in a negative way the service life of structures. Thus, detection of them even at a very small size is a very important point of view to guarantee structural safety and to safe costs. The objective of this study is to analyze the vibration behavior of beams .For this purpose, the vibrations as a result of impact shocks were analyzed. The signals obtained in defect-free and cracked steel beams were compared in the frequency domain. In this paper, an analytical, as well as experimental approach to the crack detection in steel beams by vibration analysis is established. An experimental setup is designed in which a cracked cantilever beam is excited by a hammer and the response is obtained using an accelerometer attached to the beam. To avoid non-linearity, it is assumed that the crack is always open.

Introduction

The objective of this study is to analyze the vibration behaviour of beams both experimentally and using FEM software ANSYS subjected to single and multiple cracks under free and forced vibration cases. Besides this, information about the location and depth of cracks in cracked steel beams can be obtained using this technique. Using vibration analysis for early detection of cracks has gained popularity over the years and in the last decade substantial progress has been made in that direction. Dynamic characteristics of damaged and undamaged materials are very different. For this reason, material faults can be detected, especially in steel beams, which are very important construction elements because of their wide spread usage construction and machinery. Crack formation due to cycling loads leads to fatigue of the structure and to discontinuities in the interior configuration. Cracks in vibrating components can initiate catastrophic failures. Therefore, there is a need to understand the dynamics of cracked structures. When a structure suffers from damage, its dynamic properties can change. Specifically, crack damage can cause a stiffness reduction, with an inherent reduction in natural frequencies, an increase in modal damping, and a change in the mode shapes. From these changes the crack position and magnitude can be identified. Since the reduction in natural frequencies can be easily observed, most researchers use this feature. Natural frequency of the beam has also been determined and verified experimentally. The present project work uses BRUEL AND KJAER Pulse Analyzer System Type- 3560 and Electrodynamic Vibration Shaker System for Vibration analysis of cracked steel beams.

History and literature review::

The effect of a crack on the deformation of a beam has been considered as an elastic hinge by Chondros and Dimarogonas(1980) .Variations of the natural frequencies were calculated by a perturbation method. A finite element model has been proposed , in which two different shape functions were adopted for two segments of the beam, in order to consider the discontinuity of deformation due to the crack. Cawley and Adams(1979) showed that the stress distribution in a vibrating structure was non-uniform and was different for each mode of vibration. Therefore, any local crack would affect each mode differently, depending on the location of the crack. Stubbs(1990) and Chondros and Dimarogonas(1998) used the energy method and the continuous cracked beam theory to analyze transverse vibration of cracked beams. In the analytical study of this problem, two procedures have been used by researchers to quantify local flexibility due to the crack. In the first procedure, a stiffness matrix is constructed for the cracked section, in a similar way as an equivalent spring. In the second procedure which is more practical, a cracked finite element stiffness matrix is constructed and assembled with the non-cracked elements of the structure. Dirr and Schmalhorst(1988) used a three dimensional finite element model with an elastic material to model cracked beams. Qian et al. (1990) formulated a method of crack detection in beams based on the changes in the natural frequencies and mode shapes. Narkis(1994) studied the dynamics of a cracked simply supported beam for bending and axial vibrations. He has shown that for accurate crack identification the variations of the first two natural frequencies, caused by the crack, are needed. Shen and Pierre(1994) investigated the vibration of cracked beams with single or symmetrical cracks using Galerkin's method with many terms. Nobile invoked equilibrium of elementary beam theory for evaluating the internal forces at the crack tip. Recently, Saavedra and Cuitino (2001) developed a finite element model for a cracked element to evaluate the dynamic response of a crack-free beam under harmonic forces. Dilena and Morassi (2002) detected a single crack in a beam when damage-induced shifts in the mode shapes of the beam are known.

Aim and scope of present study

- The objective of this study is to analyze the vibration behaviour of beams both experimentally and using FEM software ANSYS subjected to single and multiple cracks under free and forced vibration cases. Besides this, information about the location and depth of cracks in cracked steel beams can be obtained using this technique.

Theory:

- **Vibrations:** Vibration are time dependent displacements of a particle or a system of particles w.r.t an equilibrium position. If these displacements are repetitive and their repetitions are executed at equal interval of time w.r.t equilibrium position the resulting motion is said to be periodic.

Classification of vibration

Vibration can be classified in several ways. Some of the important classification are as follows :

- **Free and forced vibration**: If a system, after an internal disturbance, is left to vibrate on its own, the ensuing vibration is known as free vibration. No external force acts on the system. The oscillation of the simple pendulum is an example of free vibration.

If a system is subjected to an external force (often, a repeatating type of force), the resulting vibration is known as forced vibration. The oscillation that arises in machineries such as diesel engines is an example of forced vibration.

If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as resonance occurs, and the system undergoes dangerously large oscillations. Failuers of such structures as buildings, bridges, turbines and airplane have been associated with the occurrence of resonance.

- **Undamped and damped vibration**: If no energy is lost or dissipated in friction or other resistance during oscillation, the vibration is known as undamped vibration. If any energy lost in this way, however, it is called damped vibration. In many physical systems, the amount of damping is so small that it can be disregrated for most engineering purposes. However, consideration of damping becomes extermely important in analyzing vibratory system near resonance.
- **Linear and nonlinear vibration** : If all the basic components of vibratory system—the spring, the mass and the damper—behave lineraly, the resulting vibration is known as linear vibration.if ,however,any af the basic components behave non linearly, the vibration is called non linear vibration.

IMPORTANCE OF VIBRATION

- The increasing demands of high productivity and economical design led to higher operation speeds of machinery and efficient use of materials through light weight structures. Theses makes the trend of resonance conditions more frequent the periodic measurement of vibrations characteristic of machinery and structures become essential to ensure adequate safety margins. Any observed shift in the natural frequencies or other vibration characteristics will indicate either failure or a need for maintenance of the machine.

- The measurement of the natural frequencies of the structure or machine is useful in selecting the operational speed of nearby machinery to avoid resonant conditions.
- The theoretically computed vibration characteristics of a machine or structure may be different from the actual values due to the assumptions made in the analysis.
- In many applications survivability of a structure or machine in a specified vibration environment is to be determined. If the structure or machine can perform the expected task even after completion of testing under the specified vibration enviroment, it is expected to survive the specified conditions.
- Continuous systems are often approximated as multidegree of freedom systems for simplicity .If the measured natural frequencies and mode shapes of a continuous system are comparable to the computed natural frequencies and mode shapes of the multidegree of freedom model, then the approximation will be proved to be a valid one.
- The measurement of the input and the resulting output vibration of a system helps in identifying the system in terms of its mass stiffness and damp.
- The information about ground vibration due to earthquakes, fluctuating wind velocities on structures, random variation of ocean waves and road surface roughness are in the design of structures, machines oil platforms and vehicle suspensions systems.

Crack:

A crack in a structural member introduces local flexibility that would affect vibration response of the structure. This property may be used to detect existence of a crack together its location and depth in the structural member. The presence of a crack in a structural member alters the local compliance that would affect the vibration response under external loads.

Classification of Crack

Based on geometries, cracks can be broadly classified as follows::

Transverse crack : These are cracks perpendicular to beam axis. These are the most common and most serious as they reduces the cross section as by weaken the beam .They introduce a local flexibility in the stiffness of the beam due to strain energy concentration in the vicinity or crack tip.

Longitudinal cracks : These are cracks parallel to beam axis. They are not that common but they pose danger when the tensile load is applied at right angles to the crack direction i.e. perpendicular to beam axis.

Open cracks : These cracks always remain open .They are more correctly called “notches”. Open cracks are easy to do in laboratory environment and hence most experimental work is focused on this type of crack

Breathing crack : These are cracks those open when the affected part of material is subjected to tensile stress and close when the stress is reversed . The component is most influenced when under tension. The breathing of crack results in non-linearity in the vibration behavior of the beam.

Most theoretical research efforts are concentrated on "transverse breathing" cracks due to their direct practical relevance.

Slant cracks : These are cracks at an angle to the beam axis , but are not very common . There effect on lateral vibration is less than that of transverse cracks of comparable severity.

Surface cracks : These are the cracks that open on the surface .They can normally be detected by dye-penetrates or visual inspection.

Subsurface cracks : Cracks that do not show on the surface are called subsurface cracks . Special techniques such as ultrasonic, magnetic particle, radiography or shaft voltage drop are needed to detect them. Surface cracks have a greater effect than subsurface cracks in the vibration behavior of shafts.

Crack detection:

Detection of crack in a beam is performed in two steps. First, the finite element model of the cracked cantilever beam is established. The beam is discretized into a number of elements, and the crack position is assumed to be in each of the elements. Next, for each position of the crack in each element, depth of the crack is varied. Modal analysis for each position and depth is then performed to find the natural frequencies of the beam. Using these results, a class of three dimensional surfaces is constructed for the first three modes of vibration, which indicate natural frequencies in terms of the dimensionless crack depth and crack position.

Analysis and scheme::

Frequency Analysis Based on the Fast Former Transform (FFT) Algorithm is the tool of choice for measurement and diagnostic of vibration. The FFT Analyzer is recently developed pc based virtual instrument. It uses impulse execution & either frequency domain analysis or time – domain Analysis to entrant the model Parameter from the response measurement in real time. Following impulse are execution of the specimen , the measured analog response signal maybe digitalized & analyzed using the domain techniques or transformed for analysis in the frequency domain using FFT Analyzer. The peaks in the frequency response spectrum are the location of natural frequency.

