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Railway Track Monitoring System

Sponsored by IRICEN, Pune

BY

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ABSTRACT

In India, the railway network is carrying out most of the commercial transport. Today, India possesses the fourth largest railway network in the world. However, in terms of the reliability and safety parameters, we have not yet reached truly global standards. Accidents due to defects on tracks account for 5% of the total railway accidents in our country which results in significant number of derailments and casualties.

Motive behind our project is to develop a new system that would be effective for fracture (complete discontinuity) identification and reporting of the same. The system we are developing will check the tracks when requested by the concerned authority and return the results about the track health accordingly.

There are two modules in our project, one for generating the vibrations and sending them across the track and the other one for sensing the vibrations from the track. Basic idea behind the working of the system is that an uninterrupted continuous stream of vibrations will travel through the track if it is not fractured and can be picked up at the other end but if the track is damaged the vibrations will not be able to complete the desired path. Both the scenarios will be reported to the concerned authority so that required measures can be taken. This approach of track testing is much more efficient than the techniques used today in India. Hence, it can prove to be quite useful in the near future if developed efficiently.

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LIST OF NOMENCLATURE

IRICEN	Indian Railway Institute of Civil Engineering
USFD	Ultrasonic Flaw Detection
GSM	Global System for Mobile communication
LED	Light-Emitting Diode
NDT	Non-destructive Testing
UART	Universal Asynchronous ReceiverTransmitter
LQFP	Low Profile Quad Flat Package
PDIP	Plastic Dual In-line Package
PCB	Printed Circuit Board

MOTIVATION

The important reason for choosing this topic is the number of railway accidents that take place nowadays. We would feel very honoured if we were able to contribute to the Indian Railways in our own small ways if possible. Thus, our motivation for this project is to develop a new system that would be effective for Indian Railways.

PROBLEM DEFINITION & OBJECTIVE

In our project, we mainly considering detection of fractures in railway track. Our main objective is: To detect railway track fracture and transmit condition of track to control room/ station master for alerting in case of emergency.

DEFECTS IN TRACK

Any defect in the rail, which may ultimately lead to fracture or breakage, is called a flaw. The development of flaws in the rails is inevitable because of inherent defects in the rails and fatigue of rails due to passage of traffic. With the increase in the axle loads and the speed of the trains, the rail stresses are increasing day by day, which in turn results in high defect generation rate in the rails.

Fig 1

FLAW DETECTION TECHNIQUES

In general, there exist three main categories of techniques currently used for flaw identification and condition monitoring of railway tracks. These include:

- Visual inspections (Using Camera) [2]
- Non-destructive testing (NDT) technologies such as ultrasonic methods [3], magnetic field methods, eddy current techniques
- Vibration-based methods [4].

All above methods have some advantages and disadvantages. Both visual and NDT-based methods are used when small sections of track are to be inspected or when a precise location is desired. The successful implementation of these inspection methods generally requires the regions of the suspected damage to be known as a first step, and be readily accessible for physical inspection. As a result, these methods can be costly, time consuming and ineffective for large and complex structural systems such as the rail track. However, visual inspection and NDT-based technologies are the primary techniques used for defect identification in the railways.

On the other hand, vibration-based damage identification methods are based on global vibration response measurements at certain points of railway track. The theoretical basis for damage identification methods based on vibration response measurements is that structural damage causes changes in structural dynamic properties, which in turn cause changes in the global vibration response characteristics of the structure. Consequently, examination of the variations in the vibration response characteristics provides useful information regarding the existence, location and extent of the structural damage, without prior knowledge of the damage condition. So in conclusion

1. Visual and NDT-based methods are used when small sections of track are to be inspected or when a precise location is desired.
2. Vibration-based damage identification methods are suitable for long range and fast as compared to visual and NDT-based methods. Due to above mentioned reasons we have decided to use vibration-based methods. In proposed system, we are applying vibrations to railway track using vibration source, then after sensing vibrations on track by vibrations sensor located at certain distance, track fracture is detected.

SYSTEM ARCHITECTURE

I. INTRODUCTION

The basis of the working of the system is based on vibration generation and detection. The project is divided in two modules:

- *Vibration source module:*

This module of the system is responsible for the generation of vibrations based on the request received from the user. This module generates vibrations sufficient to be detected by the sensor module.

- *Vibration sensor module:*

This module of system is responsible for the sensing of vibrations, which are received from the source module. It is located at a certain distance from the source module. This module also sends the feedback to the respective user regarding the condition of track.

