Research Article

Rail Integrity Control System with Closed Loop Approach

Huseyin KARACALI[1*], Nevzat DONUM[2*], Efecan CEBEL[3*]

[1] TTTechAuto Turkey, Software Architect, Orcid ID: https://orcid.org/0000-0002-1433-4285, E-mail: huseyin.karacali@tttech-auto.com
[2] TTTechAuto Turkey, Embedded Software Engineer, Orcid ID: https://orcid.org/0000-0002-8293-8267, E-mail: nevzat.donum@tttech-auto.com
[3] TTTechAuto Turkey, Embedded Software Engineer, Orcid ID: https://orcid.org/0000-0002-2027-0257, E-mail: efecan.cebel@tttech-auto.com
[*] Correspondence: efecan.cebel@tttech-auto.com

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Abstract

Rail systems have been used for transportation and carriage purposes since the beginning of the 19th century and are still an important means of transportation today. This transportation method is actively used in densely populated Asian countries, especially in America and European countries. According to data from the National Safety Council (NSC) in the United States, rail travel is indeed one of the safest modes of transportation, second only to air travel. NSC reported that in 2019 rail fatality rates were 0.31 deaths per billion passenger miles, while the death rate for air travel was only 0.061 deaths per billion passenger miles. However, this does not mean that serious accidents do not occur. Moreover, the cause of the majority of these accidents is derailment caused by line deterioration and breaking of rails. According to technical data from the Federal Railroad Administration (FRA), in 2020 there were 1,601 accidents caused by track issues, including rail cracks and deterioration. These statistics highlight the importance of regular road maintenance and inspection to ensure the integrity of the railway and prevent accidents caused by road problems. To date, many studies have been carried out to control and ensure the integrity of the rails. In our study, the main aim is to provide a system that will verify that there is no crack in the rails, and otherwise inform the machinist. Furthermore, this study does this verification by dividing the rail structure into small blocks and checking whether the circuit is completed with the electric current it provides over the train. Thanks to this easy-to-apply system, the deformations on the rails can be easily detected pointwise and the number of fatal accidents can be reduced.

Keywords: Rail integrity, rail transportation, close loop.

1. Introduction

A rail system consists of a series of interconnected tracks and trains that transport passengers and cargo over long distances. It is an essential mode of transportation that provides efficiency, reliability, and environmental benefits.

Ensuring rail integrity is crucial to prevent accidents and incidents that can lead to injury or loss of life, as well as damage to cargo and equipment. It also helps to maintain the efficiency and reliability of the rail system, which is vital for transportation of people and goods over long distances. To evaluate the strength and integrity of rails, there are different methods are used. These are ultrasonic testing, magnetic particle inspection, visual inspection, and eddy current testing. They can detect any flaws, cracks, or anomalies in the rails and therefore ensuring that the rail system operates safely and efficiently.

In the study discussed in this article, just like the methods mentioned above, non-contact, breaks and disconnections in the rails are noticed before an accident occurs. A signal is transmitted by the train to the rail, and it circulates a block of rail. If this signal can be received by the train again the integrity of the specified block of the rail is ensured. Otherwise, an anomaly is indicated to the machinist with the help of an indicator.

In the following parts of this article, there are the methods, materials, and results of the study, which is open to development and directly affects human life.

2. Materials

2.1. Inverter

An inverter is an electronic device that converts direct current (DC) into alternating current (AC). It is an essential component in many renewable energy systems such as solar photovoltaic (PV) and wind power systems. Inverters are also used in a wide range of applications such as uninterruptible power supplies (UPS), electric vehicles, and home appliances.

The process of converting DC into AC involves two main stages: the first stage is the rectification of the AC power from the source to obtain a DC voltage, and the second stage is the inversion of the DC voltage to produce AC power of the desired frequency and voltage. The inversion process is achieved using a power electronic circuit consisting of transistors and capacitors [1].

In conclusion, inverters are an essential component in modern electrical systems, enabling the efficient conversion of DC power into AC power for a wide range of

applications. As renewable energy sources become increasingly important, inverters will play a crucial role in enabling the integration of these sources into the power grid [2]. In this study, since the current to be supplied to the rails with the at the end of the moving train is aimed to be alternating current, this electronic component was preferred in order to convert the DC current into AC current in the train.

2.2. Current Limiter

A current limiter is an electronic circuit designed to prevent or reduce excessive current in an electrical circuit. It works by creating a voltage drop across a resistor or a transistor as the current in the circuit increases. As the current continues to rise, the voltage drop across the resistor or transistor also increases until it reaches a point where the current is limited or cut off altogether. They are especially important in circuits where overcurrent can cause damage to components or create a safety hazard [3].

