RAILWAY LINES PATROLLING VEHICLE

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelor of Mechanical Engineering

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by

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ABSTRACT

This report details the development of an electric vehicle designed for patrolling railway lines, with a particular focus on the incorporation of sensors and by using AI/OpenCV to aid in flaw detection. The project involved the design, development, and testing of the vehicle and its various components, including the electric drivetrain, battery system, and sensor suite.

The report begins with an overview of the motivation behind the project, including a discussion of the current state of railway maintenance practices and the potential benefits of implementing an e-vehicle with flaw detection capabilities. The report then outlines the design process, including the selection of components and the overall vehicle architecture.

Subsequent sections of the report delve into the details of the vehicle's various systems, including the electric drivetrain, battery management system, sensors and OpenCV. These sections include detailed descriptions of the various components, as well as discussions of the design tradeoffs and challenges faced during development.

The report also includes a section on testing and validation, detailing the various tests conducted to verify the vehicle's performance and functionality. This includes both laboratory testing and field testing on actual railway lines.

Finally, the report concludes with a discussion of the project's successes and limitations, as well as potential areas for future research and development. Overall, the report serves as a comprehensive account of the design and development of an e-vehicle equipped with sensors for flaw detection on railway lines and provides valuable insights into the challenges and opportunities associated with such a project.

ACKNOWLEDGMENTS

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Finally, we would like to thank the faculty and staff of our institution for providing us the resources and facilities to undertake this project. We are grateful for the opportunities and experience that we gained during this endeavor.

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ABBREVIATIONS

AH	Ampere Hours
DC	Direct Current
FEM	Finite Element Methods
FEA	Finite Element Analysis

1. CHAPTER 1: INTRODUCTION

1.1 Motivation/Background:

Railways play a vital role in the economy of a country by contributing and aiding towards transportation of goods and people. The proper maintenance of railway tracks is crucial for ensuring safe and efficient operation of trains. One important aspect of railway track maintenance is regular patrolling, which involves inspecting the tracks at regular intervals for any potential hazards or defects. Effective patrolling is essential for preventing accidents and ensuring the reliability of the railway system. While advancements in technology have been made in recent years for railway track patrolling in many countries around the world, the methods used in Pakistan have remained relatively primitive and lack the efficiency and accuracy necessary to fully identify and address potential problems. Traditional, manual (by-foot) patrolling is still commonly used, which can be time-consuming, labor-intensive, and potentially dangerous.

To address these challenges and bring railway track patrolling in Pakistan in line with global standards, there is a growing need for modern, efficient, and cost-effective solutions that can aid in the patrolling process. In this context, electric vehicles incorporating sensors could play a crucial role in enhancing the effectiveness and efficiency of railway track patrolling in Pakistan. By utilizing electric power, these vehicles would be able to operate in a more sustainable and eco-friendly manner, while the integration of sensors would provide more accurate and comprehensive information about the track and its surroundings. With these considerations in mind, our FYP aimed to design and fabricate an electric vehicle specifically for patrolling railway tracks in Pakistan, incorporating sensors to support effective and efficient track maintenance, bringing the methods used in Pakistan in line with those used globally.

1.2 Problem Statement:

Despite the importance of railway track maintenance and patrolling, the traditional manual methods used in Pakistan have proven to be limited in their accuracy, efficiency, and safety. These limitations have resulted in a significant financial burden for the financially unstable Pakistan Railways, as well as a serious threat to human lives. The cost of poorly maintained tracks can be substantial, both property damage and loss of life. Financial data from recent years shows the cost of railway accidents in Pakistan can run into millions of rupees. For instance, in July 2020, a passenger train derailed near the city of Hyderabad, resulting in over 100 fatalities and dozens of injuries. The accident was a result of a poorly maintained track and caused damage estimated in millions of rupees, highlighting the importance of improving the efficiency and accuracy of railway track maintenance and patrolling in Pakistan.

In addition to the financial costs, manual railway track patrolling also presents significant safety risks to those conducting the patrols, particularly to gang men who are responsible for manual track maintenance. These workers are frequently run over by trains while carrying out their duties, resulting in a significant loss of life. By using an electric vehicle equipped with sensors, these risks can be reduced or eliminated, improving the safety of those conducting the patrols.

