Crack Detector Robot Using LED-LDR

S.Arul Mozhi, Avanti Prabhakaran,V.Mathivathani, R.Priyanka

Abstract--Transport is a key necessity for specialization that allows production and consumption of products to occur at different locations. Commercially, rail transport plays a vital role and it is one of the cheapest modes of transportation. India has the world's fourth largest railway network. Any problem in the railway network affects the economy at a greater pace and also leads to the loss of lives. One of the problems encountered is derailment due to the cracks in railway track. The principle problem has been the lack of cheap and efficient technology to detect the problems in rail tracks and lack of proper maintenance of rails which have resulted in the formation of cracks in the rails. This project comprises of GPS, GSM, LED-LDR and microcontroller based crack detection assembly which is cost effective and robust to facilitate better safety standards in railways. The system is designed to run along the centre of the track.

Index Terms--Railway cracks, ATMega328, GPS, GSM, LED-LDR Assembly, and Robot.

1 Introduction

In today's world transport is a key necessity because without transport, trade will come to a standstill. It would be impossible for products to be consumed in areas which are not in the immediate neighbourhood of the production centres. Throughout the past, transport played a vital role in the expansion of trade. Thus, by increasing the rationality and capacity of transport systems, economic prosperity is achieved. The proper operation and maintenance of transport infrastructure has a great impact on the economy. Transport, being one of the biggest earners of energy, its sustainability and safety are issues of paramount importance. In India, rail transport occupies a prominent position in quenching the ever burgeoning needs of a rapidly growing economy. However, in terms of the reliability and safety parameters, global standards have not satisfied.

The Indian railway network today has a track length of 113,617 kilometres (70,598 mi) over a rate of 63,974 kilometres (39,752 mi) and 7,083 stations. It stands at fourth position when compared to those of the United States, Russia and China. The rail network is spread all across India, carrying over 30 million passengers and 2.8 million tons of freight daily. Even when there is a widespread and impressive network, the Indian rail is still in the emergent stage. The rail transport in India is developing step by step. 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. To demonstrate the severity of the problem, official statistics say that there have been 11 accidents in 2011 till the month of July alone, which leaves much to be desired. On further analysis of the factors that cause these rail accidents, recent statistics reveal that approximately 60% of all the rail accidents have derailments as their cause, of which about 90% are due to cracks on the rails either due to natural causes (like excessive expansion due to heat) or due to antisocial elements. Hence, these cracks in railway lines have been a perennial problem, which has to be addressed with utmost attention due to the frequency of rail usage in India. These cracks and other problems with the rails generally go unnoticed due to improper maintenance and the currently irregular and manual track line monitoring that is being carried out. The high frequency of trains and the unreliability of manual labour have put forth a need for an automated system to monitor the presence of crack on the railway lines.

Since derailment due to cracks was detected as the major problem there have been efforts for decades to address the need of safer rail tracks.

With the advent of powerful digital signal processors, image processing techniques [1] have been explored to formulate solutions to the problem of railway crack detection. Though it provides better accuracy, this method uses techniques like image segmentation, morphology and edge detection all of which take a lot of processing power and an extreme amount of time rendering the robot slow and thereby unsuitable. Recent research has investigated the use of microwave horn antennas for crack detection [2]. Horn antenna involved as a flared out or opened out waveguides. It will produce a uniform phase front with larger aperture than the waveguide with greater directivity. Spectrum analyzer is used to locate and measure power/energy of the electromagnetic wave reflecting off the rail track frequencies between 8 GHz and 12 GHz. The cost of spectrum analyzer is high and not suitable for the real world. Eddy current based methods ([3], [4] and [5]) are used to tide over limitations associated with ultrasonic and microwave techniques. It is a system for detecting transverse cracks beneath horizontal cracks in the runway. Needs exists to reject those signals on those frequencies eddy current probe that is sensed to be transverse cracks, but are from non relevant indications such as from thermite welds, plant welds, railhead points, etc. A vast majority of the work done in the field of crack detection uses the infrared sensing technique ([6], [7] and [8]). It is a well understood technique so much so that it was initially thought to be the best solution to the problem of crack detection, but later it was found to be prone to external disturbances and hence came to be considered inaccurate. Techniques that employ ultrasonic ([9], [10] and [11]) tide over some of the problems mentioned earlier, but they can only inspect the core of the track; that is, it cannot check for surface and near surface cracking where most faults are usually located. Several other miscellaneous techniques like observation and analysis of wave propagation via model impacts and piezo actuation [12] have also been developed.