Basic idea behind the working of the system is that an uninterrupted continuous stream of vibrations will travel through the track if it is not damaged or fractured and can be picked up at the other end but if the track is damaged the vibrations will not be able to complete the desired path. Both the scenarios will be reported to the concerned authority so that required measures can be taken.

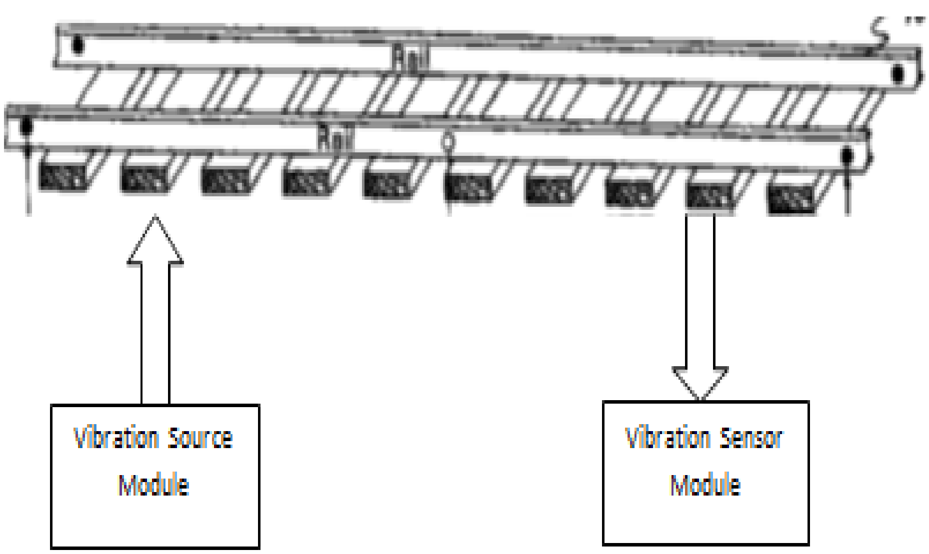

Fig 2

II. SYSTEM BLOCK DIAGRAM

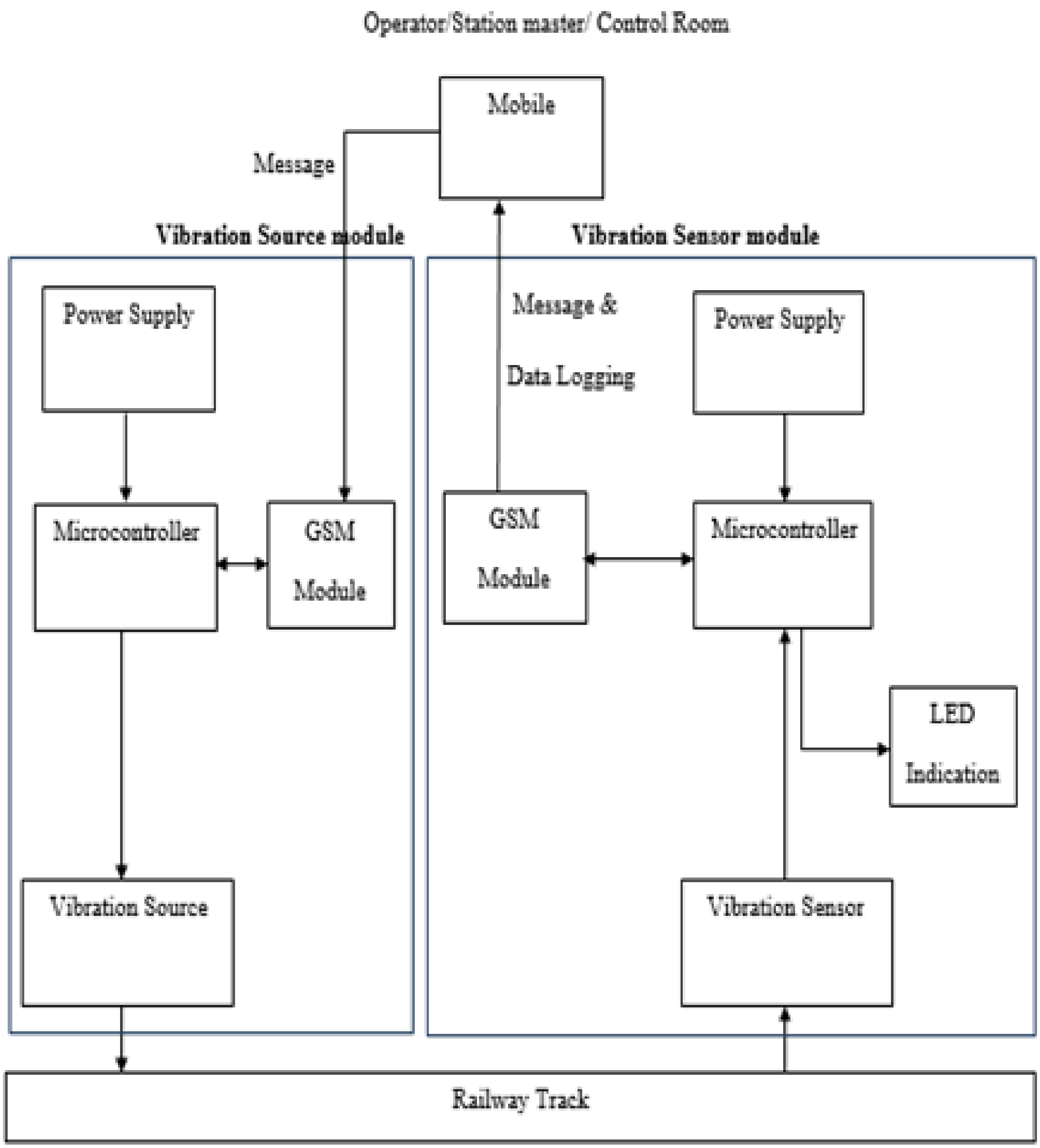

Fig 3

III. SYSTEM BLOCK DIAGRAM DESCRIPTION

➢ *Vibration Source Module*

- *Microcontroller*

The microcontroller is used for controlling the vibration source. It is also used for interfacing the GSM module.

- *Vibration Source*

This block is responsible for applying vibrations to the railway track. When user sends message for generation of vibration, it is activated.

- *GSM Module*

The GSM Module is responsible for communication between the vibration source and vibration sensor module.

- *Power Supply*

This block provides power supply required to the whole module.

➢ *Vibration Sensor Module*

- *Microcontroller*

This block is used for interfacing the vibration sensor and used to make decisions about the fracture presence/absence. It is also used for interfacing GSM module and LEDs.

- *GSM Module*

The GSM Module is responsible for communication between the user and vibration source module. It is also used for data logging.

- *Vibration Sensor*

It detects vibrations on the track and provides the respective inputs to the microcontroller for processing.

- *LED Indication*

  It is used to display condition of track: Red for fracture is present, Green for fracture not present.

- *Power Supply*

  This block provides power supply required to the whole module.

➢ *WORKING*

There are two modes of working of our system:

