Design and Development of Device Used for Detection of Cracks on Railway Tracks

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***Abstract* -** The Indian railway is one of the largest railway networks in the world. Despite being such a large network, the safety parameters of Indian railways are substandard. The safety standards and outdated technology causes numerous train accidents and puts human lives in danger. These lives can be saved by avoiding and eliminating the main cause of such accidents i.e. detecting cracks in railway tracks and detecting obstacles over the track. The objective of this paper is to design and develop a system using sensors and automation to detect and warn the station master about possible danger. This paper briefs the sensors like GPS module, GSM modem, IR sensor, PIR sensor used for application of communication purpose, crack detection, and finding of human beings present in the railway track. Here, the GPS module and GSM modem help us to find and send railway geometric parameters of crack detection to the nearest railway station. This paper completes the study of a reliable crack detection system which can also be used in physical conditions.

Keywords - GPS module, GSM module, IR sensor,Railway track crack detection, Ultrasonic distance meter

I. INTRODUCTION

In India, railway transport is the most widely used and common mode of transportation for people, covering over 1, 15,000 km in distance, all over the country[1]. Transportation helps in moving people and goods from one place to another [2]. Nowadays we often observe in the news that railway accidents are quite common. The main reason behind this is due to the presence of cracks and other problems on the railway track. These cracks and other problems with the railway generally go unnoticed due to improper maintenance and manual track line monitoring that is being carried out. For preventing this accident and reducing man power we should use an automated system. It will help to monitor the presence of cracks and other problems on the railway track and when the crack or any defect found on the track at that instant the crack detecting device will automatically stop moving on the track and find the cracks inside the railway track.

Figure 1 Wide crack on a running railway track [3].

The device consists of different sensors like IR sensor, ultrasonic sensor, PIR sensor, and GSM module, GPS module which detects and sends the information to Arduino Mega. The main aim of the robot is to find the cracks in the rail track. This device will run on the rail track with 3m/s speed. IR sensor used in this robot will detect the presence of cracks and ultrasonic sensor will detect obstacles in the path of the robot on the railway track. PIR sensor will see if an obstacle is moving or stationary. Data will be saved and displayed LCD.

When a crack or any defect will found then that location will be found by GPS module and this information will be sent through SMS to the nearby station master by GSM module. A V-shaped extrusion bar is used in the device which makes the design flexible so that we can use this on the different size rail track.

II. LITERATURE REVIEW

It is observed that many researchers have already worked on the same issue and developed some device for the same. Divya and Ritika[3] introduced PIR sensors to detect human presence on the track and avoid suicides. Also, the major parts used IR device, Ultrasonic, PIR sensor, flame detector. The cracks within the railway track will be detected by IR sensors. Infrared(IR). These sensors contain a transmitter that will transmit infrared rays and a receiver that will receive back the transmitted rays. Measure ought to be taken to form positive that each the transmitter and receiver lies in a very line. If the signal sent by the transmitteris received by the receiver section it indicates the presence of crack within the track. A fire sensor is added for the safety and smooth running of device as well.

Kuthe, Amale and Barbuddhye[4] used the LCD screen to display the data of the detected crack and save it for further more time. Paul, Varghese, Menon and Krishn[5] has approach for GPS and GSM in the decice. They discusses a Railway track crack detection using image process and could be a dynamic approach which mixes the utilization of GPS following system and LAN module to sendalert messages and therefore the geographical coordinate of location. IR detector is employed to finding the cracks and injury of tracks. unhearable sensors square measure used to discover any obstacle on the rail track. Terribly correct detection and conjointly obtaining correct output compare to the prevailing system. In traditional condition, the motor, LDR, Serial transmission is within the initial stage. Once the battery power provides the microcontroller then it's beginning the motor within the forward direction and serial transmission is employed to send the messages to the microcontroller. LDR is employed presence or absence of a crack in the railway line.

III. MATERIALS AND METHODS

A. Materials Required

The Railway Track Crack Detection System has different sensors dedicated for unique tasks. Also, materials like V-Slot aluminum extrusion bars are used to develop the modular chassis of the robot. Other required parts such as couplings for drive, motor mounts and mounts for sensors are developed by 3-D printing using the PLA material. All other components such as battery, display, microcontroller, modules and sensors are mentioned in the Table1.