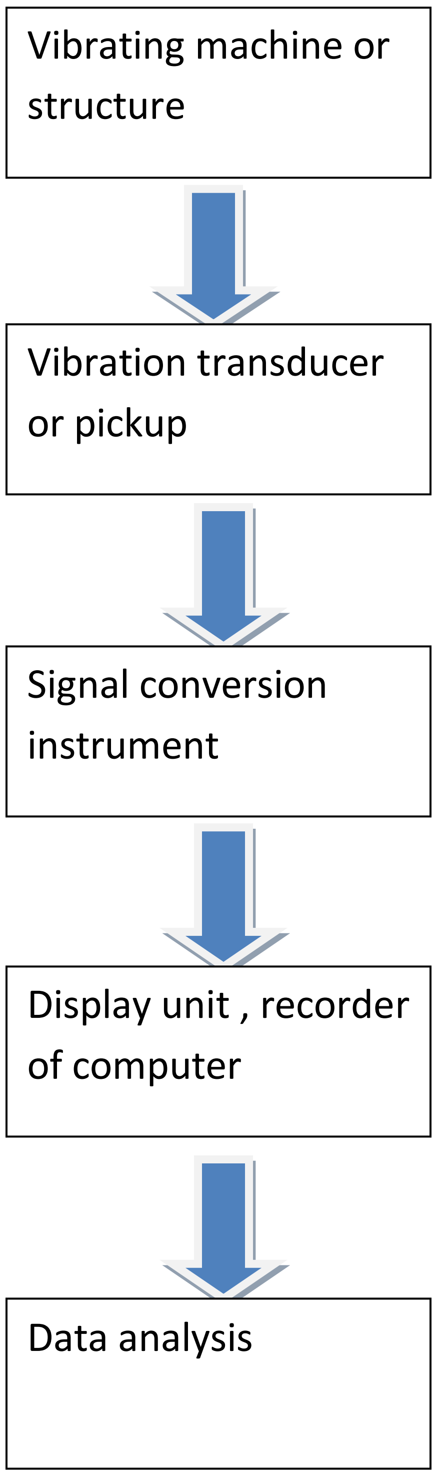
The model parameter can be entranced from a set of frequency response function (FRF) measurements between one or more reference positions & measurement position required in model. The response frequency and damping value can be found from any of the FRF measurements. On the structure the execution of the model parameter from FRF can be done using a variety of mathematical curve fitting algorithm. The FRF can be obtained using multichannel FFT measurements. The determination of frequency with the help of PULSE software requires the determination of following:

- Determination of the Mode – Shape.
- Determination of Model frequencies.

Structure experience vibration to some degree & their design generally requires consideration of their oscillatory behavior.

In the practice nearly all vibration problems are related to structural weakness, associated with response behavior (that is natural frequencies being excited by operational forces) it can be shown that completely dynamic behavior of a structure (in a given frequency range) can be viewed as a set of individual model of vibration, each having a characteristic natural frequency, damping of mode shape.

Vibration Measurement Scheme



Apparatus Required:

- ✓ Model hammer.
- ✓ Accelerometer.
- ✓ FFT Analyser.
- ✓ Notebook with PULSE software.
- ✓ Electrodynamic vibration shaker system
    - Power amplifier cum signal generator
    - Vibration table
- ➢ Specimen

Apparatus Description:

- **Deltatron Accelerometer:**

  Deltatron accelerometer combines high sensitivity, low and small physical dimensions making them ideally suited for model analysis. Easily fitted to different test objects using a selection of mounting clips

❖ Modal hammer

The model hammer exits the structure with a constant force over a frequency range of interest. Three interchange tips are provided which determine the width of the input pulse and thus the band width the hammer structure is acceleration compensated to avoid glitches in the spectrum due to hammer structure resonance.

❖ Portable FFT Analyzer - type (3560C)

Bruel and kjaer pulse analyzer system type – 3560. The software analysis was used to measure the frequency ranges to which the foundation various machines are subjected to when the machine is running with no load and full load. This will help us in designing the foundations of various machines on such a way that they are able to resist the vibration caused in them.

❖ Display unit

This is mainly in the form of PC (Laptop) when the excitation occurs to the structure the signals transferred to the portable PULSE and after conversion comes in graphical form through the software . Mainly the data includes graphs of force Vs time, frequency Vs time resonance frequency data etc.

ELECTRODYNAMIC VIBRATION SHAKER SYSTEM

SYSTEM DESCRIPTION

MEV system is developed with indigenous design and manufacture for dynamic testing to determine the fundamental physical properties of materials and products. We experienced in the indigenous manufacture of mechanical vibrators, transducers, data acquisition system, centrifuge machine and close loop Electro Dynamic techniques etc.

The series of MEV vibration system are the result of long experience in the design and manufacture of test system. It assists the user in determining the safety, reliability, durability and resonance frequency of the product.

A vibration test system consists of a signal generator, a power amplifier and vibration exciter.

ELECTRODYNAMIC VIBRATION SHAKER SYSTEM CONSISTS THE FOLLOWING ITEMS:-

1. VIBRATION TABLE
2. POWER AMPLIFIER CUM SIGNAL GENERATOR

VIBRATION TABLE

The MEV SERIES of vibrators are having drive armature connected rigidly to the moving platform and positioned in the magnetic field. When AC current flows in this drive coil gives rise to a force by converting an electric current into mechanical force which moves the platform. The vibrator can operate in the frequency range from 5Hz to 2500Hz from either sine or random input wave form. The function of a vibration generation system is to produce a selected wave form with required vibration level (i.e. Acceleration/ Velocity/ Amplitude) and frequency to test specimen mounted on the vibration exciter. The Electro Dynamic Vibrator is very much reliable as there is no rolling part to wear out and axial resonance frequency is kept quite to avoid self resonance. The system force rating and moving element mass are the primary characteristics which determine the vibration level.

SALIENT FEATURES

- Long term reliability
- Link arm suspension system
- Excellent cross-axial restraint
- Dual suspension system

SPECIFICATIONS

Model	:	MEV 0020
PEAK Sine Force	:	±20 Kgf (±200N)
Max. Displacement	:	10 mm (pk-pk)
Frequency Range	:	5 Hz to 2500 Hz (Within 0.1 db)
1st Major Armature resonance	:	>2.5 Kg
Max. Payload	:	2.5 Kg
Shaker Rotation	:	±90 kg degree from vertical
Drive power	:	Thru a solid state Power Amplifier cum Signal Generator

Cooling Method	:	Integral fan cooled

POWER AMPLIFIER CUM SIGNAL GENERATOR

The MPA Series power Amplifier Cum Signal Generator are all of solid state type permitting for excellent durability, and are equipped with self protective facility such as cooling facility check, temperature check, current supply check as well as interlock facility for mis-operation to ensuring safety operation. The amplifiers are designed for continuous full power and transient over load condition. The amplifiers of upto rated output rated output 15 KVA are of an air-cooling type. (Above functions are model dependants)

The function of Power Amplifier Cum Signal Generator is to amplify the output signal of signal generator, sufficiently to drive the exciter to the desired vibration level. D.C. supply to energize magnetic field of Electro Dynamic Vibrator is built in the power amplifier.

The amplifier generates signal which is fed to amplifier for further amplification. It has a built in sinusoidal waveform generator which provides variable frequency sine wave output adjustable from 1Hz to 10 KHz in four over lapping ranges having fine frequency setting in between the ranges.

SALIENT FEATURES

- Low distortion
- High power gain
- Internal field support
- Wide range frequency bandwidth
- Versatile design
- Built in sinusoidal waveform generator
- Integral metering of armature voltage and current

Procedure :

- The connections i.e accelerometer, modal hammer, laptop and other power connections were made.
- The surface of the beam was cleaned for proper contact with the accelerometer.
- The accelerometer was then attached with the surface of the beam.
- The above connections were made for free vibrations.
- For Forced Vibration, Electrodynamic Vibration Shaker System was used which consist of Vibration Table and Power Amplifier Cum Signal Generator.
- Readings were taken for free-free and fixed-free boundary conditions for different steel beams.
- The modal analysis results are compared with FEM package ANSYS and analytical values.

Beam specification:

Length of the steel beam used for free free condition = 30 cm

Length of the steel beam used for fixed free condition = 28cm

Breadth of the steel beam = 10mm and 9.2mm

Height of the steel beam = 10mm and 9.2mm

Natural frequency of the beam was computed from the following equation::

$\omega = (\beta l)^2 (EI/\rho a l^4)^{1/2}$

where, ω= natural frequency of vibration

βl= constant(depend on boundry conditions) i.e.

For free free :

$B_1 l$ = 4.730041(freq at 1st mode)

$\beta_2 l$ = 7.853205(freq at 2nd mode)

$\beta_3 l$ = 10.995608(freq at 3rd mode)

$\beta_4 l$ = 14.137165(freq at 4th mode)

For cantilever ::

$\beta_1 l$ = 1.875104 (freq at 1st mode)

$\beta_2 l$ = 4.694091(freq at 2nd mode)

$\beta_3 l$ = 7.854757(freq at 3rd mode)

$\beta_4 l$ = 10.995541(freq at 4th mode)

E= Youngs modulus

ρ= Density of steel

a= Area of cross section of steel

Results and discussion:

Theoretical results:

MODE → SL NO ↓	1st mode (in Hz)	2nd mode (in Hz)	3rd mode (in Hz)	4th mode (in Hz)
1.(l=0.3m,b=10mm,h=10mm)	544	1501	2944	4866
2.(l=0.3m,b=9.2mm,h=9.2mm)	528.28	1456.23	2854.79	4719.12

Comparison of experimental with theoretical results:

Steel (uncracked ,free-free boundry condition):

(l = 30 cm, b = 10mm, h = 10mm)

MODE → SL NO ↓	1st mode (Hz) (Theoretical=544)	2nd mode (Hz) (Theoretical=1501)	3rd mode (Hz) (Theoretical=2944)
1	576 (ϵ=5.78%)		
2	576 (ϵ=5.8%)	1584 (Є=5.5%)	2984 (Є=1.3%)
3	592 Є=8.8%		2976 (Є=1.08%)
4	576 (Є=5.8%)	1576 (Є=4.7%)	2992 (Є=1.63%)
5	576 (Є=5.8%)		
6	576 (Є=5.8%)	1584 (Є=5.5%)	2984 (Є=1.3%)
7	592 (Є=8.8%)		2992 (Є=1.63%)
8	576 (Є=5.8%)	1576 (Є=4.7%)	2968 (ϵ=0.8%)

Steel (uncracked, fixed-free boundry condition)::