- *On-demand Checking:*

  Vibration source module applies vibrations on track when request received from operator.

Steps:

- ✓ Sending message from mobile of operator/control room to vibration source module using GSM interface to start checking of track
- ✓ Communication using GSM module(message) between vibration sensor module and vibration source module to start receiving vibrations on track by sensor
- ✓ Application of vibrations on railway track from vibration source module
- ✓ Detection of vibrations on railway track by vibration sensor module
- ✓ Decision about fracture is present or not depending on vibrations are received or not received
- ✓ LED indication and send message to the control room/ station master about condition of track.
- ✓ Logging of sensor output (vibrations received) in spreadsheet on Google Drive along with time and result. Further actions can be taken depending upon result.

- *Automatic Checking:*

Vibration source module periodically (1 Hour) applies vibrations on track for continuous checking. Same steps are done as that of on-demand checking except step 1.

IV. SYSTEM DESIGN AND DEVELOPMENT

PIEZOELECTRIC SENSOR

➤ *Introduction*

We have opted for this as a vibration sensor for detecting vibrations. A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in pressure, acceleration, strain or force by converting them to an electrical charge.

➤ *Pin Description of sensor module*

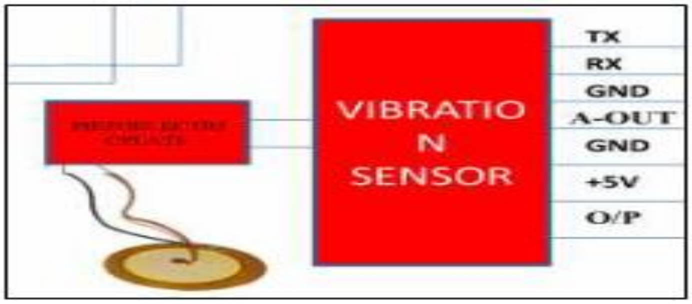

Fig 4

Pin Name	Description
OUT	Active high output
A-OUT	Analog Output
+5V	Power supply
GND	Power supply ground
RX	Receiver
TX	transmitter

Table 1

Specifications

Operating voltage: +5 V dc

Outputs: Analog, Digital, TTL level output signals

Sensor output range: 0 to 1023

Least count: 1

We have used TTL level output signals for interfacing with microcontroller.

