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IoT Based Hot Axle and Break Binding Detection System in Indian Railway Wagons

Om Pravin Shirsath
Department of Electronics & Telecommunications
AISSMS Institute of Information Technology
Pune, Maharashtra, India
omshirsath54@gmail.com

Sakshi Ravindra Tikare
Department of Electronics & Telecommunications
AISSMS Institute of Information Technology
Pune, Maharashtra, India
sakshitikare06@gmail.com

Lalita Prabhakar Bari
Department of Electronics & Telecommunications
AISSMS Institute of Information Technology
Pune, Maharashtra, India
lalitabari1@gmail.com

Under the guidance of.

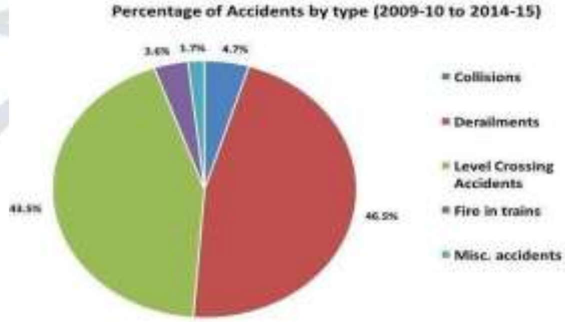
Dr. N.S. Warade
AISSMS Institute of Information Technology
Pune, Maharashtra, India
nilima_warade@yahoo.co.in

Abstract— In the realm of railway transportation, ensuring the safety and efficiency of rolling stock is paramount. The occurrence of hot axle and brake binding in wagons poses significant risks to both the cargo and personnel involved. To address this challenge, this research proposes the design and development of a battery based IoT sensor system tailored for the early detection of hot axle and brake binding incidents in railway wagons. Leveraging advanced sensor technologies and wireless communication protocols, the proposed system aims to monitor critical parameters indicative of potential failures, including temperature differentials and abnormal brake behavior. Upon detection of anomalies, the sensor system will relay real-time information to the relevant authorities, facilitating prompt intervention and maintenance actions. This paper presents the conceptual framework, design considerations, and technical specifications of the proposed sensor system, along with a discussion of its potential impact on enhancing railway safety and operational efficiency. Through the implementation of this innovative IoT solution, it is anticipated that the incidence of hot axle and brake binding incidents can be mitigated, thereby contributing to the overall reliability and sustainability of railway transportation systems.

Railway Network is the world's largest network, but there are many cases of accidents, so it is necessary to take measures to prevent these accidents.

To address this concern, this research gives the design and development of an innovative battery based IoT sensor system for early detection of hot axle and break binding in railway wagons. By using the advanced sensor technologies and wireless communication protocols, this system provides the real-time monitoring of critical parameters. By detecting and communicating essential information to the authorities, the proposed system aims to enable quick intervention and maintenance actions, which reduces the risks related to hot axle and break binding accidents.

The below diagram shows the distribution of accidents by type, with derailments accounting for the highest percentage 46.5%, followed by level crossing accidents 43.5%, collisions 4.7%, fires in trains 3.6% and miscellaneous accidents 1.7%.



create new technologies and methods to improve the safety and reliability of railways.