Table 1 Sensors, Actuators and Components used in developing the crack detection device.

Sr. No.	Name	Specific Model	Purpose
1	IR Sensor	SHARP GP2Y0A710K0F	Detect crack on track
2	Ultrasonic Sensor	JSN-SR04T	Detect obstacle in front of equipment
3	PIR Sensor	HC-SR501	Check if obstacle is moving or static
4	GSM Module	SIM 900	Send message to nearby station master
5	GPS Module	GY-NEO6MV2	Detect the location of crack
6	LCD Display	Generic 0829U8OUTCY JCE 16 x 2	Display the location of crack
7	Aluminum Extrusion Bar	V-Slot	Material for chassis
8	Ardiuno Mega	Arduino Mega 2560 R3	Use as a microcontroller
9	Fire Sensor	Infrared Flame Sensor	Detect if there is any fire
10	DC geared motor	IG32	Drive the equipment
11	Motor Driver	Robodo L298 Motor Driver	Drive the Motor
12	Battery	Orange 2200 Mah 24v	Supply Power
13	Printing Material	CREO PLA	Print Couplings, Motor mount, etc

B. Circuit Diagram

The integration of all the sub-systems is done through a central PCB. All the sensors, modules, motor drivers, etc. are controlled through a Central PCB the robot (Figure2). A dedicated drive PCB for each module containing the necessary electronics is connected to the central PCB using RS232 and DB9 connectors. Other signal connections use standard locking PTR connectors.

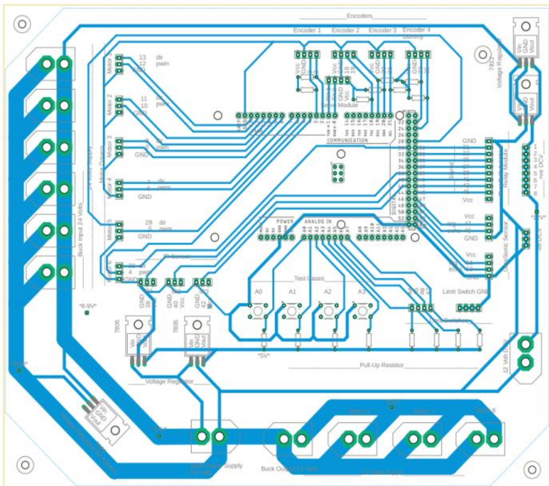


Figure 2 The main circuit board of the device

C. Proposed Solution

The block diagram shows the schematic diagram of system. Here the sensors i.e. IR sensor, Ultrasonic Sensor, PIR Sensor, GPS Module feed the input data to the microcontroller. The power is supplied to the microcontroller which operates the actuation of motors and sends signals and data accordingly (Figure 3).

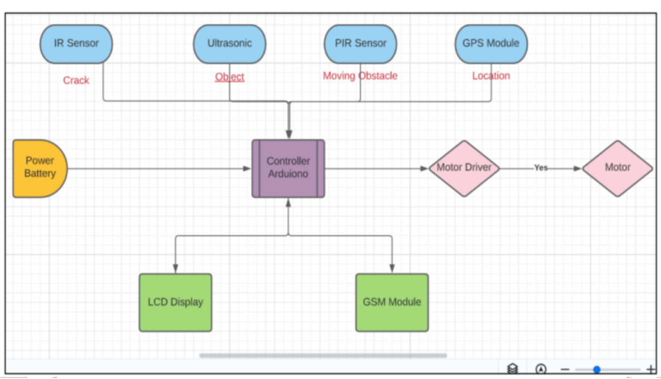


Figure 3 Schematic diagram of system.

D. Railway crack detection by ultrasonic wave

It is possible to use ultrasonic waves to find flow as well as cracks on the railway tracks. Flow is the internal defect in the railway track, whereas the crack is the defect that can be seen on the outer surface of the track. To find the flow on the railway track, we need high-frequency ultrasonic waves. On another hand, for finding the crack on the railway track we didn't require high energy ultrasonic wave and the reason for that is a crack is present o the outer surface of the track that is why it is not necessary to present ultrasonic wave in the track, so low-frequency ultrasonic wave range of kHz is used for finding the crack on the surface in any material with ultrasonic waves we have to transmit ultrasonic wave in the material and receive back these waves and measures the time between the transmitting of the waves.