V. SOLENOID ELECTROMAGNET

➢ *Introduction*

We have selected solenoid electromagnet as the vibration source. A "Linear Solenoid" is an electromagnetic device that converts electrical energy into a mechanical pushing or pulling force or motion. Linear solenoids consist of an electrical coil wound around a cylindrical tube with a Ferro-magnetic actuator or "plunger" that is free to move or slide "IN" and "OUT" of the coils body.

*Specifications***:**

1) 5 Kg Solenoid: SA-3702 Push-Pull solenoid

Rated attraction force: 5 Kg

Supply voltage: 230 V AC, 50 Hz

Current at start: 5.5 A

Holding Current: 0.45 A

Rated stroke: 20 mm

2) 8 Kg Solenoid**:** SA-4602 Push-Pull solenoid

Rated attraction force: 8 Kg

Supply voltage: 230 V AC, 50 Hz

Current at start: 14.5 A

Holding Current: 1 A

Rated stroke: 30 mm

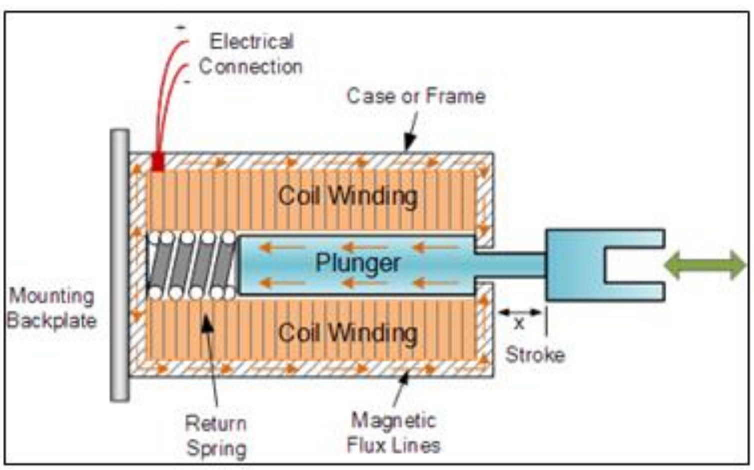

Fig 5

VI. HARDWARE IMPLEMENTATION AND RESULTS

➢ *Testing of Piezoelectric Sensor*

We carried out testing of sensor directly on trial track. We have connected piezoelectric sensor to web of the railway track, as shown in figure.

Fig 6

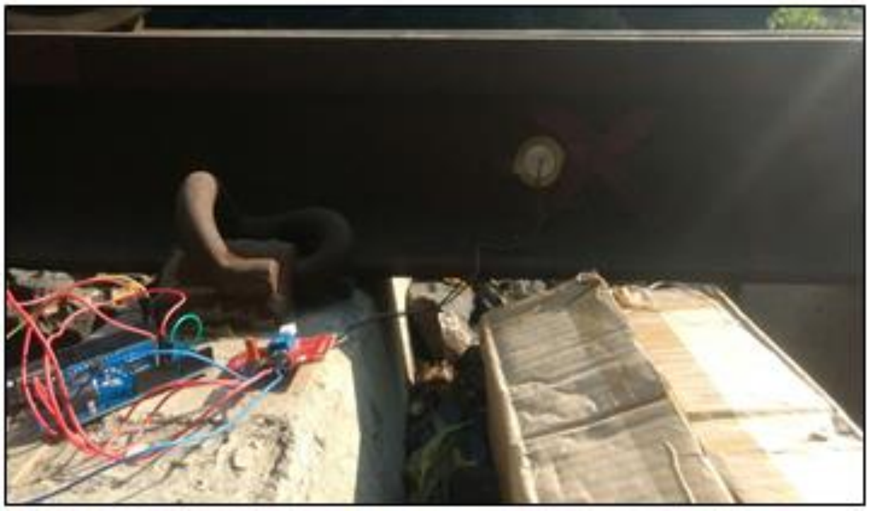

Fig 7

We have applied vibrations at other end of trial track using hammer. Readings from sensor observed on serial monitor of laptop, as shown in figure.