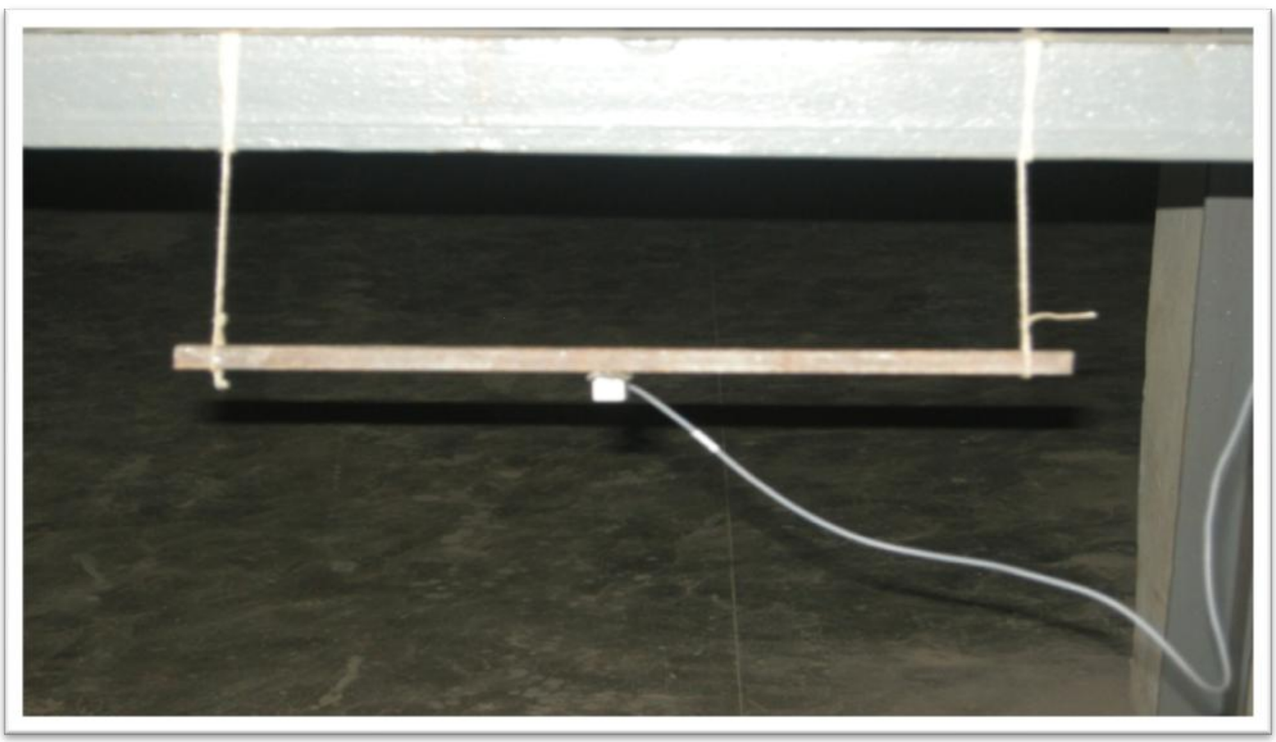
(l = 28 cm, b = 10mm, h = 10mm)

MODE → SL NO ↓	1st mode (Hz) (Theoretical=114)	2nd mode (Hz) (Theoretical=711)	3rd mode (Hz) (Theoretical=1993)
1	96 (ϵ=15.8%)	688 (Є=3.2%)	1856 (Є=6%)
2	96 (ϵ=15.8%)	688 (Є=3.2%)	1608 (Є=19%)
3	96 (ϵ=15.8%)	688 (Є=3.2%)	1720 (ϵ=13%)
4	96 (ϵ=15.8%)	688 (Є=3.2%)	1744 (ϵ=12%)
5	96 (ϵ=15.8%)	680 (Є=4.4%)	
6	96 (ϵ=15.8%)	688 (Є=3.2%)	
7	112 (ϵ=1%)	688 (Є=3.2%)	1744 (ϵ=12%)
8	96 (ϵ=15.8%)	688 (Є=3.2%)	1744 (ϵ=12%)

Steel rod (uncracked, free-free boundry condition)::

(diameter = 10mm , l= 30cm)

MODE → SL NO ↓	1st mode (Hz) (Theoretical=505)	2nd mode (Hz) (Theoretical=1393)	3rd mode (Hz) (Theoretical=2732)	4th mode (Hz) (Theoretical=4516)
1	500 (Є=0.99%)			
2	500 (Є=0.99%)	1388 (Є=0.35%)		4188 (ϵ=7.26%)
3	500 (Є=0.99%)	1400 (ϵ=0.5%)	2513 (ϵ=8%)	4425 (ϵ=2%)
4	500 (Є=0.99%)			
5	500 (Є=0.99%)	1388 (Є=0.35%)		4200 (ϵ=6.9%)
6	500 (Є=0.99%)	1313 (ϵ=1.74%)	2513 (ϵ=8%)	
7	500 (Є=0.99%)	1388 (Є=0.35%)	2513 (ϵ=8%)	4425 (ϵ=2%)
8	512 (Є=1.38%)	1313 (Є=5.74%)	2488 (ϵ=8.93%)	



Steel (free-free boundry condition):

(l= 30 cm, b = 9.2mm,h= 9.2mm)

Ansys results for single crack

Sl no	Crack location	Crack depth	Frequency (Hz)			
			1st mode	2nd mode	3rd mode	4th mode
1	Uncrack	Nil	535.81	1467.9	2852.2	4660.7
2	Crack at centre	2mm	524.30	1467.9	2807.6	4660.5
3		5mm	451.09	1467.4	2570.1	4656.1
4		7mm	307.02	1466.3	2274.4	4646.2
5	Crack at 0.33L	2mm	528.80	1422	2847.6	4628
6		5mm	478.76	1305.3	2822.0	4423
7		7mm	350.42	1129.1	2768.5	4134.4
8	Crack at 0.25L	2mm	532.23	1442	2804.8	4648.7
9		5mm	504.28	1279.6	2610.1	4589.6
10		7mm	408.49	1022	2421.0	4519.7

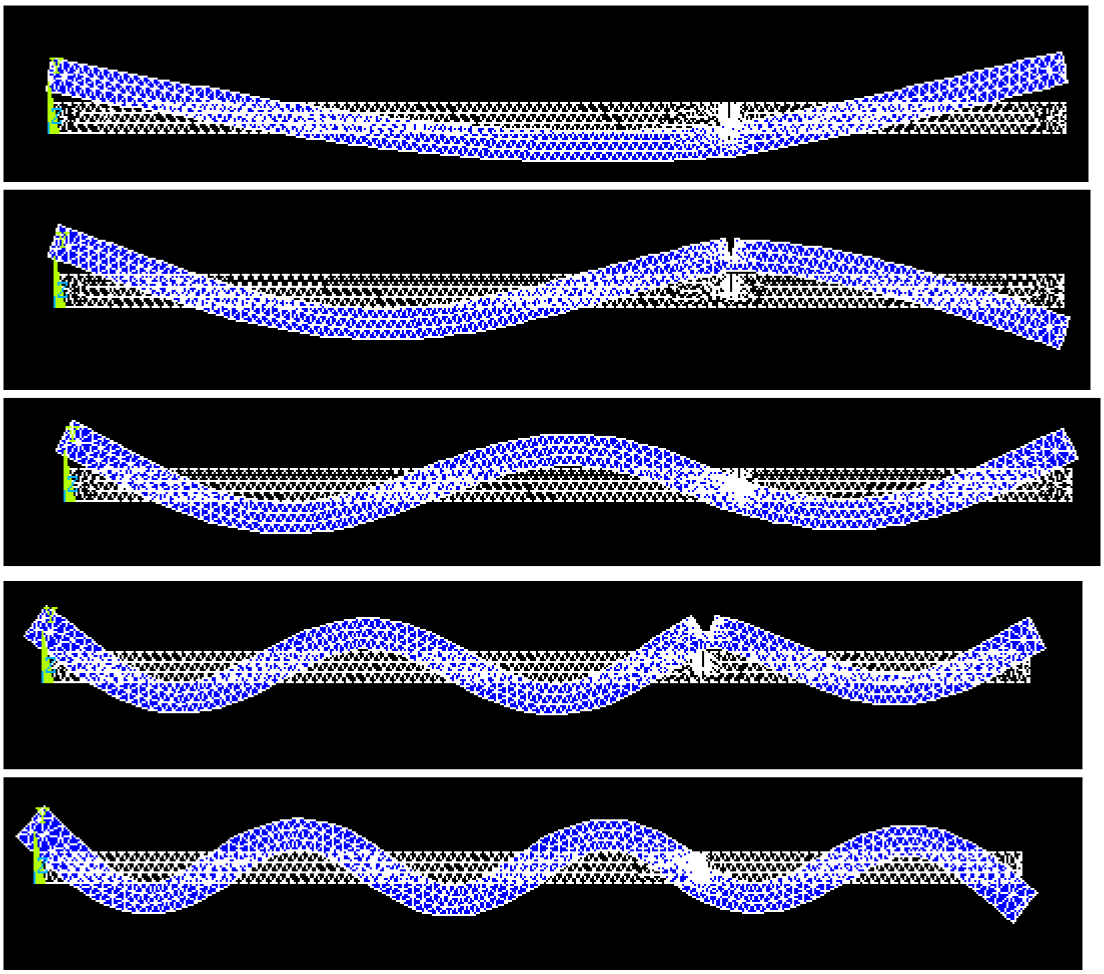
Steel free-free boundry conditions :

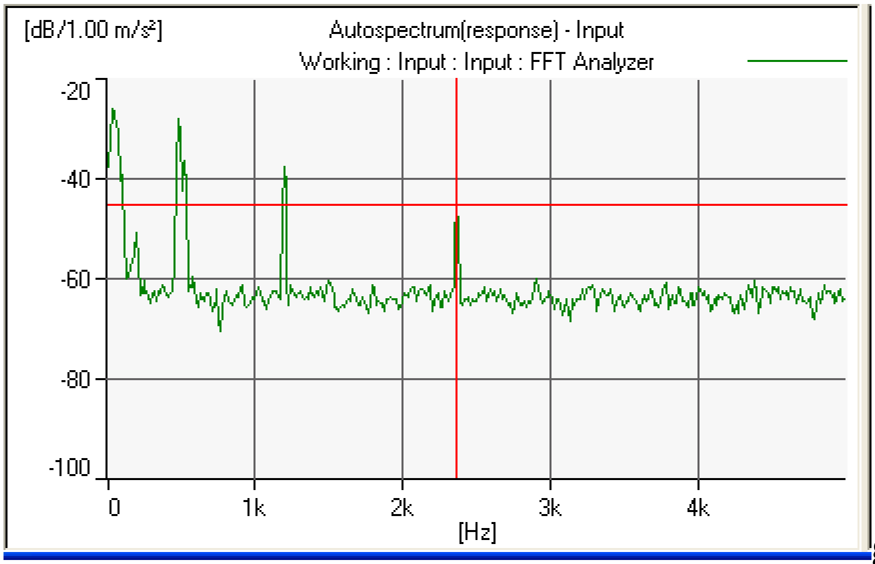
(l= 30cm, b= 9.2mm,h= 9.2mm)