The problem inherent in all these techniques is that the cost incurred is high. Hence this paper proposes a cheap, novel yet simple scheme with sufficient ruggedness suitable to the Indian scenario that uses an LED-LDR arrangement to detect the crack in railway lines, which proves to be cost effective as compared to the existing methods ([13], [14] and [15]). The important role played by transport in the development of an economy has been studied [16]. In addition, statistics on the number of rail accidents and their corresponding causes have also been studied [17]. Recently an improved method was introduced to detect the cracks. The technique uses LED-LDR detector unit with RF transmission and reception to detect the cracks on any one of the track arms. The robot was designed to run on wheels outside the railway tracks. The main imperfection of this method is that it can examine only one side of the track at a time and cannot be utilized at level crossings.

This paper is organized as follows: Section II discusses the design issues; Section III discusses the proposed scheme which uses an LED-LDR arrangement. Section IV elaborates on the electrical design and Section V explains the mechanical design. Section VI gives the implementation of the algorithm, Section VII provides the analysis and discussion about the implementation and Section VIII provides the conclusion and future work.

2 ISSUES IN THE PRESENT SCENARIO

A literature survey of the existing techniques for crack detection revealed a number of sophisticated and accurate crack detection technologies. Even as techniques based on ultrasonic imaging, IR method, RF method and electromagnetic detection offer several advantages, when their applicability for large scale implementation in the current Indian scenario was considered, they were found to lack robustness and practicality in a number of aspects.

First, in the Indian rails, typically there are small gaps in the rail tracks to provide for thermal expansion during the summer. This design is provided so as to ensure that the track does not twist or crack due to the heat. When the existing technique of crack detection was implemented, it was found that the system was giving false positive signals; that is, it was counting the thermal gaps as cracks. Another issue faced during practical implementation is the presence of railway bifurcations. If the mechanical design of the robot is unsuitable, then it will have a tendency to either get stuck in these bifurcations or in worst case even fall out of the tracks.

During the designing of prototype for actual on-field implementation, the problem of presence of debris on the outsides of the tracks was encountered. Though this problem seemed trivial, the effects of dirt on our robot wheels could have been substantial.

In addition to this the robot is designed to check only one side of the track at a time. This method proved to be inconvenient at the time required to check the entire track on both sides is large. Also, as the proposed design utilized an LED-LDR based design, the ambient light intensity variations imposed extreme challenges to our design concept.

3 CRACK DETECTOR USING LED-LDR

The proposed crack detection scheme consists of a Light Emitting Diode (LED) -Light Dependent Resistor (LDR) assembly that functions as the rail crack detector. The principle involved in crack detection is the concept of LDR. In the proposed design, the 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.

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. As a consequence, when light from the LED deviates from its path due to the presence of a crack or a break, a sudden decrease in the resistance value of the LDR ensues. This change in resistance indicates the presence of a crack or some other similar structural defect in the rails. In order to detect the current location of the device in case of detection of a crack, a GPS receiver whose function is to receive the current latitude and longitude data is used.

To communicate the received information, a GSM modem has been utilized. The function of the GSM module being used is to send the current latitude and longitude data to the relevant authority as an SMS. The aforementioned functionality has been achieved by interfacing the GSM module, GPS module and LED-LDR arrangement with a microcontroller. The robot is driven by four DC motors.

Before the start of the railway line scan the robot has been programmed to self-calibrate the LED-LDR arrangement.

4 Electrical Design

A. Microcontroller

An Arduino UNO board which has ATMega328 microcontroller forms the brain of the scheme. This board has been chosen for two important reasons other than the fact that it is cost effective. First, the ATMega integrated development environment (IDE) is an open-source paper which highly simplifies the coding and debugging process. Secondly, it has all the required pins to interface the required peripherals. It has 6 analog input pins, 14 digital I/O pins and one UART.