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Observations: Sensor output 0 to 1023

1. Value 252 is for default vibrations present on track.

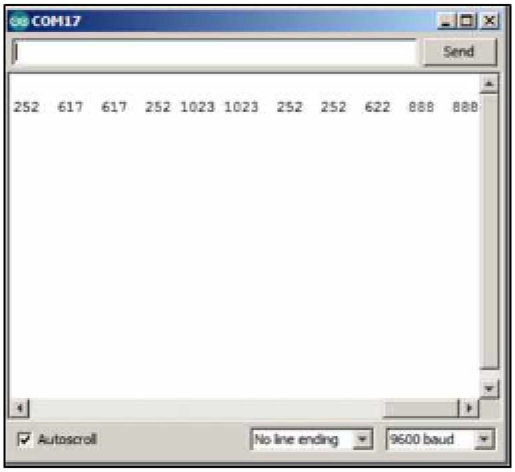

Fig 8

2. Value 1023 is maximum value when vibrations generated by hammer are received.

We have carried out testing in each stage of our project development on trial track or main line. Therefore, we can ensure that final integrated system will work on main line successfully.

➢ *Testing of Ac Solenoid Electromagnet*

We have carried out testing of solenoid also on trial track. We have used relay circuit built on general purpose PCB along with ARM LPC2148 development board for this testing. LPC2148 is programmed such that solenoid will actuate by pressing switch on development board. By pressing switch, we have actuated solenoid and applied vibrations on track. We have connected sensor to web of track at some distance from solenoid and observed vibrations received from sensor on serial monitor. Results are same as that of testing of sensor with hammer. From observations, we have decided to place solenoid in such a way that vibrations are applied to head of track. This placement results in reception of maximum vibrations by sensor. Solenoid we have tested does not have internal spring to bring back plunger to its original position. Therefore, we have also designed mechanical assembly using spring for solenoid actuator so that it will return to its original position after impact on track.

Fig 9

Fig 10

➢ *Testing of Both Modules on Trial Track without Fracture and with Fracture (by Removing Fishplate)*

Next, we have tested both sensor and source module on track with fracture. Fishplate is used for joining two different pieces of track to form continuous track. Track by removing intermediate fishplate can be considered as a track with fracture (complete discontinuity). We observed output of sensor for both cases: with fishplate and removing fishplate. Sensor received vibrations generated by solenoid with normal level when fishplate is present. Without fishplate sensor only showed default vibrations on track. It does not received any

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vibrations generated by solenoid as removing fishplate introduces compete discontinuity. By this testing, we have verified that basic concept of our project works.

*Results***:** Distance between sensor and source (Length of trial track) = 30m

Vibrations sensed with fishplate: >900

Vibrations sensed without fishplate: <300 (Due to complete discontinuity)

Fig 11

Fig 12

➢ *Testing at Ghorpadi Yard on Main Line*

Next, we have carried out testing on main line at Ghorpadi yard, Pune. Same setup is used for testing as used for previous testing. As vibrations travels along the track they will be attenuated as distance increases. Therefore, we have tested both modules on several tracks to find out maximum possible distance where sufficient amount vibrations are received by sensor.

Results: Maximum possible distance on

1. Track with fishplates: 97.9 metres

   As fishplate loosely couples two different track sections, vibrations attenuated more.

2. LWR (Long Welded Rail) Track: 127.4 metres

   LWR has single piece long rail. Hence, vibrations are less attenuated. It results in more distance as compared to track with fishplates.

Fig 13

➢ *Testing at Ghorpadi Yard on Main Line*

Next, once again we carried out testing on main line at Ghorpadi yard with same setup (5 kg solenoid). This time we have recorded vibrations received by sensor at incremental distance from vibration source. Track used for testing is LWR track.

*Results***:** Distance between source and sensor for sufficient vibrations reception: 100 metres

Vibrations received by sensor at 100 m: 500-800

Distance(m)	Vibrations
5	1023
10	1023
15	1008
20	995
25	983
30	976
35	957
40	941
45	924
50	903
55	899
60	873
65	865
70	857
75	844
80	831
85	813
90	805
95	793
100	779

Table 2

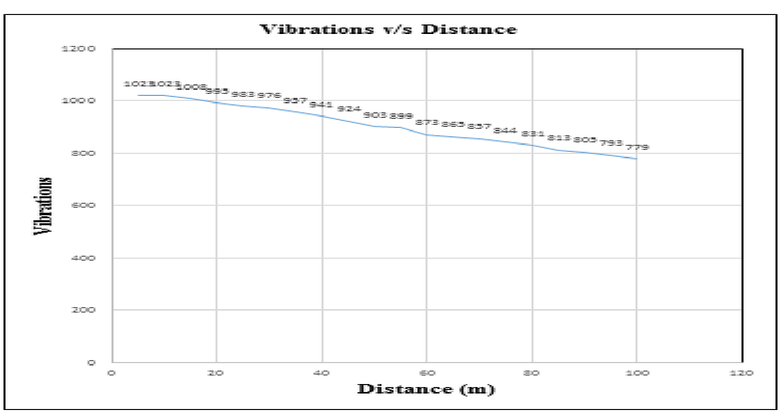


Fig 14

From above graph, it is clear that as distance between source and sensor increases, vibrations are more attenuated.

