Robust Railway Track Crack Detection using MEMS Technology

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Abstract

In India, most of the commercial transport is being carried out by the railway network and therefore, any problems in the same has the capacity to induce major damage to the economy notwithstanding the societal impact of loss of life or limb. Economic prosperity can be achieved by increasing the rationality and capacity of transport systems. The cracks in the railway line have been a perennial problem which has to be addressed with at most attention due to the frequency of rail usage in India. This paper proposes an effective railway track crack detection using MEMS accelerometer. The proposed detection system is a cost effective yet robust solution to the problem of railway crack detection utilizing a method that is unique in the sense, that while its simple the idea is completely novel and hitherto untested. By using simple components like a GPS module, GSM module and MEMS based crack detection assembly; the proposed scheme has been modeled for robust implementation in the Indian scenario.

Keywords: GSM, GPS, MEMS, Accelerometer

I. INTRODUCTION

In today’s world, transport is a key necessity because in its absence it would be impossible for products to be consumed in areas which are not in the immediate vicinity of the production centers. Transport being one of the biggest drainers of energy, its sustainability and safety are issues of paramount importance.

The Indian railway network today has a track length of 113,617 kilometers over a route of 63,974 kilometers and 7,083 stations. It’s the fourth largest railway network in the world. Though rail transport in India growing at a rapid pace, the associated safety infrastructure facilities have not come up with the aforementioned proliferation. Our facilities are inadequate compared to the international standards and as a result there have been frequent derailments that have resulted in severe loss of valuable human lives and property as well.

The problem inherent in all techniques existing is that the cost incurred is high. This paper proposes a cheap and novel yet simple scheme that uses MEMS technology with sufficient ruggedness suitable to Indian scenario. This project also aims to develop a device that sends alert messages to the control station when the vibrations on a track are above the threshold level then the GSM send an alert message to authority. The hollow area under the bridges that occur due to the flow of water cannot be found in a manual inspection. The present testing of tracks is done manually without any load. The exact tolerance can be found only if the load is applied. Also the frequency of checking is very low presently. Since this device can be implemented on test/running trains, the checking will become more frequent. This project is implemented using an accelerometer sensor which works using MEMS (Micro-Electro-Mechanical System) technology along with GSM and Global Positioning System (GPS) and has a wide range of application in different fields like vehicle accident alerts, vibration monitoring etc.

II. CONVENTIONAL SYSTEM

The existing system has railway laborers walking on the tracks and detecting the cracks manually. This requires a lot of effort and labor cost. In some countries railway track crack detection is carried out using infrared sensors. They cannot be used if there are external disturbances like hazardous weather and poor climatic conditions. Another technique practiced is detection using LED-LDR sensors where LED will be attached to one side of the rails and the LDR to the opposite side. During normal operation, when there are no cracks, the LED light does not fall on the LDR and hence the LDR resistance is high. Subsequently, when the LED light falls on the LDR, the resistance of the LDR gets reduced and the amount of reduction will be approximately...
proportional to the intensity of the incident light. This method cannot be used during night hours and slabs of the track. All these existing systems are less accurate and time consuming.

III. PROPOSED SYSTEM

A. Block Diagram:

![Block Diagram](image)

The micro-controller monitors the waveform from the accelerometer Sensor. The sensor has a circuit which uses the most advanced MEMS technology. Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. While the electronics are fabricated using integrated circuit (IC) process sequences (e.g., CMOS, Bipolar, or BICMOS processes), the micromechanical components are fabricated using compatible “micromachining” processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices.

The entire system consists of two modules. 1) An In-vehicle module. 2) A control station receiver (PC) module. The module in the train consists of a MEMS sensor; vibration detector and a GSM for alert messaging. MEMS output signals are continuously monitored by the Central Processing Unit. The analog output from sensor are fed to the filters for filtering purpose and after signal processing this outputs are given to the CPU. CPU continuously compares the output value with a predefined range (normal vibration). If there is a fault in railway track, the vibration increases more than the normal range. When a high vibration is detected, MEMS output voltage increases from the normal range of voltage. If it has found a sudden increase of voltage from the normal range of values CPU notes it and sends alert messages to the control station immediately. The messages can be viewed in the control station PC with Internet Connectivity with latitude and longitude of fault detected area. So it is easy for the authority to locate the fault and need not have to check the entire track to detect and cure the fault.