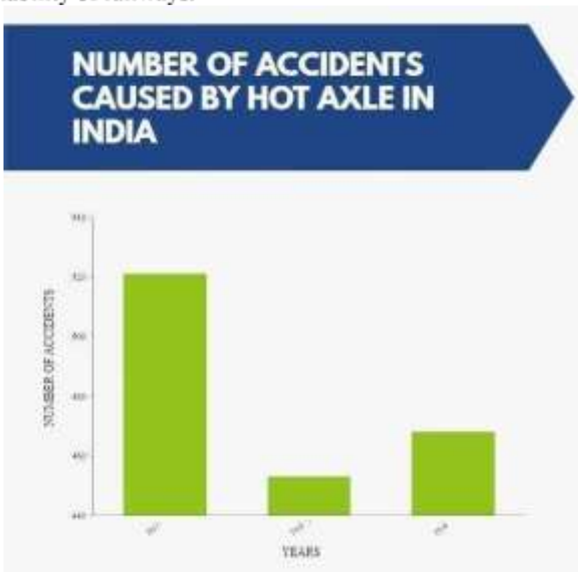


Figure. 2 Number of accidents caused by hot axle

As such this paper represents a comprehensive exploration of conceptual framework, design considerations and technical specifications with the battery based IoT sensor system. Further, this research makes a clear understanding of the potential impact of proposed solution to reduce the incidence of hot axle and break binding incidents, thereby giving safer and more efficient railway operations. Through collaboration and approaches, this research will give way for advancements in railway safety and risk management practices.

Figure. 1 Pie Chart of Percentage of accidents by type

It's important to place this research within the larger context of railway safety and efficiency. Statistics on railway accidents, especially those caused by hot axles, highlight the need for this research. By learning from past incidents, this study aims to

Onboard System Type	Description	Power Source	Advantages	Disadvantages
Portable Autonomous Device	A self-contained system that operates independently.	Battery	Portability - Can be easily moved or installed on different vehicles	Limited battery life, requires periodic recharging
Permanent Powered Device	A system that relies on a Continuous power source.	External Power Supply	Continuous operation without needs for battery replacement or recharging	Dependency on external power supply, may be limited by availability
Long Life Autonomous Device	A self-contained system designed for extended Operation	High-capacity Battery	Extended operational lifespan, minimizing maintenance	Initial cost may be higher due to high-capacity battery and robust construction
Trickle Charged Device	A device that maintains its charge through trickle charging	Battery	Continuous operation with minimal downtime due to continuous charging	Requires access to a power source for trickle charging, may not be feasible in all environments

Table 1: Types of onboard systems

I. LITERATURE REVIEW

The literature on the Internet of Things (IoT) based systems in railways shows how important these systems are to improve maintenance related issues, operating effectiveness and safety. The railway sector is a focused sector in terms of monitoring and in predictive maintenance, because Internet of Things (IoT) has become a widespread across many transportation sectors.

Bernal, Spiryagin and Cole (2018) addressed about the seriousness about the significance of railway transport globally, advocating for enhanced onboard condition monitoring systems to combat insistent derailments. [1] They proposed the real-time monitoring solutions to enable early fault detection, focusing on the potential benefits of condition-based maintenance strategies in improving safety and efficiency. The decreasing costs of monitoring technology are focused, giving a proper way for specialized applications in the good and cargo railway sector, ultimately it aims to enhance safety and reliability.

Raffik and colleagues created a system in 2021 that uses machine learning and Internet of Things (IoT) to identify hazards on railway tracks. [2] This research shows an 80% reduction in human and animal mortality in sight, this strategy places a strong impact on embedded tools and technology. The study focuses on how important is cutting-edge technologies are to rail transportation risk reduction, and it suggests automated object detection and quick communication.

A study on data-based fault diagnosis was carried out in 2018 by Lanlan Sun, Xinhong Hei, Guo Xie, Fueai Qian, Zhuxin Wang and Han Liu. [3] This study specifically addressed hot axle detection in high speed trains. This research focuses on effectively detecting and diagnosing hot axle faults, which are important for rail transport safety and using a data- driven methodology. The authors made a valuable contribution in the field of railway safety by employing data analysis techniques. This helps to improve the ability to proactively manage and resolve the issues related to hot axles in high-speed train systems.

The hot axle wheel detector system is a new railway safety feature included in 2018 in specification from the Reseach Designs and standards organization. [4] This automated system uses temperature monitoring to identify locked wheels and hot axle boxes. This focuses more on compatibility, installation requirements and output deliverables while highlighting technical, functional and safety requirements. The system's scope included installation, software confidentiality, data ownership and turnkey supply.