In this study, the whole rail is divided into sections of the same length by means of insulators to be able to be examined and analyzed block by block. When the probes at the front of the train touch to the beginning of a new block, it transfers the alternating current from the inverter to the rails. Therefore, this current proceeds until the next insulator and returns to the train if there is no break. However, during all these processes, the distance to the nearest insulator decreases as the train progresses in the block it is located. As a result, the resistance, which has a linear change, decreases and the current increases with this ratio. Especially when the rail distance is too short, too much current will be produced compared to the beginning, so the current limiter circuit is used. Thus, a current above the determined current value is not transmitted to the rails.

2.3. Ampermeter

An amperemeter, also known as an ammeter, is a measuring instrument that measures the electrical current in a circuit. The device is connected in series with the circuit being tested and is used to measure the current flowing through the circuit. The ammeter is based on the principle of electromagnetic induction, where the current flowing through a conductor generates a magnetic field, which is proportional to the magnitude of the current. This magnetic field is measured and converted into a current reading, which is displayed on the instrument.

In this study, this material is used to measure the current transferred by the train to the rail. It is not found externally; the value is taken from another probe as the current is given to the rail from the end of the train.

2.4.   Indicator

An indicator in electricity is a device that is used to show the presence, absence or value of an electrical quantity. The most commonly used indicators are meters, which can display values such as voltage, current or resistance. Meters may be analog or digital, and they can be designed to measure DC or AC signals.

Analog meters use a needle that moves across a scale to indicate the value of the electrical quantity being measured. They typically require a power source, and they are sensitive to temperature and other environmental factors. Digital meters, on the other hand, use a display screen to show the value of the electrical quantity being measured. They can be more accurate than analog meters, and they may be designed to measure multiple electrical quantities. Indicators can also take the form of warning lights or alarms that alert users to the presence of an electrical fault or other problem [4].

In this study, when the alternating current from one probe of the train cannot be received by the other probe, the machinist is warned by the indicator. The reason for this is that the signal can return to the train when there is no problem (broken, non-contact, etc.) on the rail. The machinist, who has been informed about the problem, can make the necessary intervention on his/her own initiative.

3.   Method

Railway infrastructure maintenance and inspection are critical aspects of ensuring the safety and reliability of rail transportation. Multiple methods and standards exist to maintain the integrity of railway tracks, including visual inspections, ultrasonic testing, and rail flaw detection systems. Visual inspections entail walking along the tracks to visually examine for any indications of damage, such as cracks or breaks. Ultrasonic testing involves utilizing high-frequency sound waves to locate internal flaws in the rail. Rail flaw detection systems implement sophisticated technology to identify and analyze rail defects, such as head checks and squats. These methods and standards play a pivotal role in ensuring the continued safety and dependability of rail transportation.

The Rail Integrity Control System utilizing a Closed Loop Approach, in contrast to other methods, comprises a closed circuit composed of conductive components that permit the passage of electrical current.

The primary objective of developing this circuit is to design a mechanism capable of detecting potential rail issues such as fractures or degradation of structural integrity, thereby enabling the system to signal the train operator when the circuit is not closed. In

Europe, there exist diverse standards for the length of track pieces that can be utilized. Nonetheless, on average, the length of rails utilized in Europe is approximately 12 meters. The fundamental principle of our research involves dividing rail components into three identical segments through the utilization of insulating materials, with a specific focus on 12-meter rail pieces.

In the context of electrical circuits, cells that have undergone division and are of uniform size are regarded as circuits. These circuits are regulated by a control box that governs the current flow and determines whether the circuit is closed or not. In our study, the management of current flow is crucial for achieving circuit completion. The power supply in the system creates a potential difference that allows the current to flow within the circuit. The control box employs a mechanism that regulates the current levels and safeguards the components of the circuit from damage. Resistors are utilized to provide current control, limiting the amount of current that passes through the rail cell.

The efficient functioning of the system necessitates the completion of the circuit, indicating the absence of any intercellular gaps or disconnections. The completion of the circuit ensures the normal functioning of the system, thereby eliminating warning signs. Conversely, any loss of rail integrity results in an incomplete circuit, which prompts the system to detect and report rail problems to the technician. This study seeks to prevent accidents by identifying rail deformations in the form of points.

4.   Result

Although this study, which aims to check rail integrity, was not carried out physically, visual and theoretical studies were carried out. As a result, two different scenarios can be presented. These two situations are conditions where there is no breakage or loose contact in the instantly checked rail block and there is a problem with the rail.

First, if we consider the scenario where the block in which the train is located is problem-free, the indicator on the train is off (deactivated) as seen in Figure 1. A certain electrical voltage is applied to the rail block from the train positive probe. Since there is no contact or break in the rail, this value is above the threshold value of the diode and the system receives this electrical voltage from the negative probe almost without loss. Therefore, the train continues on its normal route without warning the driver or any other employee. Since there are insulators between each block, the voltage applied to the rail only cycles within that block.

