Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

Low Cost Rail Crack Inspection System

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Abstract—This paper suggests a rail crack inspection using low cost sensors and Arduino Duemilanove microcontroller board. The present inspection systems are more bulky, expensive and have slow response time. Arduino Duemilanove microcontroller board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator. The Arduino Duemilanove can be programmed with the Arduino software and the major advantage of using these boards is that they can program the microcontroller through the ICSP (In-Circuit Serial Programming) header. The aforementioned functionality has been achieved by interfacing the GSM module, GPS module and LED-LDR arrangement with a microcontroller. In this system the GPS receives the signal and gives the current latitude and longitude of the crack. By using GSM the user is able to receive the information through subscribed services and users can often continue to use their mobile phones when they are traveling, hence GSM is also implemented in the present design. The present design has a vast application in hardware industries like structural health monitoring (SHM) of critical aircraft components, pipe, welding process etc .The sensors were able to detect crack by LDRs and due to its flexible design it could be used as an embedded sensor for online and unmanned monitoring systems.

Keywords- Arduino Duemilanove, LDR, global positioning system(GPS), Railway Condition Monitoring, GSM.

I. INTRODUCTION

Transport is a key necessity for specialization that allows production and consumption of products to occur at different locations [4]. Transport has throughout history been a spur to expansion as better transport leads to more trade. Economic prosperity has always been dependent on increasing the capacity and rationality of transport. But the infrastructure and operation of transport has a great impact on the land and is the largest drainer of energy, making transport sustainability and safety a major issue. In India, we find that rail transport occupies a prominent position in providing the necessary transport infrastructure to sustain and quench the ever-burgeoning needs of a rapidly growing economy. 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.

The principal problem has been the lack of cheap and efficient technology to detect problems in the rail tracks and of course, the lack of proper maintenance of rails which have resulted in the formation of cracks in the rails and other similar problems caused by anti-social elements which jeopardize the security of operation of rail transport. In the past, this problem has lead to a number of derailments resulting in a heavy loss of life and property. Cracks in rails have been identified to be the main cause of derailments in the past, yet there have been no cheap automated solutions available for testing purposes. Hence, owing to the crucial repercussions of this problem, we have worked on implementing an efficient and cost effective solution suitable for large scale application. We hope that our idea can be implemented in the long run to facilitate better safety standards and provide effective testing infrastructure for achieving better results in the future.

II. LITERATURE SURVEY

2.1. AC Bridge

The differential and summing outputs of the bridge are measured using a digital lock-in method. The differential signal is used to detect the rail defects and the summing signal is used to calculate the lift-off distance and to compensate the lift-off effect [1].

2.2. ACFM Sensor

The RCF defects will be located while the ACFM sensor is fixed in position and the trolley moves at a controlled speed. The detected defects are then re-visited and the robot arm is utilized to perform a detailed scan over the defects while the trolley is stationary [2].

2.3. CCD Sensor

The system takes the universal linear CCD as image sensor, processes the image signal collected, judges out the crack signal, and displays the curve through the LCD, and gives off the alarm [3].

2.4. Image Processing

According to characteristics of different defects, two methods based on region width and region position are applied effectively to eliminate interfering objects. Percentage of wear of rail head and length of cracks, as evaluation of defects of rail head section, are calculated and outputted automatically by image processing operations [5].

The prompt detection of the conditions in rails that may lead to a crack or rather a break now plays a critical role in the maintenance of rails worldwide. The understanding of these mechanisms is constantly improving and the evolution of a range of complementary (Non Destructive Testing) NDT techniques has resulted in a number of tools for us to choose from. Among the inspection methods used to ensure rail integrity, the common ones are image processing, microwave, ultrasonic inspection and eddy current inspection.

With the advent of powerful digital signal processors, Image Processing techniques have been explored to formulate solutions to the problem of railway crack detection. Though it provides good 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. This technique was found to produce very accurate results in lab based testing. But, unfortunately it requires spectrum analyzers which are both costly and also can't be placed on- board a moving robot because of their delicacy. Eddy current based methods are used to tide over limitations associated with ultrasonic and microwave techniques. However they have the problem of very slow overall speed which reduces the usability of the same. A vast majority of the work done in the field of crack detection uses the infrared sensing technique. 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's 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 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. The important role played by transport in the development of an economy has been studied. In addition, statistics of the number of rail accidents and their corresponding causes have also been studied. The currently existing technical solutions offered by many companies in the detection of cracks in rails involve periodic maintenance coupled with occasional monitoring usually once a month or in a similar timeframe. Our project however possesses the inherent advantage of facilitating monitoring of rail tracks on a daily basis during nights when the usual train traffic is suspended. Further, we believe that the simplicity of our idea and the easy-availability of the components make our project ideal for implementation on a large scale with very little initial investment. The simplicity of our project ensures robustness of operation and also the design has been carefully modified to permit rugged operation. Another disadvantage that can be attributed to the conventional commercially available testing equipments is that they are heavy which poses a practical limitation. However, this important disadvantage has been rectified in our project as the design is simple and sensible enabling the device to be easily portable.