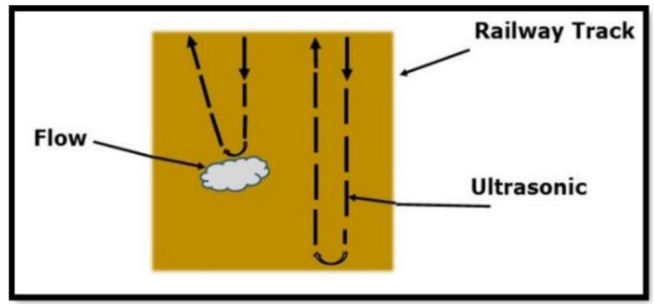


Figure 4 Ultrasonic wave propagation.

There are two different methods for transmitting and receiving the ultrasonic waves

1. Pulse echo method

2. Phase measurement method.

In the pulse-echo method, the transmitter and receiver are in the same module, while in the phase measurement method separate module for transmitter and receiver with different phase angles is used.

E. Mathematical Modelling

In order to ensure smooth running of robot, an appropriate motor was required that would satisfy the demands of RPM and torque. At first through the help of research papers, speed of the robot was finalized. Then the following calculations were done in order to calculate the torque. Through the values of RPM and torque, motor was finalized.

Weight of robot = 12kg

Velocity required = 3 m/s

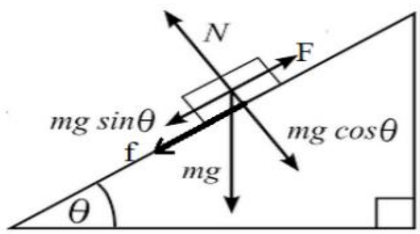
Radius of wheel = 95 mm

$v = rw$

Therefore RPM required = 300

RPM Factor of safety = 15 degree elevation

Considering body on an incline,



$$mgsin(15°) + \mu mgcos(15°) = F$$

Figure 5 Free Body Diagram of the Robot and forces acting on it.

Taking coefficient of friction as

0.35 F = 45.25 N

Power = Force x Velocity

Total Power = 135.75 W

Power for single motor = 135.75/4 = 33.9

W $P = \tau \times \omega$

Therefore,

Torque on a single motor = 0.927 Nm = 9.45 kg-cm

F. Methodology

Our proposed solution has two parallel operations running first one is the detection of crack and the second is the detection of an obstacle. In the detection of crack, we are using a Sharp IR sensor. As the speed of our robot won't exceed 3m/s sharp IR can detect crack easily. The data of IR every 20 meter will be neglected as it is the gap between the tracks (as piece of railway track is 20 meter long). After the detection of any crack in assigned 20 meter distance by IR in assigned 20 meter distance, it will send a signal to the microcontroller. The microcontroller will then send the signal to the GPS module to get the exact location [6]. The GPS module will send the data about the location to the microcontroller which further will send the location data to the station master and driver using the GSM module [7]. For the case of low signal or no signal which is the most common problem when the robot goes inside a tunnel, we have added an LCD display screen that will be displaying the location of the crack and will save it. When the robot will get out of the tunnel the data stored from the LCD screen will be sent to the station master. In the detection of obstacles, we are using an ultrasonic sensor and a PIR sensor. An ultrasonic sensor will detect if there is any obstacle in the front of the robot and will continuously send signals to the PIR sensor. If ultrasonic finds any obstacle then the robot will stop and then PIR will check if the obstacle is a static or moving obstacle. In case, if the obstacle is moving, the robot will wait until the obstacle passes by and the movement of the obstacle will be checked by an ultrasonic sensor. If it's a moving obstacle then it will wait till the obstacle passes, the passing of the obstacle will be checked by an ultrasonic sensor. If it's a static obstacle then it will send a location with an obstacle message to the station master [9].