Sasa D. Milic and Milesa Z. Sreckovic (2008) described about stationary system intended for hotbox detection and noncontact temperature measurement. [5] Through the indirect contact, this system aims to improve railway safety by detecting temperature variations and hotboxes. By offering a solid solution to problems pertaining to train axle conditions, the authors advanced the field of railway monitoring technology.

W.H. Sneed and R.L. Smith present a real-time on-board system for identifying and tracking bearing defects in railroads in their 1998 study. [6] This groundbreaking study highlights the direct integration of real-time monitoring technology on trains to quickly detect and resolve bearing problems. By offering prompt detection and monitoring of bearing defects, the proposed system aims to improve the overall safety and dependability of railroad operations, demonstrating advancements in onboard diagnostic capabilities.

'SMART-BOLT,' a hot bearing detection system, was introduced by R.R. Newman, R.C. Leedham, J. Tabacchi, D. Purta, G.G. Maderer, and R. Galli in 1990. [7] By concentrating on the real-time detection of hot bearings, this novel approach improves railway safety by addressing a crucial maintenance issue. The 'SMART-BOLT' system improves rail transportation reliability by demonstrating technological advancements in bearing defect detection and helping to identify potential problems early.

In 2014, Ufuk Sanver demonstrated a technique called "Identification of Train Number Wagons." [8] The goal of this study is to come up with a method for precisely identifying the wagons with train numbers. This approach probably makes use of the cutting-edge methods or tools that will improve the effectiveness and accuracy of wagon identification in the context of railroad networks.

2020 saw the presentation of a study by Qin Cao, Qi Li, Zengqiang Jiang, and Mingcheng E, entitled "Reliability Assessment of Few-Failure Data and Zero-Failure Data for Wheel Axle of Railway Wagon." [9] The study most likely looks into ways to assess wheel axle reliability in railroad wagons, especially in situations where there are few failures or no failures at all. The present evaluation advances the comprehension and dependability assessment of wheel axles within the framework of railway transportation networks.

II.SYSTEM DESIGN

We have created an IoT based system which will detect hot axles and break binding in railway wagons which involves the network of sensors connected to each other, communication modules, data processing units and user interface for real time monitoring and maintenance. Temperature sensors and infrared cameras are mounted on railway wagons to detect unusual axle and break temperatures. These sensors transmit data to central processing unit via wireless communication network (Example: LoRa, LTE or 5G), where it is examined using machine learning algorithms to spot potential problems.

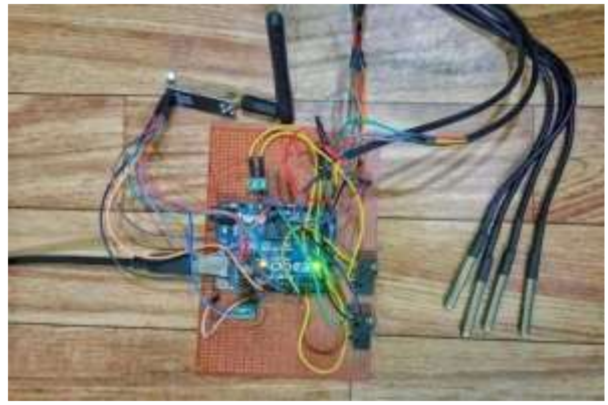


Fig. 3 Overall system

Figure.4 Circuit Design

Figure.5 Train communications network topologies.

III.SYSTEM DISCRIPTION

Using a wireless IoT sensor network, the proposed system aims to amplify railway safety by detecting hot axle and break-binding incidents in railway wagons. The system consists of a transmitter subsystem, located in each casnub boogie, and a receiver subsystem installed in the locomotive or engine. By increasing the advanced sensor technologies and wireless communication protocols, the system provides real-time monitoring and alarming capabilities, contributing to the trustworthiness and safety of railway operations.