We have not used serial monitor on laptop for this testing. As it is very difficult for changing sensor position along with laptop for testing many times. Therefore, we have used serial monitor on mobile phone, which functions similar as that of laptop. It is very comfortable and easy with mobile phone to change sensor position many times.

Fig 15

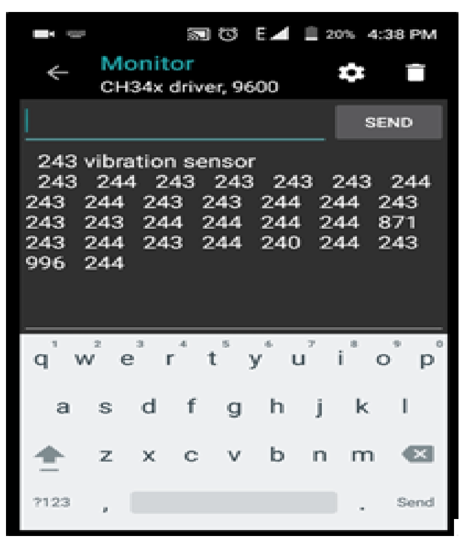


Fig 16

➢ *Testing on Main Line at Ghorpadi Yard (8 Kg Solenoid)*

To increase distance checked by system further we have changed old 5 kg solenoid with 8 kg solenoid. Then we again tested both modules on main line at Ghorpadi yard. Readings are observed on serial monitor of mobile. Track used for testing this time is LWR track. Using high force solenoid causes more distance to be checked.

1) Vibrations received before weld at 100 m: 900-1000

   In Long Welded Rail (LWR) track, two different sections of track are joined using welding instead of fishplate. We have observed that weld also loosely couples two different sections of track. Therefore, vibrations are attenuated more after passing through weld same as in fishplate.

2) Vibrations received at 150 metres: >500

   With continuous track, we got vibrations received at 150 m always greater than 500. If there is any partial or complete fracture, then vibrations received will be less than 500. Hence, we have decided to keep threshold as a 500, for decision between track condition is good or bad (Fracture is present or not).

Fig 17

We have used only one sensor module for testing but vibrations travel on both sides of source module along track. If we kept sensor modules on both sides of source module at same distance then distance checked will be doubled.

Total distance checked by system= 2*150 m = 300 m

Fig 18

➢ *Testing on Main Line at Manjari, Pune (8 Kg Solenoid)*

Previous all testing we have done successfully at trial track and main line at Ghorpadi. However, system needs to be tested on different locations and types of tracks, so to verify that it will give same result on all types of environments and tracks. Hence, we have tested our both modules on main line at Manjari, Pune. Main line at Manjari is part of Pune-Daund railway track. Track used for testing is LWR track. 8 Kg solenoid is used and sensor readings are observed on serial monitor of mobile.

Results: Vibrations received just before weld at 100 m: 900-1000

We have observed same result as that of previous testing. Vibrations are attenuated more after passing through weld. Therefore, it is verified that system will give same result on different locations and tracks.

➢ *Testing of Final Integrated Project on Model Track*

We have tested finally integrated project on model track at IRICEN, Pune. Complete source module is used along with 8 kg solenoid. Complete sensor module provides LED indication, message to user about condition of track and data logging on Google drive spreadsheet.