Sl no	**Crack location**	**Crack depth**	**Frequency (Hz)**			
Sl no	**Crack location**	**Crack depth**	**1st mode**	**2nd mode**	**3rd mode**	**4th mode**
1	**Uncrack**	**Nil**	**537.5**	**1496**	**2663**	**4480**
2	**Crack at centre**	**2mm**	**512.5**	**1452.8**	**2625**	**4713**
3		**5mm**	**437.5**	**1375**	**2475**	**4388**
4		**7mm**	**287.5**	**1363**	**2113**	**4388**
5	**Crack at 0.33L**	**2mm**	**487.5**	**1363**	**2625**	**4425**
6		**5mm**	**462.5**	**1275**	**2820**	**4538**
7		**7mm**	**337.5**	**1088**	**2600**	**4675**
8	**Crack at 0.25L**	**2mm**	**512.5**	**1400**	**2625**	**4425**
9		**5mm**	**487.5**	**1238**	**2488**	**4400**
10		**7mm**	**450**	**1100**	**2442**	**4388**

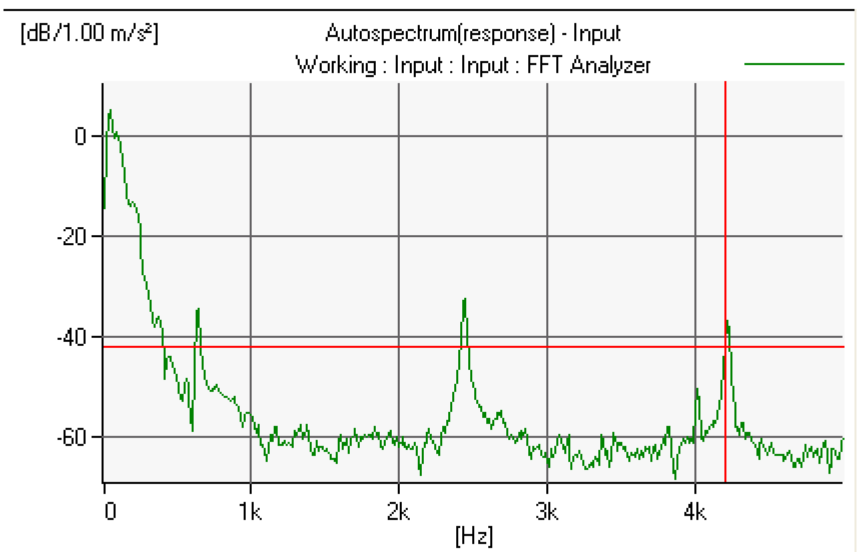
Experimental results for single crack

Different mode shapes for crack location 0.33L and depth 5mm

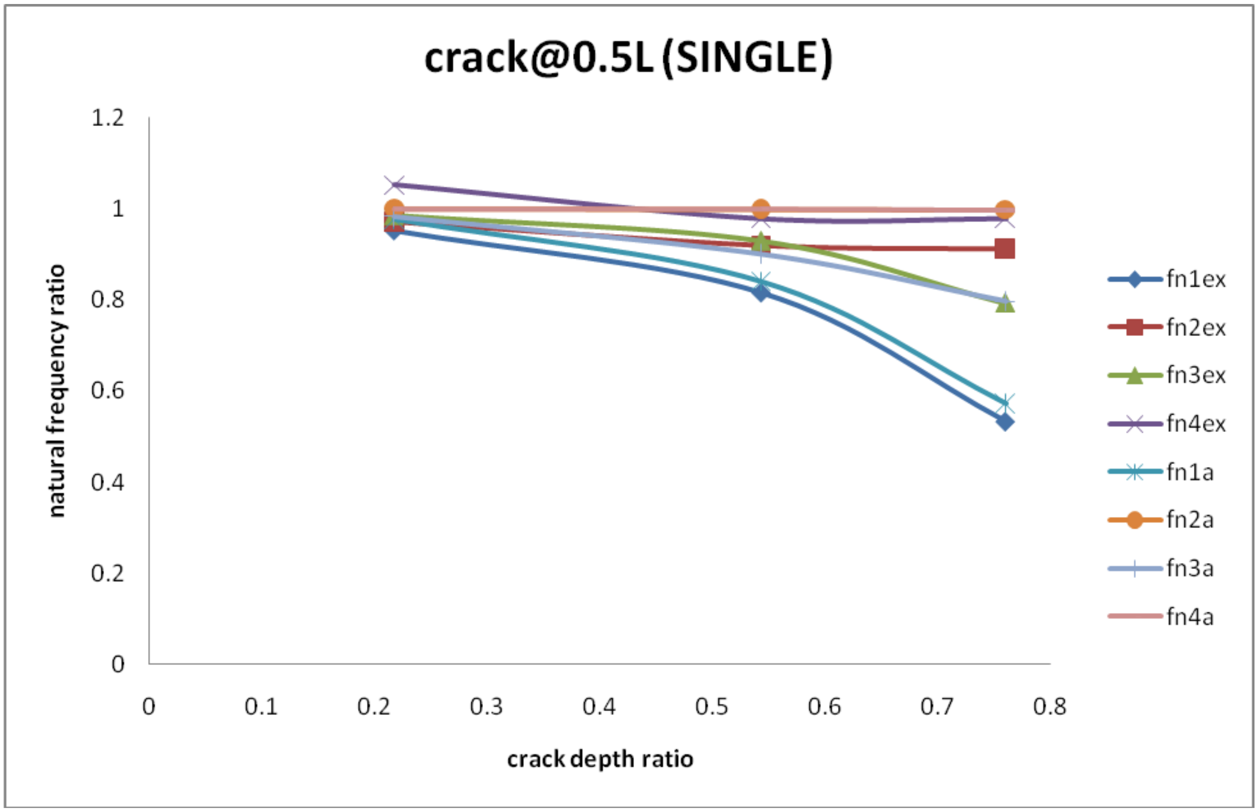


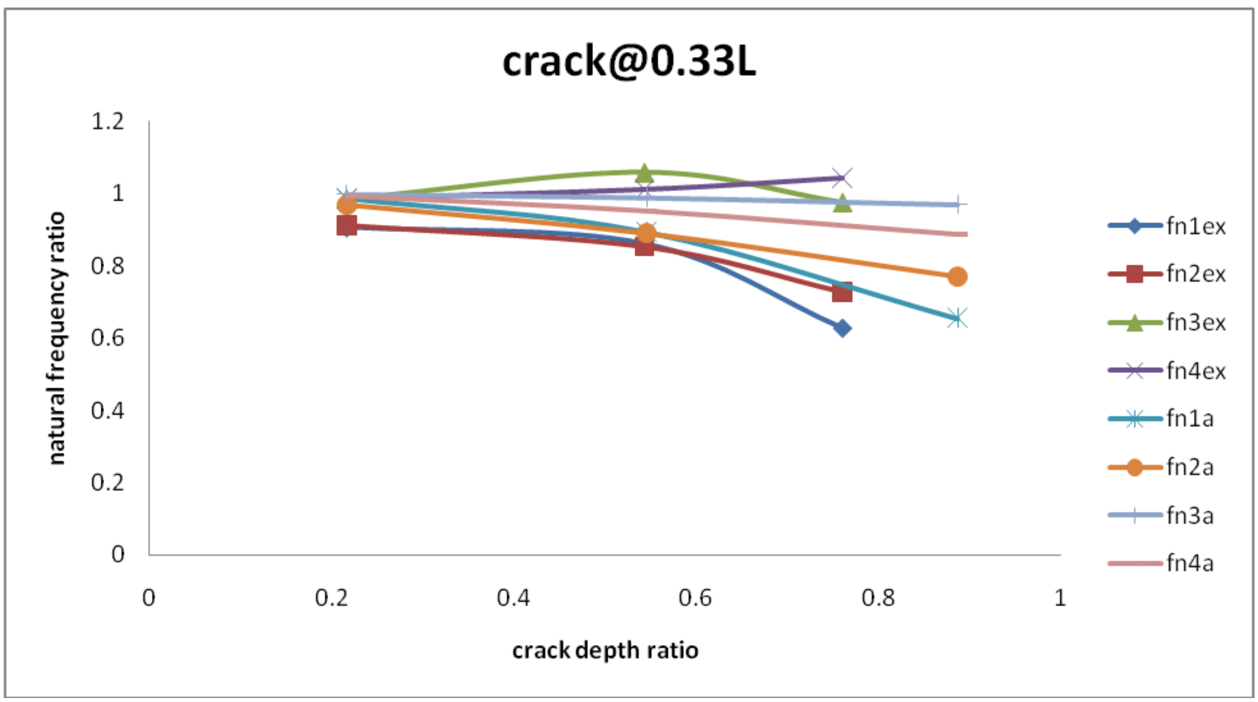


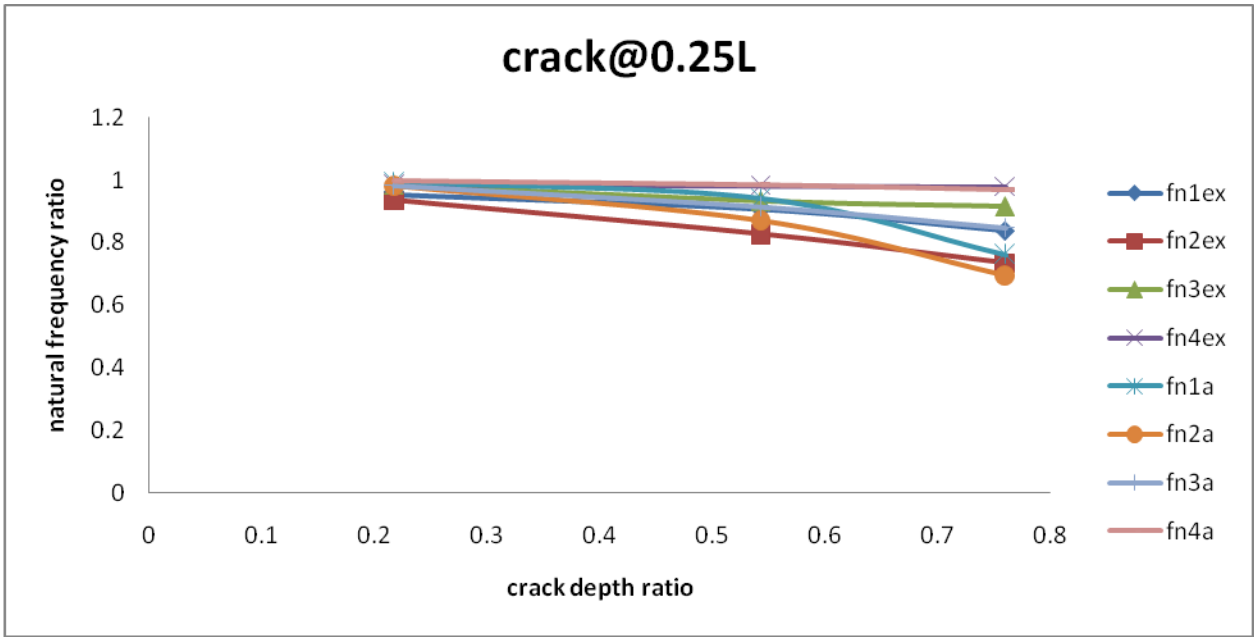
graph for 0.25L, 5mm



graph for 0.33L, 7mm


crack@0.5L (SINGLE)
natural frequency ratio
crack depth ratio
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
fn1ex
fn2ex
fn3ex
fn4ex
fn1a
fn2a
fn3a
fn4a


crack@0.33L
natural frequency ratio
crack depth ratio
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
fn1ex
fn2ex
fn3ex
fn4ex
fn1a
fn2a
fn3a
fn4a



crack@0.25L
natural frequency ratio
crack depth ratio
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
fn1ex
fn2ex
fn3ex
fn4ex
fn1a
fn2a
fn3a
fn4a

