Design and Development of an Automatic Unmanned Railway Level Crossing Gate

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Abstract. In rapidly developing countries like India, Railways are an important mode of transportation among all the people. In the railway sector, the level crossing gate plays a vital role, which should be taken into consideration. But in the level crossing gates, due to poor monitoring by the humans, many accidents are happening day-by-day. So, there is a need to develop technology to solve this issue. This paper deals with the automatic railway gate at the level crossing, which replaces the gates operated by the gatekeepers. By making it in an automatic way, can reduce the time consumption for closing the gate and also reduces human power. Streamlined the working of level crossing gate through a mini prototype model that solves this problem. Here the sensor is placed safely near the level crossing gate, which is kept at a certain distance in the railway track. Whenever the train is fastened in the railway track, the vibrations which are produced during its motion are being sensed by a sensor and it provides the necessary signal pulses to the controller which is kept at the level crossing column setup. Then the controller activates the motor, therefore the gate closes and opens automatically. Visualized the design calculation for making this setup. Hence by implementing this idea, can able to control the accidents in unmanned areas, therefore the precious human life can be saved.

1 Introduction

Generally, people like to travel from one place to another place, and their mode of travel may be a part of entertainment or a part of their daily life. For travelling purpose people may chose different modes of transportation based on their status and comfortless [1]. Usually, railways are the best mode of transportation among all the people, because the train travel saves a lot of time than roadways and it was cheaper too [2]. Indian railways are the fourth largest network in the world. At present 49% railway routes are electrified and 33% routes are double and multi tracked. Therefore, there is a necessary to construct a very large number of level crossing gates across India. Since there is large number of leveling gates is to be present, it’s difficult to keep a separate monitoring stations and gate keeper to notify the process [3]. So, the monitoring and controlling of level crossing gates is to be automated to make it more precise and accurate [4]. Automatic level crossings are installed on the railway lines to regulate and control the road traffic [5]. Different type of level crossings is available in the market, they are named as Road Over Bridge (ROB) or Road Under Bridge (RUB) [6]. The simple representation of level crossing gate is represented in Figure 1.
In the existing level crossing gates different mechanisms like locking arrangement which includes, the hasp and staple type with padlocks, two chains with loops which is available at both the ends [8]. The gates are designed in such a fashion that it should be in the form of lifting barriers along with chains which should be in a standard design. In the existing manned level crossings, it consists of two long spare chains which is located at both the ends, and it should be placed near the tracks. The spare equipment consists of two discs painted red with the words "stop" is also fixed to the ground. The level crossings gates which is located between the outermost stop signals which should be monitored and controlled by separate Operating Department [9]. The pertaining structures and the level crossings structures shall be maintained by the Engineering Department. This prototype model deals with the automatic process of closing and opening of gates, therefore the manual operation of performing the tasks gets reduced. The main advantage in the process is that once installed this concept in the real time, there is no need of regular maintenance of this setup, hence it encourages the government to use it [10].

2 Construction

The main objective of this research work is to make the leveling gate mechanisms in an automated way, thereby reducing the manual power and to eliminate the inaccuracy in the work. Here the vibration sensor is being fitted at a certain range from the level gate. This sensor is kept near the railway track so that the vibrations produced by trains is taken into consideration by the sensor. The entire operations are being controlled by the Arduino UNO. The different level gate setup is being made with horizontal beam and vertical column. Here the DC motor is being fitted in the column, where the motor shaft gets connected to the beam. The power source for the entire operations is taken from the electric station which is used for electric trains. Therefore, there is no need to keep a separate power source for the process. The simple step-down transformer is needed to reduce the power and it provides the appropriate power suited for performing the operations. The components used in this process is briefly listed below:

2.1 Vibration sensor

Vibration sensor SW-420 is a type of sensor which includes a comparator and an adjustable potentiometer for sensitivity selection, and a LED for signal indication. This sensor produce a logic states which depends on the vibrations which being produced by the motion of trains[11]. When there is no vibration it gives low output, when it senses the vibration the output will be high[12], [13]. Here the sensor is fitted in such a fashion that it should not be made contact with the wheels of train, hence a precaution setup is to be there in which the sensor is being kept. The real time installation of the vibration sensor in the railway track is shown in the Figure 2.
2.2 Beam and Column

The column is being made up of definite length, which is used to hold the beam (lever). One of the column end is fixed to the ground and in the Centre position of it, the beam is being inserted which is used to stop the movement of the vehicles crossing the railway gate[15]. Once the vibration is being sensed by the sensor, the controller sends the necessary signals to the motor and hence the beam is being actuated automatically. In the real time scenario, the actuating mechanisms is being done with the help of pulley/belt. The power source for actuating the motor is provided by the electric station from where the power is provided to run the train.

2.3 Servo Motor

A servo motor is a rotary actuator which provides the precise movement of the beam during the controller signals. The reason for choosing the servo motor is that, the direction of the beam can be controlled precisely. The motor is being controlled by providing pulse width modulation (PWM) through the control wire. It works based on the servo mechanism which basically consist of three main parts namely controlled device, output sensor and feedback system. Generally, servo motor is a kind of DC motor which is regulated and controlled by using a variable resistor called as potentiometer knob. It can be rotated from 0 to 180 degree and check the pulse in every 20 milliseconds.