Given these challenges, there is a clear need for a more efficient, accurate, and safe solution for railway track patrolling in Pakistan. This FYP aimed to address this problem by designing and fabricating an electric vehicle specifically for this purpose, incorporating sensors to support effective and efficient track maintenance. By doing so, this project aims to reduce the financial burden on Pakistan Railways, improve safety for those conducting the patrols, and enhance the overall reliability of the railway system, ultimately saving precious human lives.

1.3 Objectives:

1. To design and fabricate a modern and efficient electric vehicle for patrolling railway tracks in Pakistan.
2. To incorporate sensors in the electric vehicle to enhance the safety and efficiency of the railway track patrolling process.
3. To evaluate the performance of the electric vehicle in terms of its speed, range, and capability to detect and report track anomalies.
4. To assess the financial and environmental benefits of using electric vehicles for railway track patrolling compared to traditional methods.
5. To improve the safety of railway track patrolling by reducing the risk of accidents caused by human error or poorly maintained tracks.
6. To support the efforts of the Pakistan Railways to modernize its operations and enhance the efficiency of its track maintenance processes.
7. To provide recommendations for future improvements to the electric vehicle design, incorporating the latest advancements in technology and sensors.

2. CHAPTER 2: LITERATURE REVIEW

2.1 Railways : History and Importance

The invention of railways revolutionized transportation and changed the course of history. The invention of railways provided faster, more reliable, and efficient transportation during the industrial revolution, when there was a significant increase in the need for transportation of goods and raw materials. This led to a boost in trade and commerce. Railways also made travel more accessible and affordable for people, allowing the middle class to travel for work or leisure more easily and quickly.

Railways have had significant economic, social, and historical impacts. They revolutionized transportation, enabling faster and more efficient movement of goods and people. They facilitated trade and commerce, made travel more accessible and affordable, and played a critical role in the development of new settlements and towns.

2.2 Importance of tracks in railway system:

The tracks are an essential component of the railway system, as they form the basis for smooth and safe rail operations. They are responsible for supporting the weight of the train and providing a stable platform for the train's movement. The tracks must be laid down with precision and maintained regularly to ensure they remain in good condition.

Proper maintenance is a key to avoid the issues related to derailments and train accidents, For this purpose, the tracks must be inspected regularly and maintained as needed. This includes replacing worn or damaged rails, repairing broken or cracked ties, and checking for proper alignment of the rails.

In conclusion, the tracks are a crucial part of the railway system, and their maintenance is critical for the safe and efficient operation of trains. Tracks that are well maintained can help prevent accidents, reduce delays, and extend their lifespan. Therefore, it is essential that railway companies prioritize track maintenance to ensure that they remain in good condition and meet current safety and technological standards.

2.3 Survey of track patrolling methods:

The main methods commonly employed for maintaining railway tracks around the globe are presented and discussed in this section.

2.3.1 By-foot patrolling :

This is the earliest, trivial, and most primitive method used to patrol and maintain railway tracks. Railway workers are grouped into ‘gangs’ and are assigned a definite length of a particular section of a specific railway line.

The workers continuously patrol railway tracks by foot and repair minor flaws.

Figure 1: Gang men evade the track as a vehicle approaches (Sukkur)

There are several advantages and disadvantages associated with this method.

Advantages :

1. Low direct costs : There is no need to pay for additional fuel for any vehicle to transport the people. Moreover, train operation can continue without disruption as the track is empty of any vehicle and the workers can leave the track whenever any train is approaching.

2. Detailed inspection: If done properly, the particular segment of the track being patrolled can be checked very minutely and in different aspects. Human-based decision making also ensures that the most critical flaws are addressed on a priority basis.

Disadvantages:

1. Safety concerns: It has been reported at numerous occasions and at numerous sites that trains have run-over or collided with gang men as high speed trains may not know the presence of gang men at a particular section.

2. High indirect (hidden) costs : Although apparently this method seems very less costly, its implied and hidden costs can be very high at times. Ill-maintained railway tracks may cause accidents which can result in huge losses to the railway department.