G. Robot Design

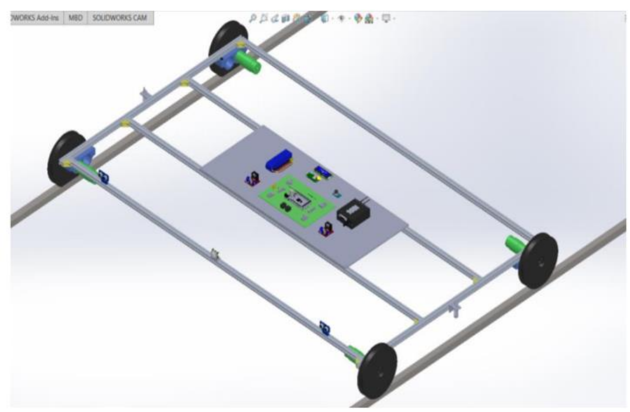


Figure 6 Robot Design

Figure 6 shows design of the device. It has modular aluminum chassis which is grey in color and t does have T-nut slots in it. It has 3-D printed motor mount which are blue in color. The yellow color L-shaped brackets are aluminum T-nut slots brackets. Ultrasonic sensors are mounted on front and has navy blue color. Front-center is occupied by PIR sensor and has white color. Two IR proximity sensors are also mounted on chassis and in the central line of wheels and has grey color. The mounts for ultrasonic sensor, PIR sensor and IR proximity sensor have the same color as of the sensors. One polycarbonate sheet is mounted in center of chassis and has grey color and it has electronics mounted on it. Everything is arranged properly so that the center of gravity should be as low as it can be to reduce toppling effect and it is maintained at center so that every wheel gets almost equal load. The wheels are slotted so that they get fixed on the dark grey color railway track. Further some simulations are done on this design and results are obtained for torque in the motor versus time and velocity versus time graphs.

IV. RESULTS AND DISCUSSION

Our basic motion was smooth in running. The results of motion analysis were also as expected. Our first analysis of Motor torque versus Time shows that when a robot will start moving the torque will be highest but as its speed starts increasing the torque starts reducing. Our second analysis of Velocity versus Time shows that its maximum speed goes to 3m/s and minimum is 0. The graph also shows speed as -3m/s because the analysis is done for reciprocating motion when coming back its speed is - 3m/s.

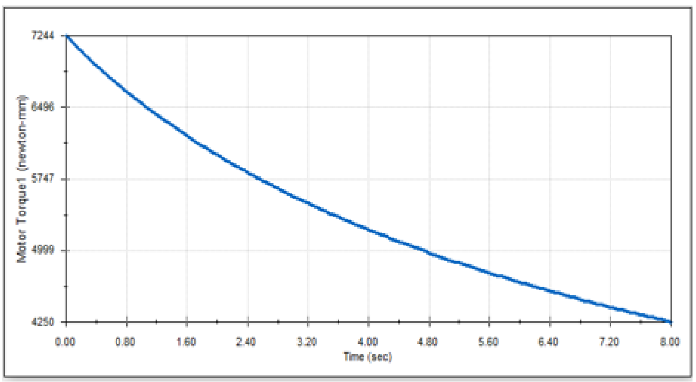


Figure 7 Result graph of motor torque versus time analysis.

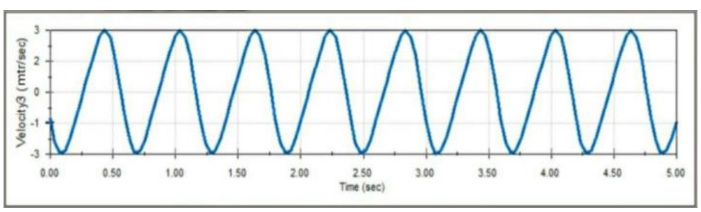


Figure 8 Result graph of velocity versus time calculation.

With the help of 24 volt batteries the device can run about 3 hours consistently which can be increased by adding batteries in parallel. Considering its normal speed in one go the device can cover a distance of 32 kilometers.

V. CONCLUSION

The method we proposed in this paper can be used to find the crack in the railway track. By using this technique for railway track inspection, manpower can get reduced. IR sensor-based railway crack detection and PIR sensor-based presence of human detection system with GSM module for the alarming station was developed. High efficient ad simple system is designed ad analyzed successfully. A V-shaped extrusion bar has used this device which makes it flexible and can use on different sizes of railway tracks. In the future, this device can be used by Indian railways to inspect and secure wide network tracks. Develop technology that can be used at the domestic ad at commercial places with future vision.

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