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Positive
Probe

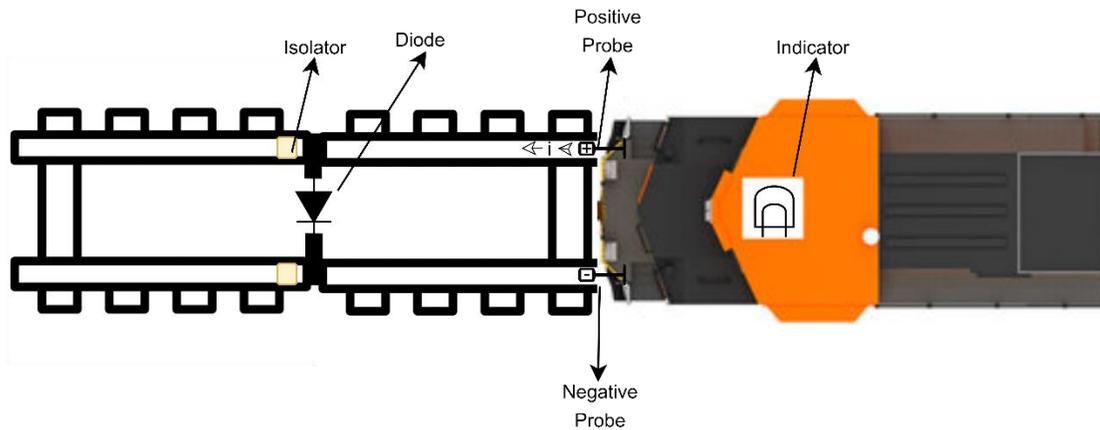Isolator   Diode   Indicator

Negative
Probe

Figure 1: The case that the rail block is problem-free.

The other scenario is that there is a problem in the block that the train actively controls. If a problem such as loose contact or a break occurs at any point on the rail, in this scenario, the system will warn the driver and other employees thanks to the indicator, and the driver will be advised to slow down or stop the train urgently. Since the voltage given from the positive probe will encounter an open circuit due to a physical problem, or high resistance if there is a crack, it will either not be able to pass through the diode, or even if it does, it will be noticed that there is a large loss in the negative probe. Thus, it will be possible to detect that there is a problem at some point until the next insulator. Since there is a crack at one point in Figure 2, electric current will not be transmitted, an open circuit will occur and the indicator will be active.
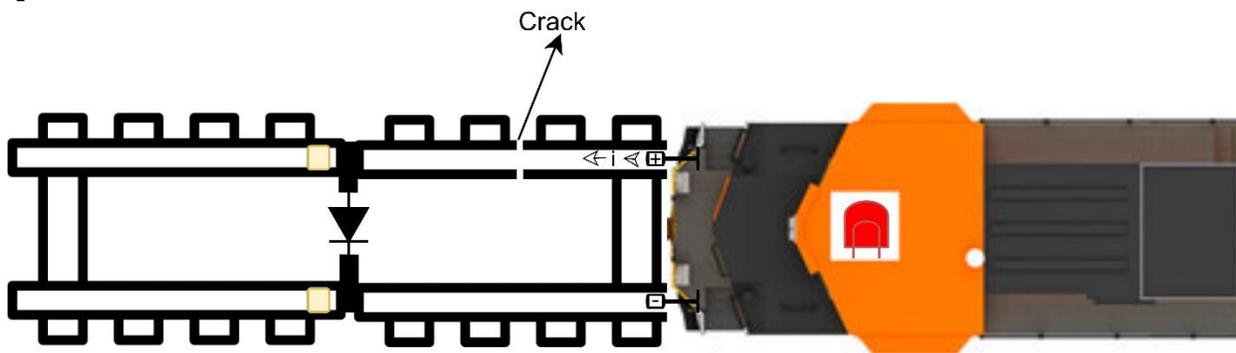
Crack

Figure 2: The case that the rail block has breakage.

5.   Discussion and Conclusion

The Closed Loop Approach Rail Integrity Control System has the capability to promptly identify degradation in rail integrity. Consequently, the objective is to mitigate the likelihood of additional damage or accidents resulting from such deterioration. The

system's notable feature is its closed electrical circuit logic, which renders it an easily implementable system.

The system can be made more reliable by integrating an image processing algorithm that monitors rail integrity into the system. The system can be made more advanced and reliable by analyzing the color and brightness of the pixels in each frame with image processing algorithms and monitoring the rail integrity. In addition, foreign materials on the rail can be detected with object recognition.

6.   Acknowledge

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