III. DESIGN

An Arduino Duemilanove board which has ATMega328 microcontroller forms the brain of the scheme (Figure 1). This board has been chosen for two important reasons other than the fact that it is cost effective. First, the Arduino integrated development environment (IDE) is an open-source project 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 (of which 6 provides PWM output) and one UART.

SKG13C 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. It is interfaced with Pin 4 and 5 of Arduino.

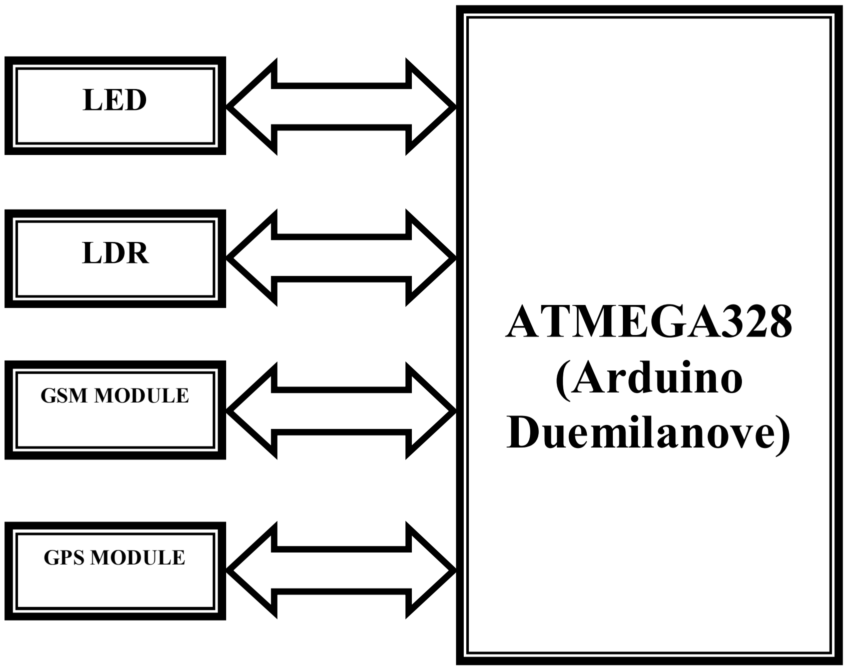

Figure 1: Block Diagram

The SIM 300 GSM module has been chosen to achieve the SMS functionality. Since the Arduino Duemilanove board has only one UART, it was necessary to program 2 of the digital pins of Arduino to act like a virtual UART so as to interface the GSM with the Arduino. The GSM T_x and R_x pins are interfaced with pins 2 and 3 of Arduino respectively.

The common 3V LED and cadmium sulphide LDR was found to be sufficient. The LDR is calibrated initially. We have used just one threshold point in our scheme. The LEDs are powered using 5V of Arduino through 100Ω of pull-up resistor. The LDR and 10KΩ resistor form a potential divider arrangement. The output of potential divider is given to one of the analog pins of Arduino(A0 in our case).

IV. IMPLEMENTATION

4.1.Working Principle

The core of the proposed crack detection scheme consists of a Light Emitting Diode (LED)-Light Dependent Resistor (LDR) assembly that functions as the rail crack detector [4]. The principle involved in crack detection is the concept of LDR. In the proposed design (Figure 2), 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. 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. 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.