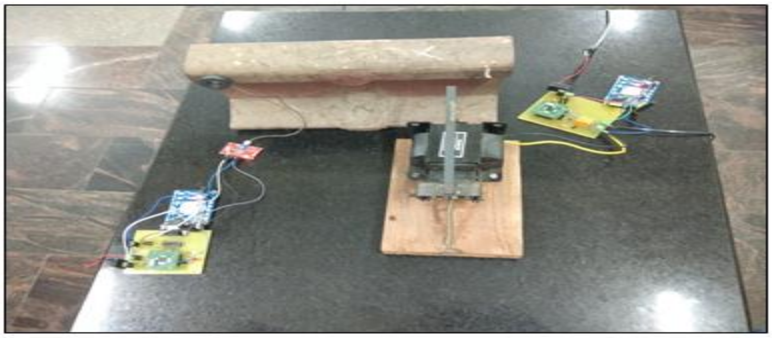


Fig 19

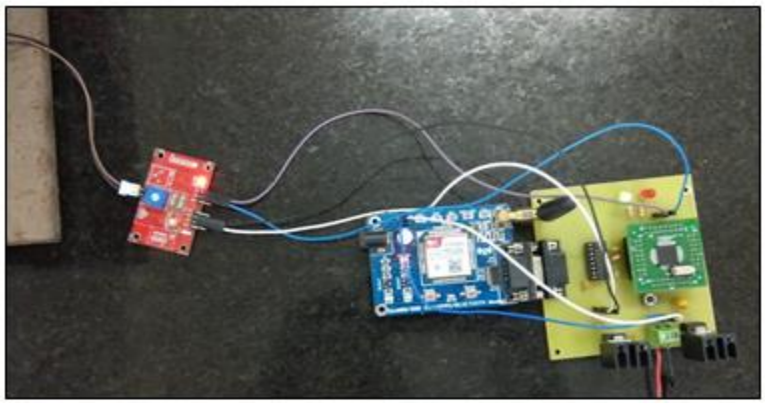
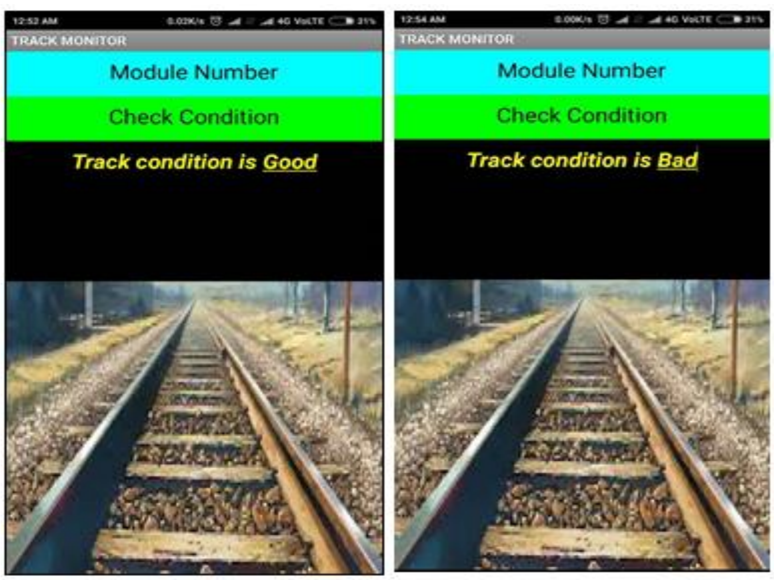


Fig 20



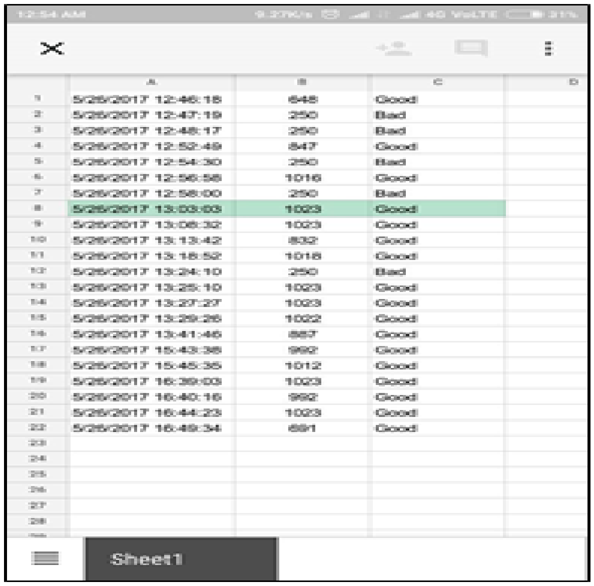
(a)When track has no fracture (b) When track has fracture

Fig 21

Sensor modules sends message to user about condition of track. It is received in app on user side.

1. If track has no fracture, then message is "Track condition is Good"
2. If track has complete or partial fracture, then message is "Track condition is Bad"

Readings of sensor stored in spreadsheet can be viewed in App or also on PC. Reading of sensor logged with respect to time, so we can continuously monitor condition of track.