Steel free-free boundry conditions：

Sl no	Crack location	Crack depth	Frequency (Hz)			
			1st mode	2nd mode	3rd mode	4th mode
1	Uncrack	Nil	535.81	1467.9	2852.2	4660.7
5	Crack at 0.33L	2mm	528.75	1417.3	2766.7	4636.3
6		5mm	479.87	1134.5	2335.6	4506.4
7		7mm	358.54	705.93	1482.1	4341.6
8	Crack at 0.25L	2mm	521.78	1416.7	2841.0	4595.1
9		5mm	439.61	1133.6	2784.1	4315.5
10		7mm	291.37	701.65	2679.8	4045.2

Ansys results for multiple crack

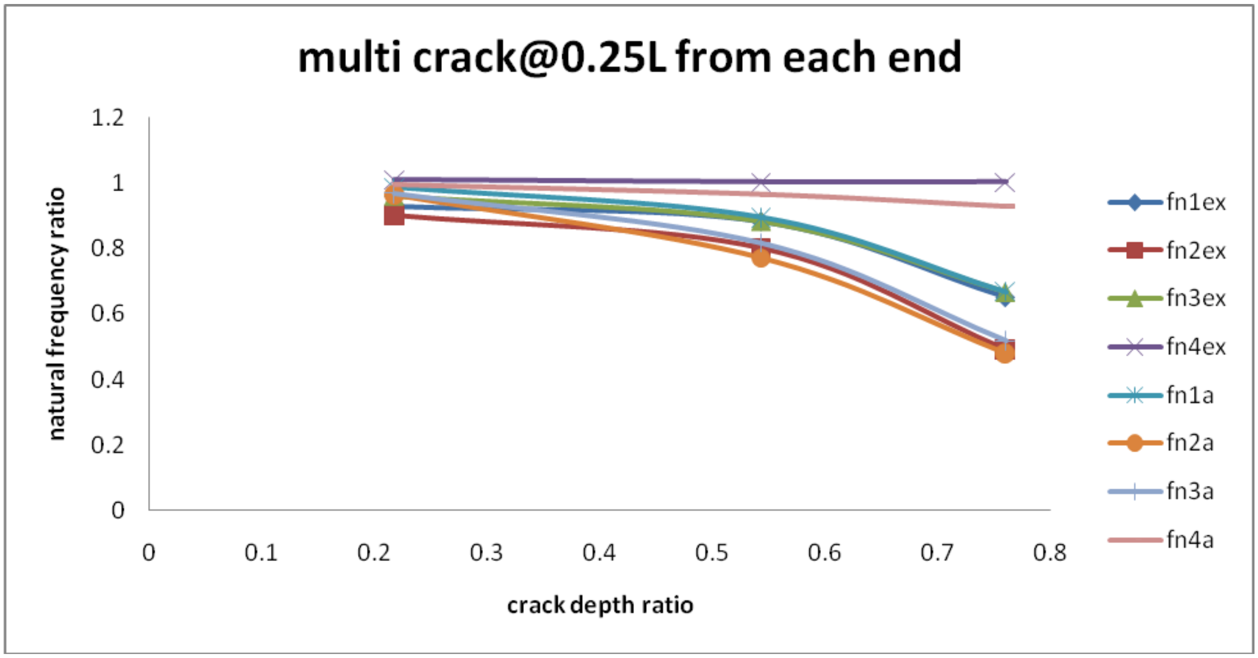
(l= 30 cm, b= 9.2mm, h=9.2mm)

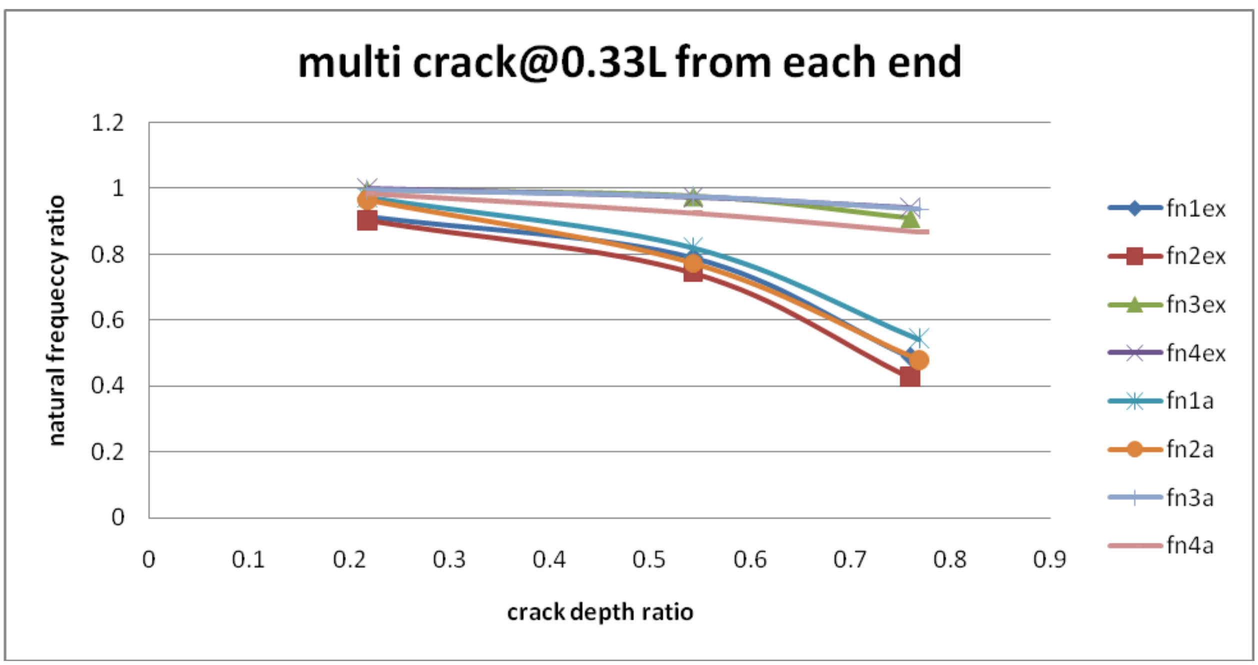
Steel free-free boundry conditions :

(l= 30 cm, b= 9.2mm, h=9.2mm)

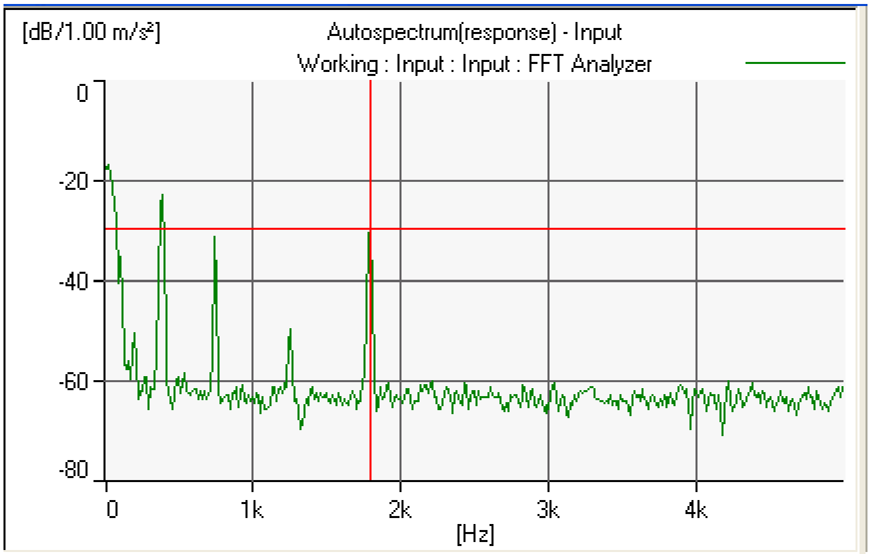
Sl no	Crack location	Crack depth	Frequency (Hz)			
			1st mode	2nd mode	3rd mode	4th mode
1	Uncrack	Nil	537.5	1496	2663	4480
5	Crack at 0.33L	2mm	492	1350	2650	4500
6		5mm	425	1113	2600	4363
7		7mm	262.5	637.5	2422	4213
8	Crack at 0.25L	2mm	500	1350	2563	4525
9		5mm	475	1200	2356	4500
10		7mm	350	737	1775	4500

Experimental results for multiple crack

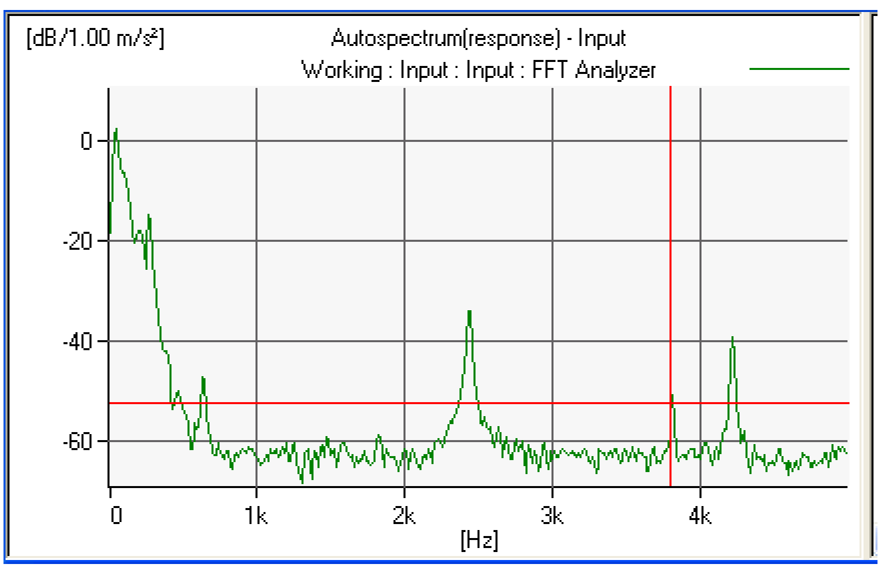

multi crack@0.25L from each end
1.2
1
0.8
0.6
0.4
0.2
0
natural frequency ratio
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
crack depth ratio
fn1ex
fn2ex
fn3ex
fn4ex
fn1a
fn2a
fn3a
fn4a


multi crack@0.33L from each end
1.2
1
0.8
0.6
0.4
0.2
0
natural frequeccy ratio
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
crack depth ratio
fn1ex
fn2ex
fn3ex
fn4ex
fn1a
fn2a
fn3a
fn4a