IV. SIMULATION OF THE PROPOSED SYSTEM

![Simulation Diagram](image)

This simulation diagram shown has a pot which represents the accelerometer, PIC16F877, LED, LCD and GSM module. The pot has a preset normal range of about 270-330, the value of accelerometer varies when it is subjected to vibrations and once it crosses the threshold value, which is beyond 330 the led glows indicating crack detection. As soon as led glows, the LCD will display “the crack is detected”. The GPS module will trace the exact location of crack and the message is send to the concerned authority by the GSM module. Message The GSM module sends the latitudinal and longitudinal location to the concerned authorities.
V. HARDWARE DESCRIPTION

A. Components of Hardware:

The main hardware modules used in our system are
- PIC 16F877A
- GSM module
- GPS module
- MEMS

1) PIC16F877A:
It’s a 40pin device and port D and port B are used. It has an operating frequency of 20MHz, RISC architecture, 35 I/O pins, 8K ROM memory, 256 bytes EEPROM memory, 368 bytes RAM memory, 3 independent timers/counters and requires a power supply of 0-5.5 V.

2) MMA7260Q – Accelerometer Module:

MEMS-based accelerometers are available in 1-, 2- and 3-axis configuration, with analogy or digital output in low-g or high –g sensing ranges. For high g-force MEMS accelerometer 1-2 axis is used. When it experience vibration or shock, it will produce proportional output voltage.

They are available are one of the simplest but also most applicable micro-electromechanical devices. They find application in cost A 3 Axis Low-g Micro machined Accelerometer module has used with a sensitivity selection using MMA7260 accelerometer Sensor from free scale. This Module is suitable for Robotic application and other Tilt Measurements. Board Form factor is very small for robotic design and is easily fixable.

3) GSM Modem:

GSM is a wireless modem which works with wireless network. The operation of GSM modem requires a SIM card to identify the subscriber. GSM module has a TXD and RXD pin. For interfacing the GSM module with the pic16f877, The USART serial input pin RX and TX of the microcontroller are connected to the TXD and RXD pins of GSM module. The GSM module can be interfaced with either RS232 or TTL. The module’s voltage characteristics are 6.5V as minimum and maximum of 15V respectively. 500Ma is the maximum current.

4) GPS Module:
The GPS module calculates the geographical position of the crack. The module has 4 pins basically 5V, TXD, RXD, and GND. TXD is the transmit pin of the module and it is the output pin. TXD is TTL logic compatible. RXD represents the receive pin of the module and GND is the ground. There is no setting required, only needed to plug in to the power (5V).

To interface the GPS module with PIC16F877 microcontroller, the TXD pin of the GPS TTL is connected to RXD pin of the microcontroller. The module has high sensitivity and low power consumption of around 50 mA. The module provides current time, date, latitude, longitude, speed, altitude, and travel direction/heading among other data. This helps to locate the exact position of the crack.

5) LCD Display:

LCD display is used to display the position i.e., the latitude and longitude of the crack. LCDs are the materials, which combine both the properties of both liquids and crystals. They consume less power. The LCD display is interfaced with the PIC16F877A module.

B. Working:

The proposed system uses PIC Micro-controller PIC16F877A. Whenever a proper power is given to the embedded module i.e., 12 Volt and 2 Ampere current. The GSM modem is initializing through AT commands. After initializing GSM modem it will check the vibration in the track. When MEMS value change above or below the threshold level the crack has been detected. That time automatically a message (Latitude and longitude) is send to the authority as the position of the crack detected.

C. Control Algorithm:

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START

INITIALIZING LCD

INITIALIZING ADC

INITIALIZING UART

CONTINUOUSLY TAKING ADC VALUE FOR MEMS READINGS

WHEN MEMS VALUE EXCEEDS THE THRESHOLD VALUE THE LOCATION OF GPS IS TAKEN

THE LOCATION IS SEND TO THE AUTHORITY VIA GSM MODEM

STOP
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Fig. 5: Control Algorithm

D. Advantages and Disadvantages:

This system of railway track crack detection system is compact and gives accurate measurements compared to manual detection. Tilts can also be detected using this method. Another major advantage is that the proposed system can be operated in tunnels also without any interruption. Low cost, low voltage operation, and low power consumption are the other advantages of using MEMS technology.

One of the major disadvantages of this system is that the whole system has to be reset once a crack is detected. The availability of network is very important factor in the proper functioning of the system. Poor network is one of the demerit of the system. This defect can be corrected by incorporating the ZIGBEE module which is costly.
VI. HARDWARE SETUP

Fig. 5: Hardware Setup

VII. CONCLUSION

As the railway network is one of the important and common means of transport in India by which most of the commercial transport is carried out, the safety of the whole system is equally important and must be taken care of efficiently. This paper, has presented the rationale, design of robust MEMS based railway crack detection scheme. The discussed detection system has used the most compact, simple and robust modules like GSM, GPS, and MEMS-accelerometer which can be implemented easily in the present scenario. The authors hope that their idea can be implemented in large scale in the long run to facilitate better safety standards for rail tracks and provide effective testing infrastructure for achieving better results in the future.

More technological advancement can be incorporated in the system by using laser and ultra violet rays. Both the systems are more compact and accurate than the one discussed. There is a lot of scope for improvement in the detection system in the future days.

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