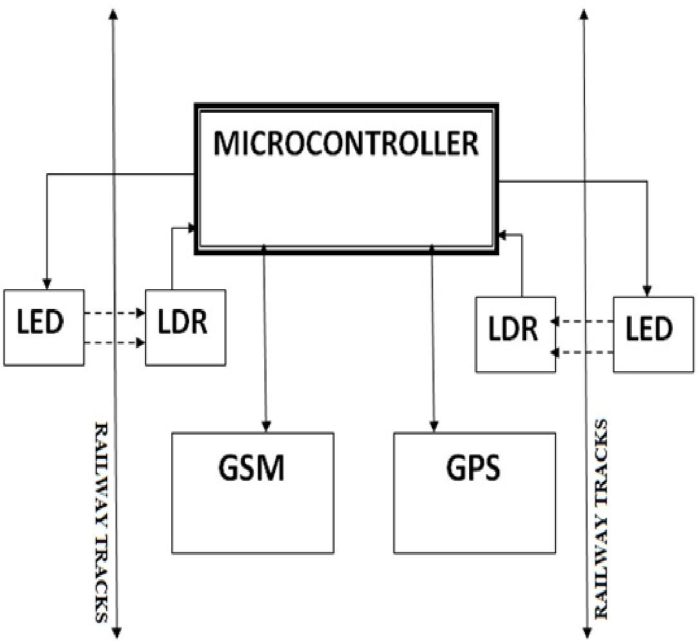

Figure 2: Placement of sensors

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4.2.Algorithm

- STEP1. Set the threshold value of LDR by trial and error method, before experimentation.
- STEP2. Turn On GPS.
- STEP3. Turn On GSM and set GSM to text mode.
- STEP 4. Start the robot.
- STEP 5. Monitor resistance value of LDR
- STEP 6. If LDR value < Threshold
    - Read the robot's coordinates using GPS.
    - Send robot's coordinates to the mobile of concerned authority as a SMS using GSM.
    - After the SMS is received stop the robot.

4.3.Component Description

4.3.1.GPS (Global Positioning System)

Firstly, the signal of time is sent from a GPS satellite at a given point. Subsequently, the time difference between GPS time and the point of time clock which GPS receiver receives the time signal will be calculated to generate the distance from the receiver to the satellite. The same process will be done with three other available satellites. It is possible to calculate the position of the GPS receiver from distance from the GPS receiver to three satellites. However, the position generated by means of this method is not accurate, for there is an error in calculated distance between satellites and a GPS receiver, which arises from a time error on the clock incorporated into a GPS receiver. For a satellite, an atomic clock is incorporated to generate on-the-spot time information, but the time generated by clocks incorporated into GPS receivers is not as precise as the time generated by atomic clocks on satellites. Here, the fourth satellite comes to play its role: the distance from the fourth satellite to the receiver can be used to compute the position in relations to the position data generated by distance between three satellites and the receiver, hence reducing the margin of error in position accuracy.

4.3.2.LED (Light Emitting Diode)

LEDs are p-n junction devices constructed of gallium arsenide (GaAs), gallium arsenide phosphide (GaAsP), or gallium phosphide (GaP). Silicon and germanium are not suitable because those junctions produce heat and no appreciable IR or visible light. The junction in an LED is forward biased and when electrons cross the junction from the n- to the p-type material, the electron-hole recombination process produces some photons in the IR or visible in a process called electroluminescence. An exposed semiconductor surface can then emit light.

4.3.3.LDR (Light Dependent Resistor)

A light dependent resistor works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity (Hence resistivity) reduces when light is absorbed by the material. When light falls i.e. when the photons fall on the device, the electrons in the valence band of the semiconductor material are excited to the conduction band. These photons in the incident light should have energy greater than the band gap of the semiconductor material to make the electrons jump from the valence band to the conduction band. Hence when light having enough energy is incident on the device more & more electrons are excited to the conduction band which results in large number of charge carriers. The result of this process is more and more current starts flowing and hence it is said that the resistance of the device has decreased. This is the most common working principle of LDR.

V. TESTING

The test plan formulated involved initial testing in a simulated track to study the feasibility of crack detection. The arrangement utilized some wooden planks kept in the form of tracks and the robot was made to traverse it. We included a crack manually and found that the device successfully detected that user-created crack and the current latitude and longitude values were received by the GPS receiver, converted into a suitable text format and then finally transmitted to a mobile phone by means of the GSM module (Figure 3). Thus, these trials indicate a fairly good degree of accuracy and also the GSM and GPS modules worked properly by transmitting the current latitude and longitude data to a mobile phone on detecting our simulated crack. The obtained coordinates are almost equal to the coordinates obtained using maps on web.

5.1.Threshold Fixing

The relationship between LED and LDR was observed for various distances. A distance was fixed between LED and LDR for our system. The corresponding LDR resistance value gave the threshold.

VI. CONCLUSION

In robot engine instead of operating the robot separately, it can be made a part of the engine in a moving train hence it can be used in hazardous areas to perform necessary nondestructive inspections. In Industries inspection is carried out in crankshafts and machinery by using sensitive sensors . For maintenance of structures like bridges by detecting big cracks can be done. Multiple Communication is possible instead of sending a SMS only to the central office; it can be even forwarded to the authorities of nearby stations along with indication in the form of SMS or invoking any other systems.

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