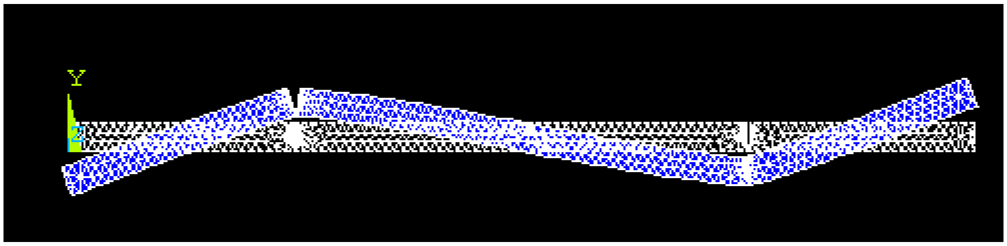
Double crack, crack depth = 7mm @0.25l from each end

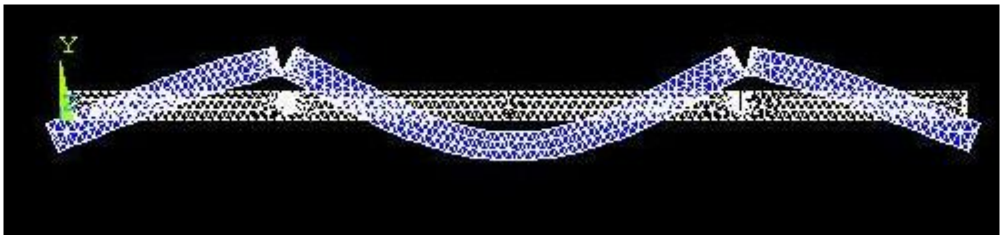


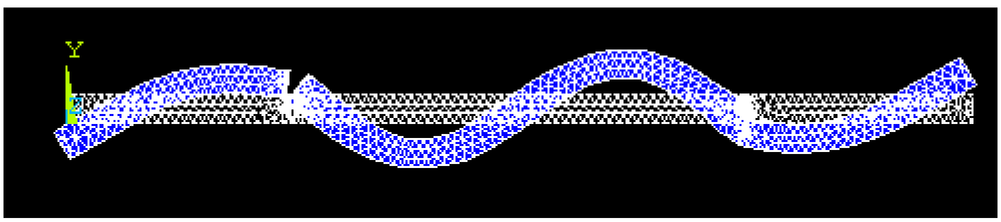
Double crack, crack depth = 7mm @0.33l from each end

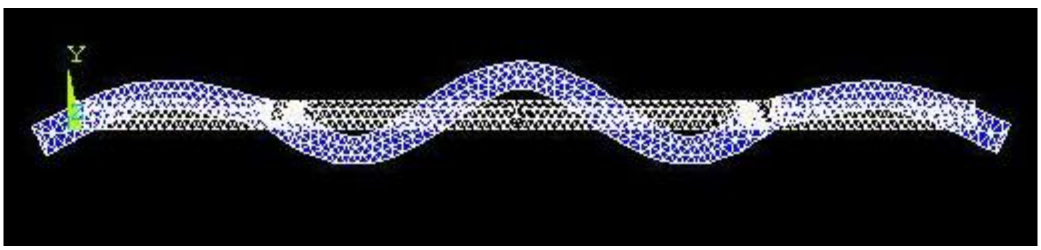


Mode shapes for crack @0.25l, 7mm multicrack









Forced vibration results

For Single crack beam (l = 30 cm , b = 9.2mm , h = 9.2mm)

Sl no	Crack location	Crack depth (in mm)	Frequency (in Hz)			
			1st mode	2nd mode	3rd mode	4th mode
1	Uncrack	Nil	487.5	1400	2663	4488
2	Crack at 0.25l	2	475	1363	2625	4438
3		5	462.5	1250	2475	4363
4		7	450	1100	2400	4338
5	Crack at 0.33l	2	1350	1350	2625	4363
6		5	1263	1263	2625	4325
7		7	1080	1080	2563	4000
8	Crack at centre	2	487.5	1475	2637	4469
9		5	412.5	1475	2425	4400
10		7	275	1369	2119	4387.5

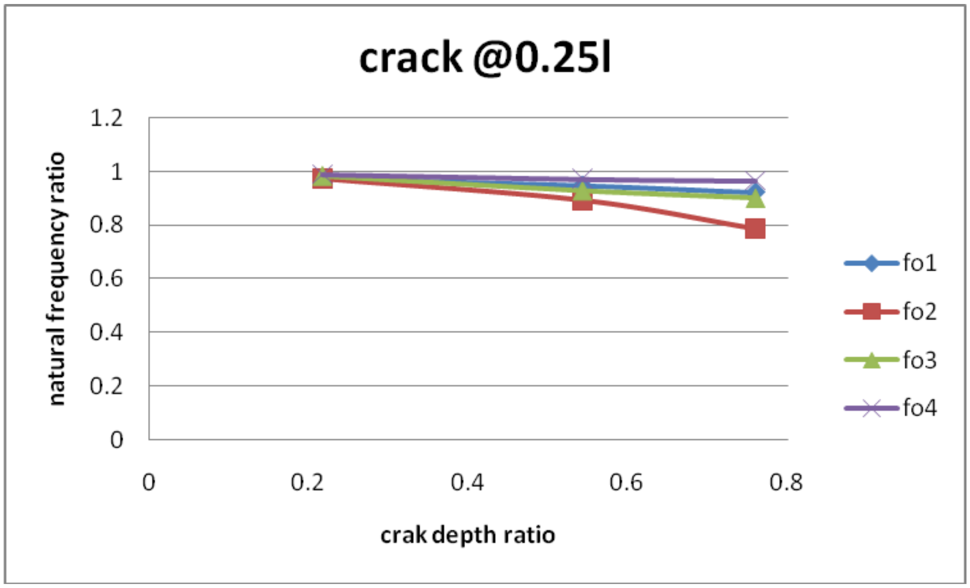
Forced vibration results

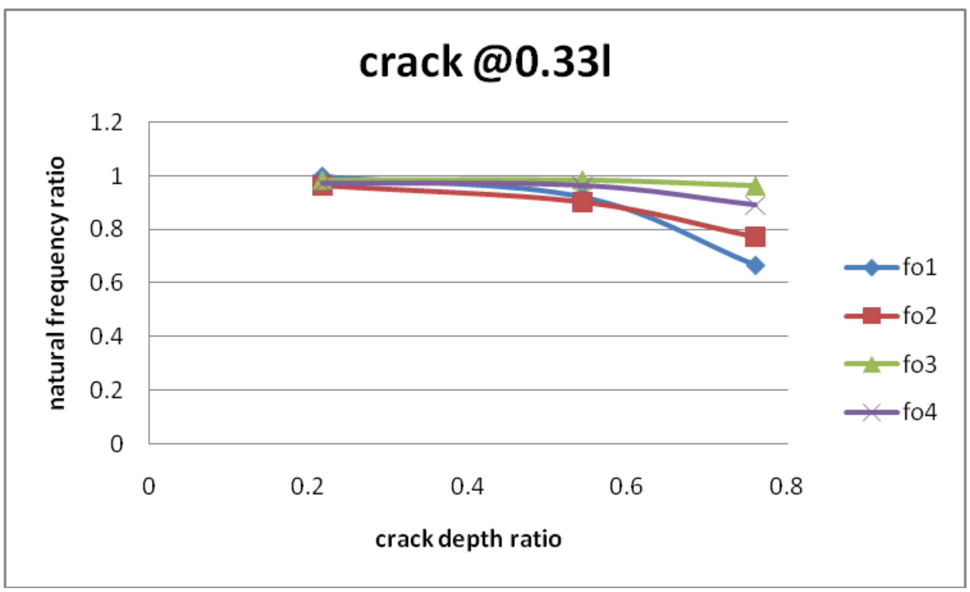
For multicrack beams

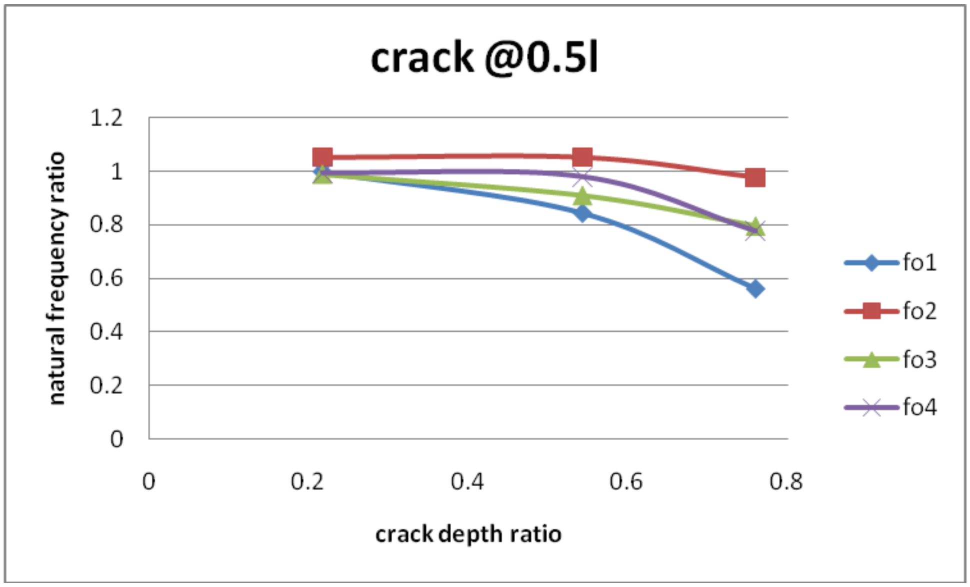
(l = 30 cm , b = 9.2mm , h = 9.2mm)