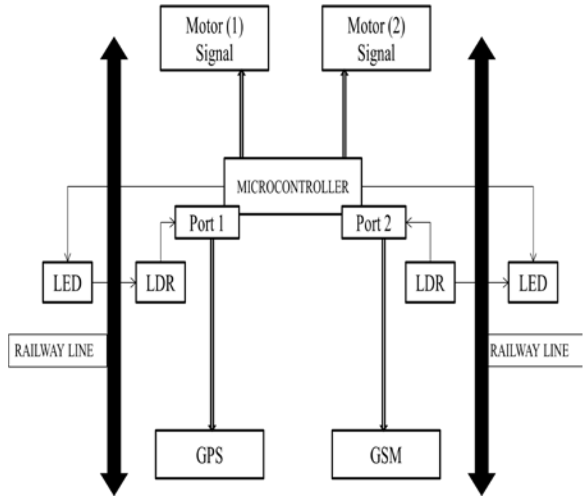

Fig. 1. Technical Design

B. GPS Module

The EM-406 is a GPS receiver module by USGlobalSat utilizing the SiRF Star III chipset. This module is similar to the ET-301, but with added on-board voltage regulation, LED status indicator, battery backed RAM, and a built in patch-antenna.

An EM-406 GPS receiver has been used as the GPS module. It follows NMEA convention. With a baud rate of 9600 bps, 1Hz update rate and 1 sec hot start time, the properties of the said module was found to ideally match the requirements.

C. GSM Module

The SIM 300 GSM module has been chosen to achieve the SMS functionality. Since the Arduino UNO board has only one UART, it was necessary to program 2 of the digital pins (pins 2 and 3 in our case) of ATMega to act like a virtual UART so as to interface the GSM with the ATMega.

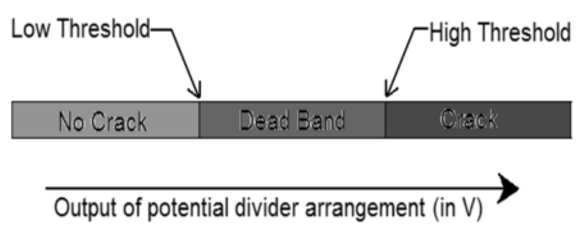

Fig. 2. Deadband concept

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D. DC Motor

2 DC motors are connected to the outputs on the right. ATMega controls the inputs so that the motor terminals are connected to Ground or Vcc (Motor Power Supply). So voltage can be applied in either direction through the motors, or both terminals can be connected to Ground to stop. The "Enable" inputs EN A and EN B can be connected to an ATMega "PWM" pin to control motor speed. It is also possible to use all 4 outputs at once to operate a single Motor. To traverse a distance of 22 Km in 4 hrs, an average speed of 1.5 meters/sec is needed. The proposed design uses 4 DC motors (Torque Rating: 1ss0Kg and Speed Rating: 500 RPM).

E. LED-LDR Assembly

The common 5V LED and cadmium sulphide LDR was found to be sufficient. The LED is powered using one of the digital pins of the Arduino. The LDR and a 45kΩ resistor form a potential divider arrangement. The output of the potential divider is given to one of the analog input channels of the ATMega. The LDR is calibrated every time the robot is used. To compensate for the ambient light we use the concept of dead band.

5 Mechanical Design

The robot runs on sleeper plates of the railway tracks. This increases its stability, preventing it from damages when the train passes. The main advantage of the robot is its wheels. It uses conveyor, type tracked wheels which keeps it almost steady in rugged paths. The circuit box containing mainly the ATMega328 Board, the GPS and the GSM module is exactly centred on the aluminium rod. Two bunches of 10 wires (2 each of the LED, the LDR, the two motor and the battery) each enter the circuit box from its left and right side.

The proper packaging of these many wires is a crucial in the design of the robot. The entire circuit box is set up on a platform fitted with conveyor track wheels. Two arms with LED- LDR are extended outward from this assembly for the purpose of detecting the crack. This system forms the crack detecting robot. When the train approaches the side arms disintegrate and get positioned at the centre of the track. This keeps the robot safe from the probable damage when the train passes.

6 Proposed Algorithm

After the robot is powered ON it executes the following algorithm:

1) Set Low Threshold = 200, High Threshold = 800.
2) Calibrate LDR:
   a) Switch OFF left LED
   b) Set LOWleft = Average of the left LDR signal
   c) Switch OFF right LED.
   d) Set lowered = Average of the right LDR signal.
   e) Switch ON left LED.
   f) Set LOWleft = Average of the left LDR signal.
   g) Switch ON right LED.
   h) Set lowered = Average of the right LDR signal.
3) Turn ON GSM. Set GSM parameters.
4) Turn ON GPS.
5) REPEAT
   a) Read Latitude from NMEA string
   b) Read Longitude from NMEA string
   UNTIL (Latitude and Longitude not equal Zero)
6) Turn ON motors.
7) Read left LDR and right LDR signal.
8) Map left and right LDR signals between 0 and 1000 using the following formulas