3. Time-consuming: The maintenance of railway tracks by foot means that the speed by which patrolling takes place is limited by human considerations. Hence, patrolling takes place and a slow pace, and this slow pace can also hinder the movement of trains thereby resulting in counter productivity.

2.3.2 Velocipedes:

This method involves the usage of human powered vehicles that are used to patrol the railway tracks. Some forms of this method that have been and are currently in use include Sheffield velocipede, push trolley and rail bicycle.

Figure 2: One of the many variants of velocipede

In all of these methods, either the rider on his own or some other driver makes the vehicle operate and ensures that the railway segment they travel is properly maintained. The vehicles can be stopped at will and certain segments of the track examined in more detail.

As a train approaches, the vehicle (which is usually lightweight), is removed from the track and subsequently placed back when the train passes by. This method has also been long used in developing nations and various forms of it continue to be used.

Figure 3: A Railway Push Trolley

Some advantages and disadvantages of this method include:

Advantages :

1. Good Efficiency: Transportation and patrolling can be done at a relatively high pace and keeping in view the track situation we can also remove the vehicle as and when needed.

2. Accessibility: Certain areas and weather conditions that inhibit movement of gang men by foot are no longer a cause of concern as this vehicle can be moved to those locations which are not easily accessible otherwise.

3. Low direct cost: These vehicles are generally cheap and do not have much operation and maintenance costs hence they do not burden the resources of a railway system.

Disadvantages:

1. Low capacity: Most designs of these vehicles, as shown in the pictures above, have a very low load carrying capacity. The physical ability of the driver pushing or driving the vehicle further limits the maximum load that a push trolley can carry.

2. Safety: If the removal of the trolley in case of an approaching train is not ensured in time, serious safety concerns can be raised with regards to the vehicle and its rider.

2.3.3 Hi-rail trucks :

The most advanced method used for patrolling railway tracks consists of using high-rail truck. The name of high-rail truck is derived from "Highway-Railway truck". The distinguishing feature of this method is that it can be used on both roads and rails. It typically consists of a double cabin type vehicle, on which hydraulically operated folding wheels are mounted. When needed, these folding wheels are opened, and they enable the vehicle to move on railway tracks as well.

Figure 4: A Hi-Rail Truck Operating on Railway Tracks

Advantages:

1. Versatility: High-rail trucks can operate on both road and rail, which makes them a versatile and efficient option for maintenance and patrolling of railways. This eliminates the need for separate vehicles for rail and road transportation, which can save time and money.

2.Speed: High-rail trucks can travel quickly on both road and rail, making them a faster option than traditional maintenance vehicles. This can reduce the time needed for maintenance and repair work, and can also minimize disruption to railway traffic.

Disadvantages:

1.Cost: High-rail trucks are more expensive than traditional maintenance vehicles. They also require specialized equipment and training, which can add to the overall cost of maintenance and operations.

2.Maintenance: High-rail trucks require regular maintenance to ensure their safety and reliability. This can be time-consuming and costly, and can also result in downtime for the vehicle.

Now, after covering each railway track patrolling method in detail, we can resort to provide a summary of these three methods in a compact and concise form so that the suitability of each of these methods for a particular application be better judged and hence the application decided.

Table 1: Comparison of different patrolling methods

Method / Feature	By-foot patrolling	Velocipede	Hi-Rail trucks
Direct cost	Minimal	Medium	High
Operation and Maintenance cost	Minimal	Minimal	High
Indirect costs	High	Medium	Low
Effectiveness	Low	Medium	Very high
Reliability	Low	Medium	Very high
Safety	Low	Low	Very high
Environmental impact	Zero	Minimal	High

Components

The main components studied were :

1. Chassis
2. Wheels
3. Battery
4. Motor
5. Power transmission mechanism
6. Sensors and other flaw detection methods in the rail sector

2.4 Chassis:

We considered different types of chassis design for our vehicle:

2.4.1 Ladder Frame Chassis

The ladder frame design consists of two long parallel beams, known as side rails or ladder rails, that run the length of the vehicle and are connected by a series of cross members.

Figure 5: A Ladder Frame Chassis

Advantages

1. Strength and durability: The design is extremely torsion, bending, and deformation resistant, making it perfect for heavy-duty applications.
2. Versatility: The ladder chassis is extremely adaptable since it can be adjusted to match many body types and configurations.