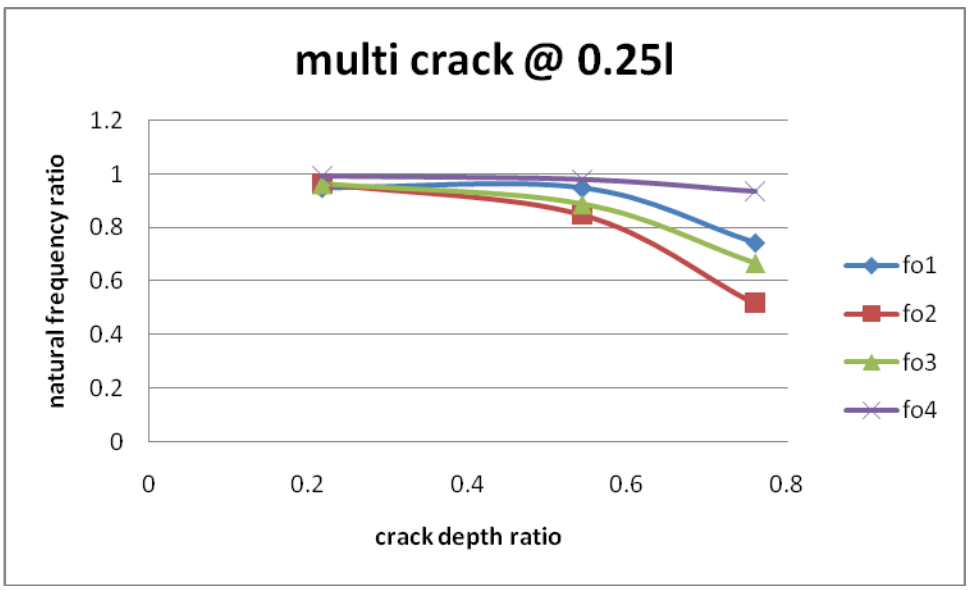
Sl no	Crack location	Crack depth (in mm)	Frequency (in Hz)			
			1st mode	2nd mode	3rd mode	4th mode
1	Uncrack	Nil	487.5	1400	2663	4488
2	0.25l from each end	2	462.5	1350	2563	4462.5
3		5	462.5	1188	2362.5	4406.5
4		7	362.5	725	1775	4200
5	0.33l from each end	2	475	1338	2613	4463
6		5	412.5	1100	2588	4375
7		7	237.5	625	2413	4188

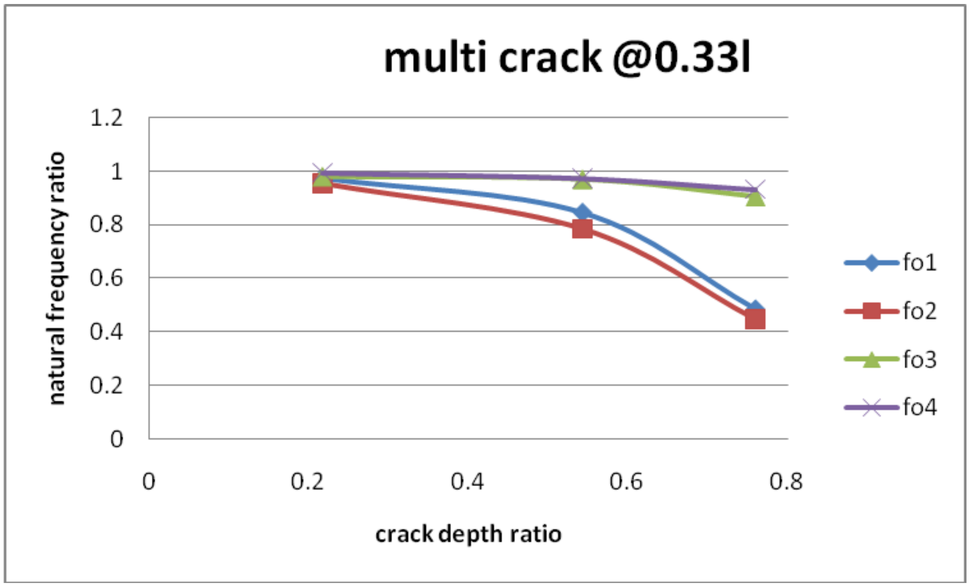
Forced vibrations graphs :






crack @0.5l
natural frequency ratio
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
crack depth ratio
fo1
fo2
fo3
fo4

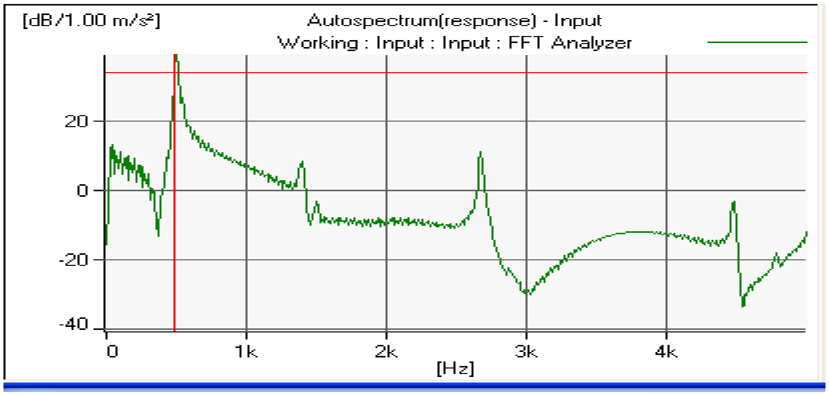

multi crack @ 0.25l
natural frequency ratio
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
crack depth ratio
fo1
fo2
fo3
fo4



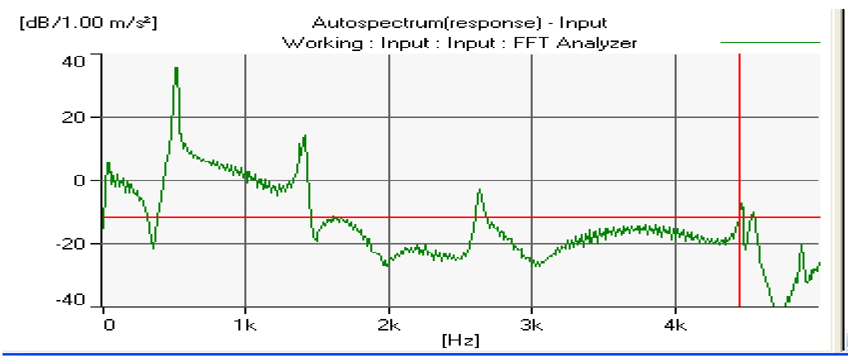
multi crack @0.33l
1.2
1
0.8
0.6
0.4
0.2
0
natural frequency ratio
0
0.2
0.4
0.6
0.8
crack depth ratio
fo1
fo2
fo3
fo4

Various experimental readings :