	A	B	C
1	5/26/2017 12:46:18	648	Good
2	5/26/2017 12:47:19	250	Bad
3	5/26/2017 12:48:17	250	Bad
4	5/26/2017 12:52:49	847	Good
5	5/26/2017 12:54:30	250	Bad
6	5/26/2017 12:56:58	1016	Good
7	5/26/2017 12:58:00	250	Bad
8	5/26/2017 13:03:03	1023	Good
9	5/26/2017 13:08:32	1023	Good
10	5/26/2017 13:13:42	832	Good
11	5/26/2017 13:18:52	1018	Good
12	5/26/2017 13:24:10	250	Bad
13	5/26/2017 13:25:10	1023	Good
14	5/26/2017 13:27:27	1023	Good
15	5/26/2017 13:29:26	1022	Good
16	5/26/2017 13:41:46	887	Good
17	5/26/2017 15:43:38	992	Good
18	5/26/2017 15:45:35	1012	Good
19	5/26/2017 16:39:03	1023	Good
20	5/26/2017 16:40:16	992	Good
21	5/26/2017 16:44:23	1023	Good
22	5/26/2017 16:49:34	691	Good

Sheet1

Fig 22

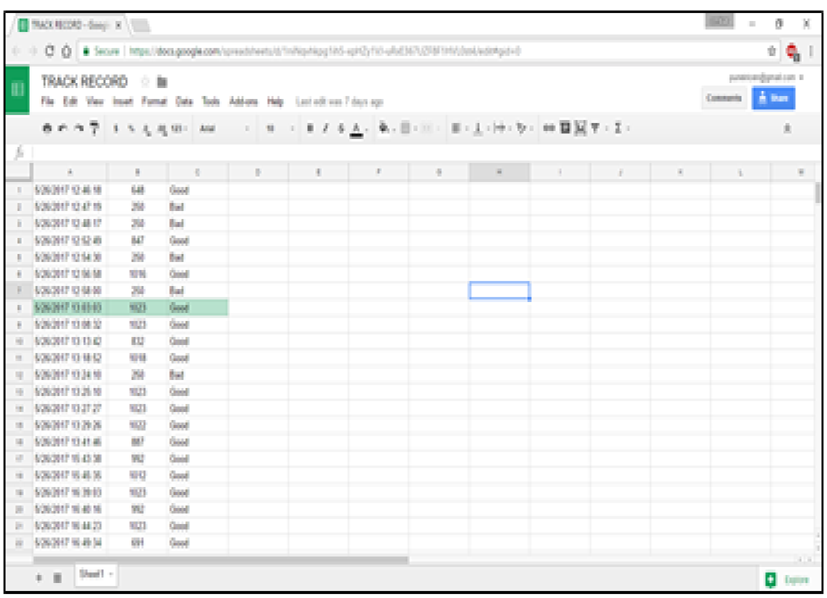


Fig 23

VII. CONCLUSION

- Visual and NDT-based methods of crack detection are used when small sections of track are to be inspected or when a precise location is desired. Vibration-based damage identification methods are suitable for long range and fast as compared to visual and NDT-based methods. It is possible to check long tracks in less amount of time with vibration-based method.
- Our system sends message about condition of railway track to user on-demand. If fracture is present, then message is warning to user. Further actions can be taken if fracture is present to prevent any accident to occur. It includes checking and repairing that fractured track part. It results in decrease in number of railway accidents and casualties.
- Our system also support automatic mode for automation of checking of tracks. It results in fast and checking without any manual errors.
- If track length is divided into parts and our project module is used for each part, then it easy to check long tracks and finding location of fracture present on part of track.
- Our system has user interface of Android App. Hence, it is very comfortable for operator/station master to check condition of track from any location and at any time.
- As data about vibrations received is stored in Google Drive spreadsheet using Internet, our system can be considered as IoT application for enhancing safety and reliability.
- Stored data in spreadsheet can be used for analysis of change in response of track due to defects. Change in response may be due to internal cracks.
- As data of vibrations is stored with respect to time, it can be observed at central control room from any location on PC or from any location on mobile App. It results in real time monitoring of railway track.

FUTURE SCOPE

- Stored data in Google Drive spreadsheet can be used for analysis of change in response of track due to defects. Change in response may be due to internal cracks. If proper analysis model is developed, then it can be used for detection of internal cracks also.
- If long railway track is divided into different parts with vibration module for each part, the condition of all railway tracks can be displayed at control room.
- Our system supports automatic mode, but GSM SIM800 module requires pressing reset manually after power-on. For complete automation, GSM modules with power-on-reset or software reset can be used.
- We have used AC solenoid electromagnet as a vibration source, which requires 230 V AC supply. Today, 230 V AC supply is not available always besides all railway track. Hence, for implementation of our system 230 V AC supply grid needed to be established on all railway tracks. If any vibration source with DC supply is used then it will be cost-effective for railways for implementation.
- As an IoT application, Wireless Sensor Network (WSN) of such vibration sensor and source modules can be formed for all tracks, which can be, controlled from central control room. For resource-constrained modules, clustering concept can be used with such WSN, which results in less power and cost requirement.

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