Transmitter Subsystem:

The transmitter subsystem is inducted within each casnub bogie and contains the following components:

Arduino UNO board: It is equipped with four DS18B20 temperature sensors and two limit switches.

Temperature Sensors: Mounted on the bearings of each wheel (W1, W2, W3, W4) to observe axle temperatures.

Limit Switches: Mounted on brake pads to detect their positions (pressed or not pressed).

LoRa SX1278 Module: It makes possible for the wireless transmission of data due to receiver subsystem.

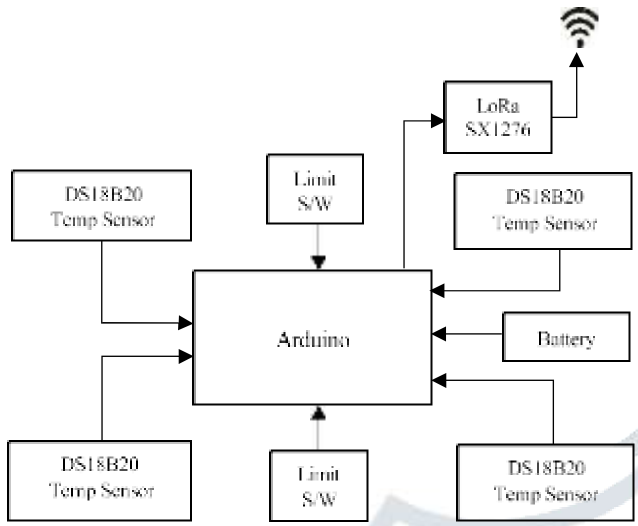


Figure. 6 Block Diagram of Transmitter

When the temperature of any wheel increases beyond 65 degree Celsius, the Arduino Uno provokes the transmission of data vis LoRa module. This data includes the wheel name and the temperature reading.If the temperature difference between the adjacent wheels (W1 & W2) increases beyond 20 degree Celsius, suitable data indicating the wheel names and temperature difference is transmitted. Additionally, the state of the limit switches (pressed or not pressed) is transmitted to indicate the brake pad position.

Data Flow:

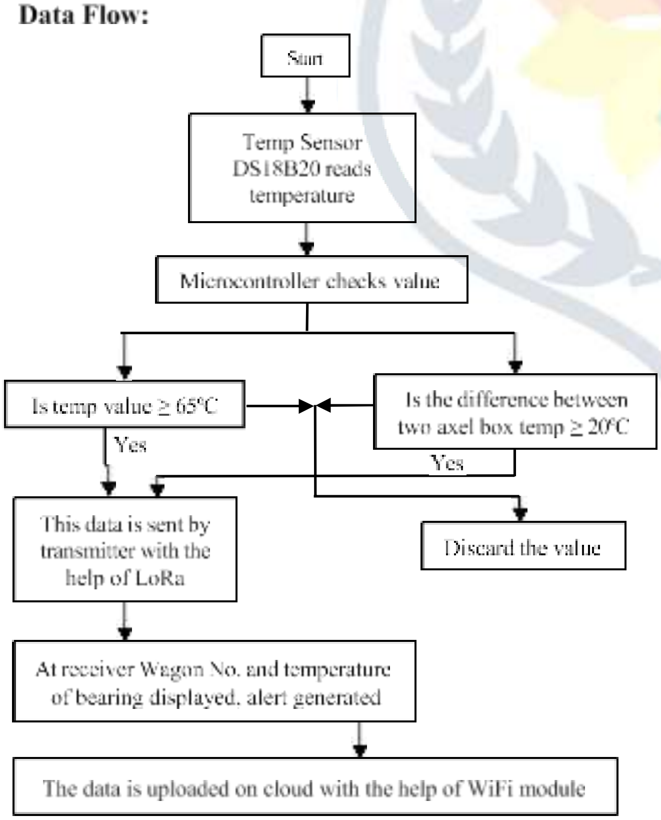


Figure.7 Data Flow Diagram of transmitter

When the temperature of any wheel exceeds or equals 65 degrees Celsius, the Arduino Uno triggers the transmission of data via the LoRa module. This data includes the wheel name and its temperature reading.
If the temperature difference between adjacent wheels (W1 & W2) exceeds or equals 20 degrees Celsius, relevant data indicating the wheel names and their temperature difference is transmitted.
Additionally, the state of the limit switches (pressed or not pressed) is transmitted to indicate the brake pad position.