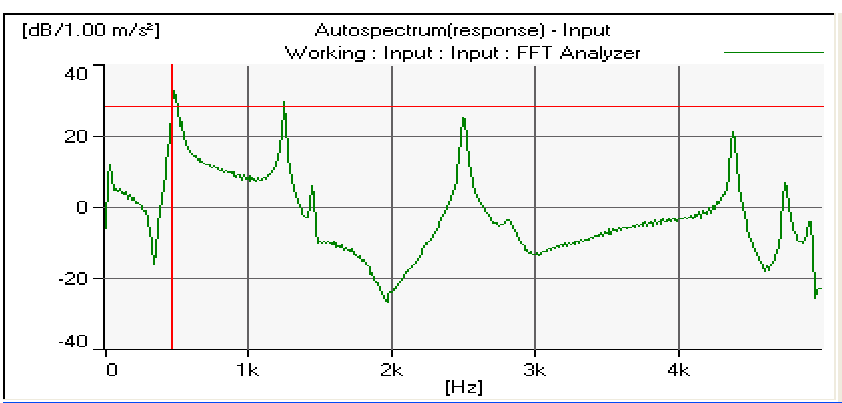
Uncrack



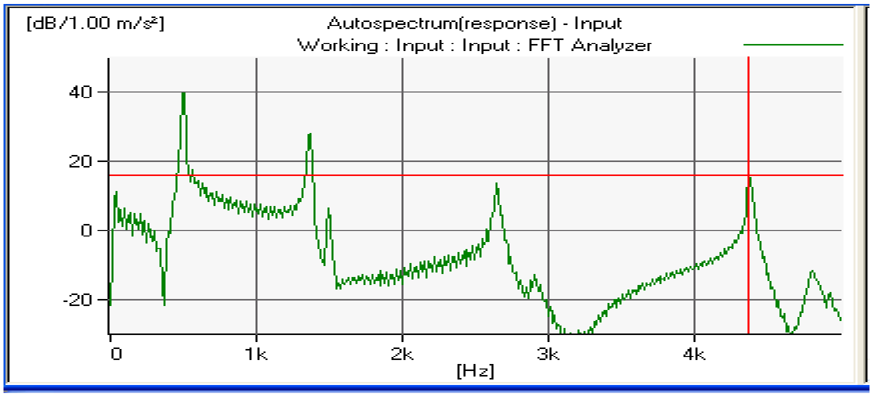
0.25l, 2mm crack



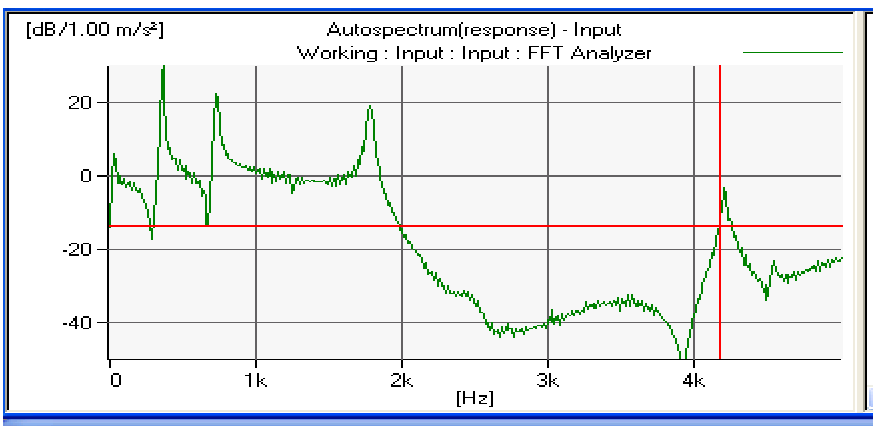
0.25l, 5mm crack



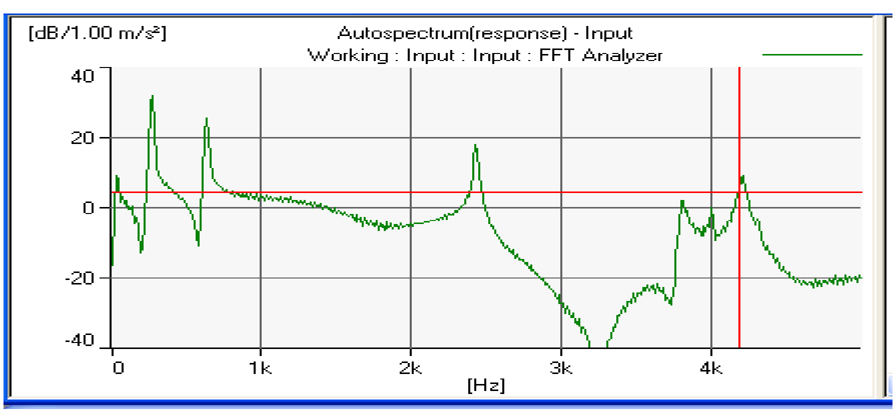
0.33l, 2mm crack



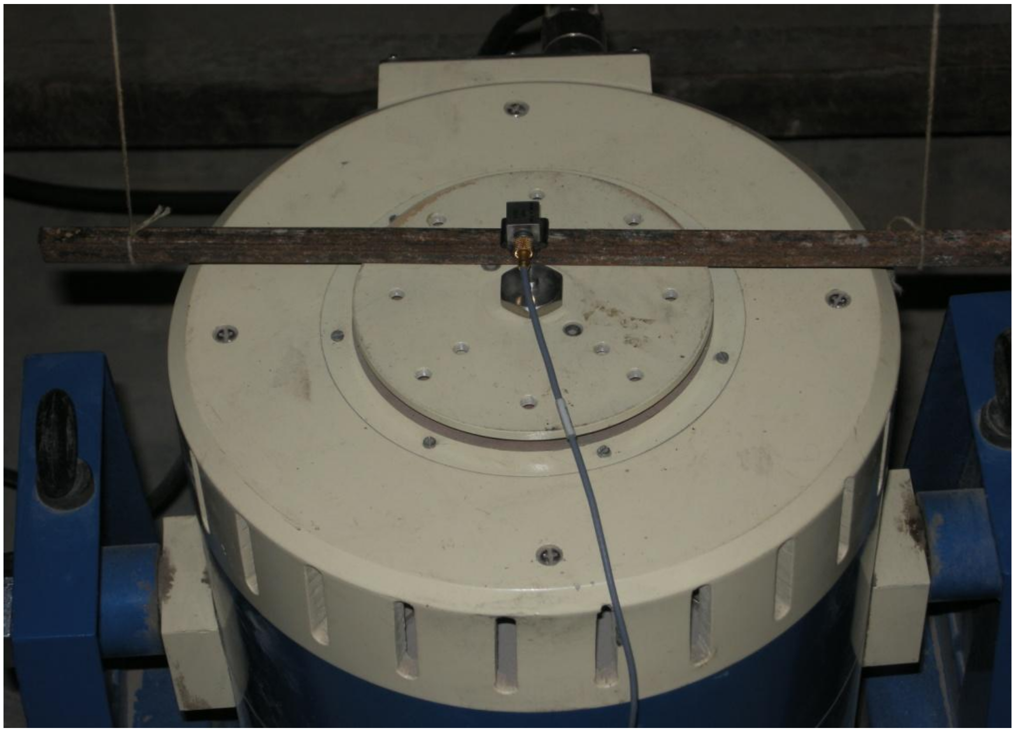
Multicrack, 0.25l ,7mm

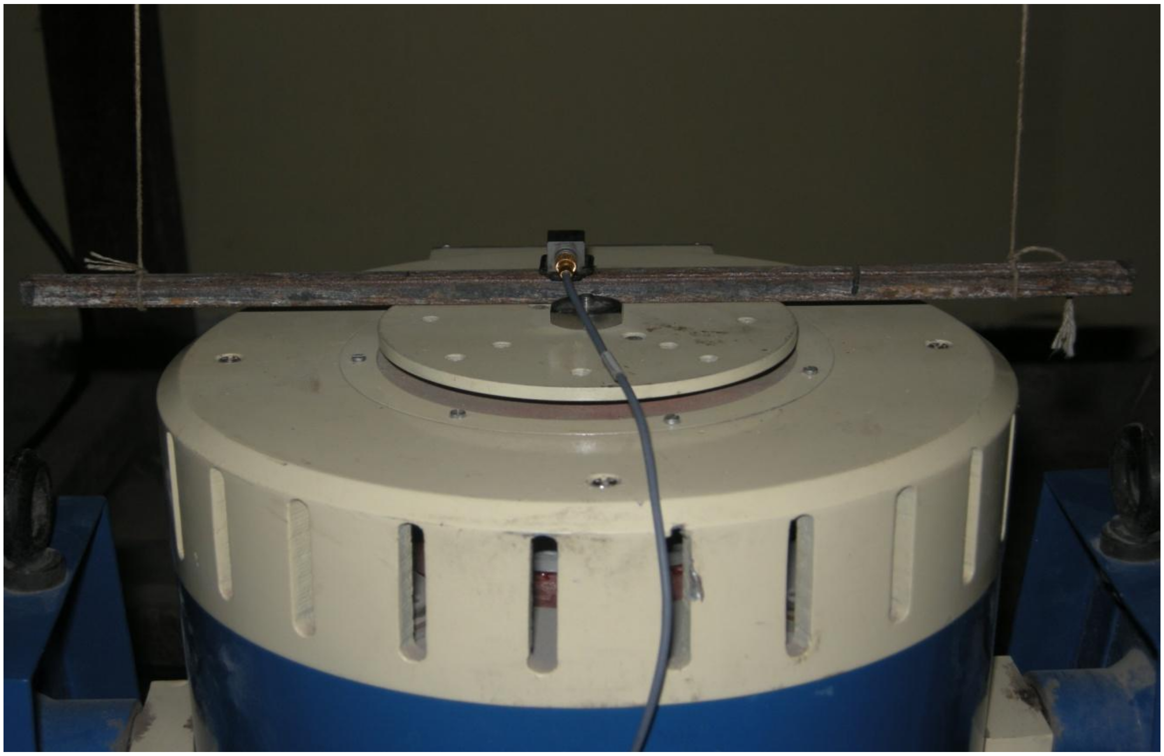


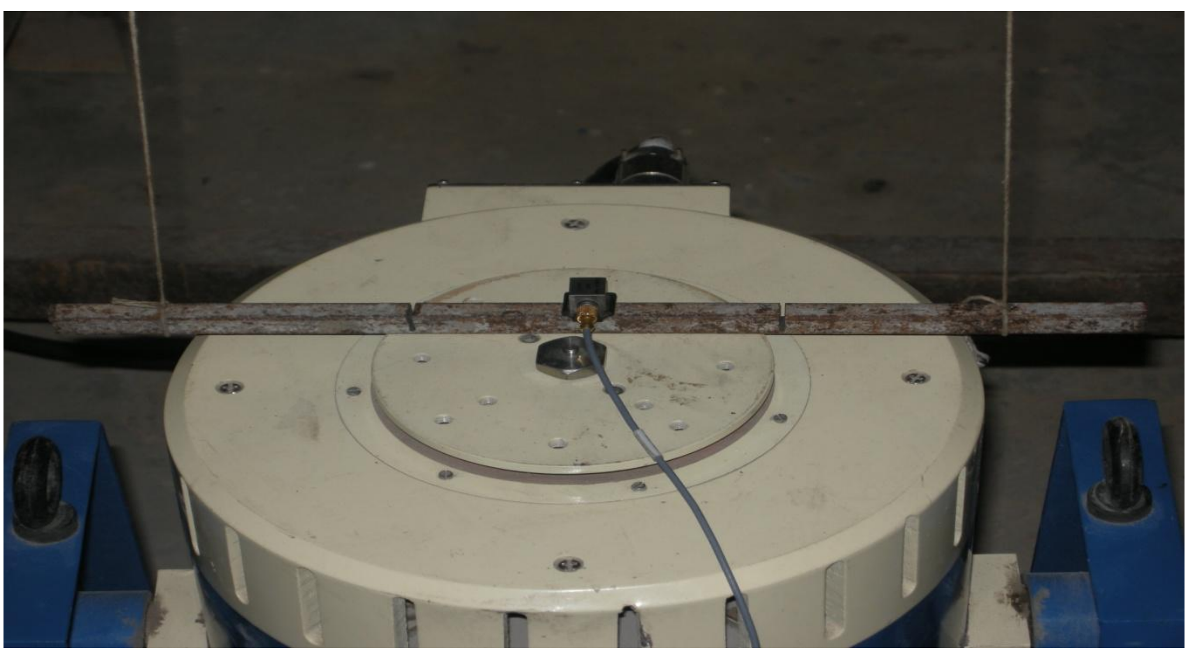
Multicrack,0.33l,7mm




POWER AMPLIFIER CUM SIGNAL GENERATOR
MODEL : MPA-0200
TEQIP
DIGITAL VIBRATION METER







Conclusion:

- In steel beam free-free condition it was seen that the results were in good co ordinance with theoretical values. The lowest frequency was in lowest mode. The frequency was increasing with each subsequent mode of vibration. The percentage of error was also decreasing as frequency is increasing.
- In first mode the natural frequencies of free – free beam decreases more rapidly for crack close to centre than the ends (i.e. the centre cracks are more affected).
- In second mode the natural frequencies of free – free beam decreases more rapidly for crack close to ends than the centre (i.e. the end cracks are more affected).
- For forced vibration, it was seen that the natural frequencies were nearly similar to that of free vibration.

References:

[1] Radhakrishnan V.M, Response of a Cracked Cantilever Beam to Free and Forced Vibrations , *Defence Science Journal*, Vol. 54, No. 1, January 2004**,** pp. 31-38

[2] Nahvi.H, Jabbari.M, Crack detection in beams using experimental modal data and finite element model, *International Journal of Mechanical Sciences* 47 (2005) , pp - 1477–1497

[3] Viola.E , Nobile. L and Federici. L, Formulation of Cracked Beam Element for Structural Analysis, *Journal Of Engineering Mechanics / February 2002*,pp – 220-230

[4] Ertugˇrul C¸ am*, Sadettin Orhan, Murat Lu¨y, An analysis of cracked beam structure using impact echo method, *NDT&E International 38 (2005)*,pp-368–373

[5] Bruel And Pulse Manual

[6] Electrodynamic Vibration Shaker System Manual