INTENSITYleft= (analogRead (LDRleft) LOWleft) *1000/(HIGHleft-LOWleft)

INTENSITYright= (analogRead (LDRright) LOWright) * 1000/(HIGHright-LOWright)

INTENSITYleft and INTENSITYright -Mapped values

9) If INTENSITYleft < Low Threshold and INTENSITYright < Low Threshold then,
   a) Motors are powered ON.
10) If INTENSITYleft < High Threshold and INTENSITYright < High Threshold then,
   a) Motor is powered OFF.
   b) Read robots coordinate using GPS.
   c) Send robots coordinate to a mobile as SMS Using GSM
11) Jump to step 7.

7 Analysis and Discussion

The design is expected to be robust and cost effective and will also function efficiently. It can travel about 11km on battery. This method will be helpful in regular track checking as it is more convenient than the handheld checking system. Also, chances of error are less as Global Positioning Satellites are used to determine the exact location of the crack.

The robot will move over the rail sleeper beds lay at the centre of the rail track. Robot consists of two arms like structure on either side of the system. The two arms

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have an assembly unit in which each consists of two leads, one is LED and another one is LDR. The cracks in the rails are detected by the LED-LDR system. LED emits the light continuously while moving over the sleeper beds. If there is a crack in the railway track, the light of the LED will fall on the LDR through the gaps formed due to crack.

The variation in light intensity will vary the resistance value of the LDR, since the resistance of LDR is inversely proportional to the intensity of light. The output of LDR is analog in nature. LDR is connected with 10Ω resistor, the change in potential difference between the light dependent resistor and 10Ω resistor gives the required output to identify cracks in rails. Analog to digital converter in the microcontroller converts the analog input to the digital value which is easier to operate with the controller.

For thermal expansion there will be small cracks in track that are made during the manufacturing process. These small cracks may also be considered as the crack during LED-LDR detection, to avoid such false crack detection we introduce a new concept called a dead band concept. The dead band concept reveals an idea in which the threshold value is set for crack detection that is only when the generated output is greater than the threshold value, there is a crack. Thus, when the output produced from LDR is greater than the fixed threshold value, then it is decided as crack else there will be no crack in the rails.

Exact location of the crack in rails is located by the GPS receiver. It is a device that receives the satellite signals from the orbiting satellites of our earth. Using the method of triangulation, it generates the output, which gives the latitudinal and longitudinal position of the system in earth surface. Once the crack was identified the robot will get stopped so that the crack location is found accurately. The coordinates of the GPS receiver then send to the corresponding mobile number via GSM module.

Fig. 3. LCD displays when crack found

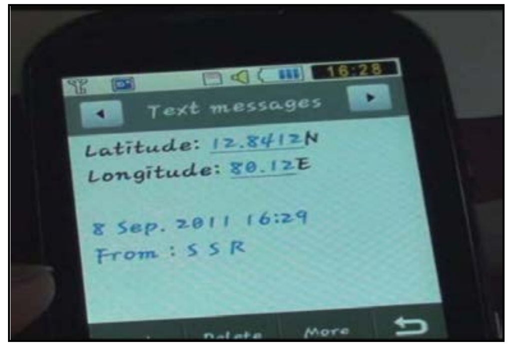

Fig. 4. Detected crack received as SMS

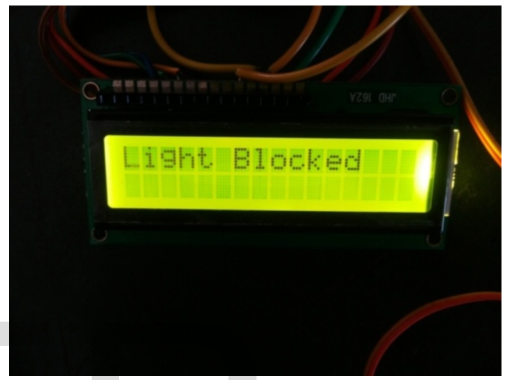

Fig. 5. LCD display when no crack is found

8 CONCLUSION

The majority of people in this world depend upon the railway system for transport. The railway is the cheapest and widespread means of transport. Inspite of all this statistics rail transport claims lots of life every year. The main causes of rail accidents are collision and derailment. Derailment of trains can occur mainly due to cracks in railway tracks. The proposed system helps to detect these cracks. The system designed is robust and cost effective. The method is far better than the earlier models as it can be used to check both sides of the railway track at a time and detect any cracks.