Receiver Subsystem:

The receiver subsystem is placed in the locomotive or engine and consists of the following components:

Arduino Uno Board: It is interfaced with a limit switch, 16*2 LCD display, buzzer, Neo 6m GPS module and LoRa SX1278 module.

Limit Switch: It receives data regarding the brake pad position from the transmitter subsystem.

LCD Display and Buzzer: It displays the temperature data, warnings (Example: "Hot Axle Detected"), and also activates the buzzer for alerting.

Neo 6m GPS module: It provides current location data.

A7670c 4G module or ESP32: It uploads temperature and location data to the cloud.

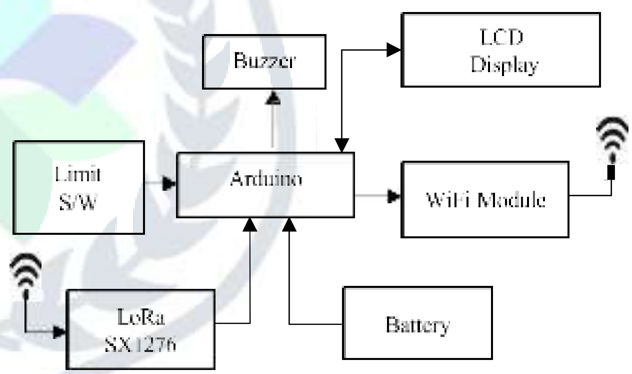


Figure. 8 Block Diagram of Receiver

The temperature data which is received from the transmitter via LoRa is displayed on the LCD along with their respective wheel names. In case if hot axle is detected a warning message is displayed and simultaneously buzzer is activated for alerting.

The temperature and the location of railway wagon are uploaded to the cloud with the help of 4G module or ESP32, enabling remote monitoring and visualization.

The brake binding detection data which is received from the transmitter is compared with the state of the receiver's limit switch.When the brake binding is detected, the information is displayed on the LCD and the buzzer is activated. Then this data along with its location is uploaded on the cloud.

Data Flow:

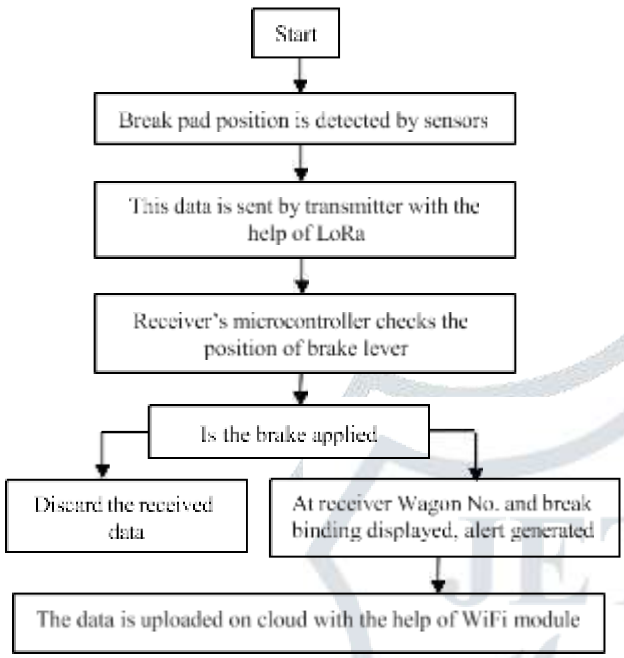


Figure. 9 Data Flow Diagram of Receiver

IV.RESULTS

The IoT system for railway wagons displayed the improved safety and operating efficiency for hot axle and brake binding detection, which produced outstanding results. Real-time tacking of brake pad positions and axle temperatures were cultivated in the transmitted subsystem, which included components such as Arduino Uno board, temperature sensors, limit switches and LoRa module. The system sent data, including the wheel's name and temperature reading, with the help of LoRa, when the temperature of any wheel increases beyond 65 degree Celsius. In addition to it when the temperature difference between any two adjacent wheels is more than or equal to 20 degree Celsius it will then also generate alert message. This data was successfully received and processed by the locomotive's receiver subsystem.

Temperature	Hot Axle Detection
31	Hot Axle not detected
34	Hot Axle not detected
38	Hot Axle not detected
48	Hot Axle not detected
54	Hot Axle not detected
56	Hot Axle not detected
60	Hot Axle not detected
65	Hot Axle Detected
68	Hot Axle Detected

Table No.2 Hot Axle Detection

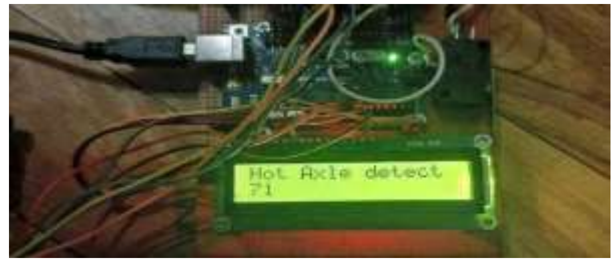


Figure No. 10 Hot Axle Detection

Figure. 11 Hot Axle Detection on Cloud Platform

Switches			Break Binding Detection
Switch 1	Switch 2	Receiver Switch	
0	0	1	No break binding
0	0	0	Break Binding
1	1	1	No break binding
0	0	0	Break Binding
0	0	0	Break Binding
0	0	1	No break binding
1	1	1	No break binding
0	0	1	No break binding
0	0	1	No break binding
0	0	0	Break Binding

Table No.3 Brake Binding Detection

Figure. 12 Brake Binding Detection

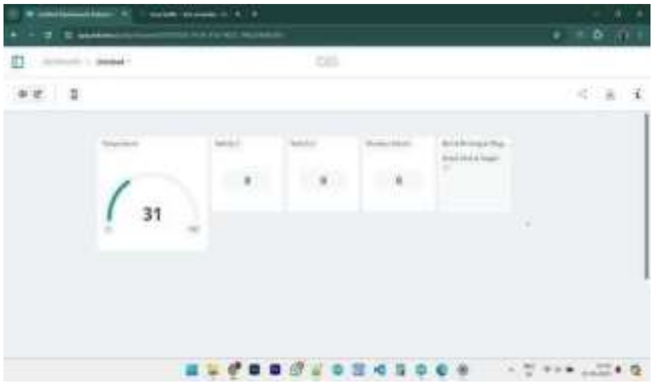


Figure. 13 Brake Binding Detection on Cloud Platform

V.CONCLUSION

The project's safety and efficiency in the railways is improved by creating a battery powered Internet of Things (IoT) sensor system to identify hot axle and brake binding. With the help of limit switches, DS18B20 temperature sensor, LoRa SX1278 modules and Arduino Uno controllers, the system offers a accurate wireless communication and monitoring. Comprehensive local and remote monitoring was made possible by real-time data that was integrated with the Arduino Cloud and was displayed on the 16*2 LCD screen. The system's was able to recognize critical circumstances, like the axle temperature beyond 65 degree Celsius and brake binding and also it was able to communicate this information with the locomotive's main controller and was validated through extensive testing. The real-time warnings and data logging, ESP-32 was guaranteed with the uninterrupted cloud connectivity and an audible buzzer offered timely on-site alerts. An innovative development in the IoT sector in the railway safety was the improvement of scalability and installation through wireless connection.

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