2.4 Controller

The controller used in this project for controlling the entire operation is done by Arduino UNO which is the open source microcontroller. The Arduino is well equipped with digital and analog pins which is being used for different applications[16]. The programming can be easily done by using Arduino IDE (Integrated Development Environment) [17]. The power source for the controller is provided by a USB cable or by external 9-volt battery. The hardware interfacing with the board can be easily provided and user friendly. Arduino UNO differs from other board because it doesn't use FTDI USB-to-serial driver chip, instead it uses ATMEGA8U2 microcontroller chip programmed as a USB to serial converter. It has 14 digital input or output pins, 6 analog input and operate at a clock speed of 16MHz. It has a 32kb of flash memory for storing the IDE code. This board is popular among the people because it doesn’t need additional hardware package it uploads the code. Arduino board generally consist of three main memories which makes the board to use it more easily. The memories are Flash memory, SRAM memory, EEPROM memory. The Arduino uses Harvard architecture in which separate memory called Program memory and Data memory [18]. In Arduino board an additional feature called reset button in which once upload the code, can able to use it again and again by pressing the reset button. The architecture of the Arduino UNO is given below in Figure 3.
3 Working

The working prototype of an innovative project deals with the fixing of vibration sensor (SW-420), which consist of a comparator, potentiometer and a LED for indication. Here the sensor is being fitted at a certain distance from the railway closing gate. The distance between the gate and the sensor is calculated based upon the real time application scenario. Whenever the train is moving in the track at a pre-determined distance the sensor gets automatically actuated and it provides the high output signal to the controller. Here the sensor is isolated from the railway track so that it doesn’t get affected by the movement of wheels of the train. Once the signal is sends to the Arduino UNO board, it suddenly actuates the servo motor which is being fitted at the middle of the column. From the column setup there is an elongation of a lever which is called as a beam, which is an external rod used to block the movement of road vehicles across the railway track during the motion of the train. Once the train crosses the level crossing gate, the closed beam automatically gets open by the instruction given by the second vibration sensor which is being fitted at the other end of railway track. In the real time scenario, wireless sensor network based on fuzzy logic is employed for more accurate way of sensing the vibrations. The beam and column setup is designed based on the calculation research which includes stress, moment of inertia, radius of gyration, slenderness ratio, shear stress, yield stress etc., here the selection of material for beam and column plays a vital role. The motor for actuating the beam is selected by using the torque calculation[19], [20], [21], [22], [23]. The diagrammatic representation of the entire system is visualized in Figure 4 and this developed using Solidworks software [24].

4 Design Calculations

For checking the system model the design calculations are illustrated below:
4.1 Column design

This column calculation is used for identify the column type (short column or long column).

Length of the column, \( l = 837.5 \text{ mm} \)

Breadth of the column, \( b = 280 \text{ mm} \)

Width of the column, \( d = 150 \text{ mm} \)

Area moment of Inertia of the column cross section can be calculated using the equation (1),
\[
I = \frac{bd^3}{12}
\]

Area of the column cross section, \( A = b \times d \)
\[
A = 42000 \text{ mm}^2
\]

The above calculated values \( I \) and \( A \) are used for finding radius of gyration in equation (2) and then this value is helpful for finding the slenderness ratio i.e. equation (3).

Radius of gyration, \( K = \frac{r}{A} \)
\[
K = 43.30 \text{ mm}
\]

Slenderness ratio \( \frac{l}{k} \)
\[
\frac{l}{k} = 19.3
\]

Yield stress, \( \sigma_r = \frac{2n\pi^2E}{l} \)

From the above equation the slenderness ratio is calculated.
\[
\frac{l}{k} = 64.2
\]

Comparing the values(a) and (b), (a) is less than (b). Hence it is short column. On short column the critical load is acting. This load will be calculated with the help of Johnson’s formula, equation (4).

Critical load, \( P_r = \sigma_r A \left( 1 - \frac{\sigma_r}{4n\pi^2E} \right) \frac{l^2}{k} \)
\[
P_r = 9855300 \text{ N}
\]

Allowable load, \( P = \frac{P_r}{FOS} \)

Where,
\[ FOS \text{ – Factor of safety} \]
\[ n \text{ – Number of columns} \]
\[ P = 4927650 \text{ N} \]

Since, \( P < P_r \) Hence the column is safe.

4.2 Shear stress and Torque developed on beam

These calculations shear stress and torque value are used for selecting the motor to operate the beam.

Diameter of beam, \( d = 75 \text{ mm} \)

Length of beam, \( L = 4000 \text{ mm} \)

Density of mild steel, \( \rho = 7850 \text{ Kgm}^{-3} \)

Yield stress of mild steel, \( \sigma_r = 247 \text{ Nmm}^{-2} \)

Shear Stress, \( \tau = \frac{\sigma_r}{2} \)
\[
\tau = 123.5 \text{ Nmm}^{-2}
\]

Torque, \( T = \text{Force} \times \text{Perpendicular distance} \)
\[
T = 6 \times 10^5 \text{ N.mm}
\]
5 Summary and Conclusions

Due to poor monitoring system in the railway tracks, many accidents are occurring day-by-day. So, there is need to prevent those accidents and to helps the railway department for providing a better solution in a simplest form. Hence this project, Automatic Unmanned Railway Level Crossing Gate provides a better solution by making the entire level crossing process in an automatic manner. If this project is being implemented in a real time scenario there is no need of separate person to open/close the railway gate. It also eradicates the human error completely, since there is no human involvement. Accidents can be prevented in the unmanned areas. Once installed in the real time, there is no need of regular maintenance of this setup, hence it encourages the government to use it. The developed prototype model of this system is shown in Figure 5.

Figure 5. Developed model of automatic level crossing gate

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