The crack detection unit is used in the project is the simple unit comprises of LED-LDR The circuit boards that are completed in the phase-I are power supply unit, microcontroller board, GSM module, LCD display and crack detection module LED-LDR system. The work to be continued in phase-II are construction of GPS modules, motor drive unit, conveyor type tracked wheels to drive the robot in hard surface and the automatic arm structure which will be helpful in protecting the robot from the running train. The mechanical setup only can provide a good structure to the system.

REFERENCES

[1] Qiao Jian-Hua; Li Lin-Sheng; Zhang Jing-gang; "Design of Rail Surface Crack-detecting System Based on Linear CCD Sensor", IEEE Int. Conf. on Networking, Sensing and Control, 2008

[2]K. Vijayakumar, S.R. Wylie, J. D. Cullen, C.C. Wright, A.I. AIShamma'a, "Non invasive rail track detection system using Microwave sensor", Journal of App. Phy., 2009

[3]Tranverse crack detection in rail head using low frequency eddy currents, Patent US6768298, www.google.com/patents/US6768298

[4]M. Cacciola, G. Megali, D. Pellicanμo, S. Calcagno, M. Versaci, and F. C. Morabito, "Rotating Electromagnetic Field for Crack Detection in Railway Tracks", PIERS ONLINE, Vol. 6, NO. 3, 2010

[5]Wojnarowski, Robert John Welles, II, Kenneth Brakeley Kornrumpf, William Paul, "Electromagnetic system for railroad track crack detection and traction enhancement", Patent US6262573, www.patentstorm.us /patents/6262573/description.html

[6]Richard J. Greene, John R. Yates and Eann A. Patterson, "Crack detection in rail using infrared methods", Opt. Eng. 46, 051013, May 2007

[7]R.J. Greene, J.R. Yates,E.A. Patterson, "Rail Crack Detection: An Infrared Approach to In-service Track Monitoring", SEM Annual Conference & Exposition on Experimental and Applied Mechanics,2006

[8]Hartman, G.A., Infrared Damage Detection System (IDDS) for realtime,small-scale damage monitoring, Proc. SEM Ann. Conf. on Exptl Mech., Charlotte, North Carolina (2003)

[9]Stuart B Palmer, Steve Dixon, Rachel S Edwards and Xiaoming Jian,"Transverse and longitudinal crack detection in the head of rail tracks using Rayleigh wave-like wideband guided ultrasonic wave", Centre for Materials Science and Engineering The University of Edinburgh,www.cmse.ed.ac.uk/AdvMat45/Rail-crack-detection.pdf

[10]Thomas Heckel, Hans-Martin Thomas, Marc Kreutzbruck and Sven Ruhe, "High Speed Non-destructive Rail Testing with Advanced Ultrasound and Eddy-Current Testing Techniques", NDTIP Proceedings, Prague, 2009

[11]Lanza di Scalea, F., Rizzo, P., Coccia, S., Bartoli, I., Fateh, M., Viola,E. and Pascale, G., "Non-contact ultrasonic inspection of rails and signal processing for automatic defect detection and classification, Insight – NDT and condition monitoring", Special Issue on NDT of Rails 47(6) 346-353 (2005)

[12]Spencer Ackers, Ronald Evans, Timothy Johnson, Harold Kess,Jonathan White, Douglas E Adams, Pam Brown, "Crack detection in a wheel end spindle using wave propagation via modal impacts and piezo actuation", Health Monitoring and Smart Nondestructive Evaluation of Structural and Biological systems V, SPIE (2006)

[13]http://www.tc.gc.ca/media/documents/railsafety/technologies.pdf, "Railway Safety Technologies"

[14]http://www.fra.dot.gov/downloads/Research/ord0416.pdf, "A comparison between different crack detection techniques"

[15]http://en.wikipedia.org/wiki/Rail_inspection, "Basic tehniques of rail crack detection"

[16]http://en.wikipedia.org/wiki/Transport, "Importance of Transport"

[17]http://en.wikipedia.org/wiki/Indian_Railways,"Statistis about Indian Railway accidents