Disadvantages

1. Ride Quality: Because of the stiff build and absence of suspension, the ride can be uncomfortable, especially over uneven terrain.
2. Stability: The ladder chassis design can have an effect on a vehicle's stability, especially during high-speed cornering or sudden changes in direction.
3. Safety: While ladder chassis designs are strong and durable, they can be less safe in the event of an accident. The rigid construction can cause the vehicle to absorb the impact, leading to more severe injuries for passengers.

2.4.2 Platform Chassis

It consists of a flat, solid platform made of steel or aluminum that extends the full length of the vehicle and serves as the base for the body of the vehicle. A platform type chassis for railway vehicles is one in which the vehicle's undercarriage is built on a platform that extends the entire length of the vehicle. This platform serves as the vehicle's foundation and supports the train or tram's body.

Figure 6: A Platform Chassis

Advantages

Versatility: A platform chassis' flat, stable platform enables for easy customization and modification, making it appropriate for a wide range of applications.

Durability: The sturdy platform gives the vehicle a strong and stable basis, which is vital for heavy-duty commercial operation. Also, weight distribution reduces stress on individual components and improves overall durability.

Easy maintenance: A platform chassis' flat platform makes it simple to access and maintain the vehicle's components.

Disadvantages

1. Difficulty in repair: Repairs to the platform can be difficult and may necessitate specialized equipment or experience, resulting in increased repair costs.
2. Lower stability: In some circumstances, platform chassis may be less stable than other types of vehicle frames or superstructure, notably in high winds or when transporting significant loads.

2.5 Wheels:

We also surveyed different types of wheels to be installed in our vehicle. There were some very intricate differences in the design of the wheels we studied. The main factors considered for wheel design were :

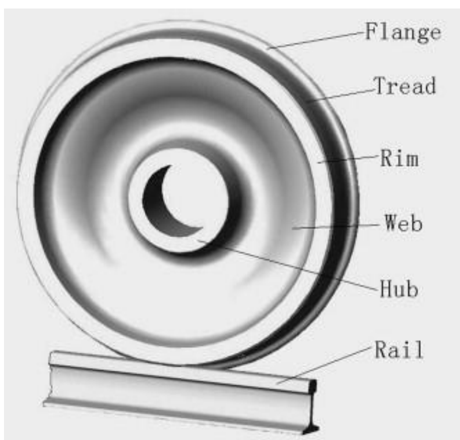

Figure 7: A Railway Carriage Wheel

Taper angle:

The taper angle refers to the angle between the outer diameter of the wheel and the rail contact surface. A higher taper angle means a more conical wheel shape with a smaller diameter at the point of contact with the rail. This angle has a significant impact on wheel design, primarily affecting wheel-rail interaction and wear characteristics.

A higher taper angle can reduce wear on wheels and rails by distributing the load more evenly and reducing sliding friction. However, at high speeds, it can reduce wheel stability as the conical shape may cause shifting and wobbling on the rails.

Flange depth:

The depth of flange, which is the raised edge on the inside of railway wheels, is an important factor to consider in their design. It is determined by factors such as the weight and type of the railcar, track conditions, and desired level of safety and stability.

Deeper flanges provide better stability and reduce the risk of derailment, especially in uneven track or tight curves, but can increase rolling resistance and wear. Shallower flanges are used in applications where stability is less of a concern, such as passenger cars or straight tracks, and can reduce rolling resistance.

Tread width:

Tread width is an important consideration in railway wheel design as it determines the contact area between the wheel and rail. It is typically slightly narrower than the track gauge to allow for the passage of the wheels over switches and other track features.

Tread width is influenced by factors such as the weight and type of railcar, desired level of stability and safety, and track conditions. A wider tread width can increase stability and reduce derailment risk, but also increase rolling resistance and wear. A narrower tread width can reduce rolling resistance and improve energy efficiency, but also increase derailment risk, particularly on poor tracks or tight curves.

2.6 Power transmission mechanisms:

2.6.1 Chain Drive

A chain drive system is a type of power transmission in which power is transmitted between two or more spinning shafts through a roller chain. Chain drives are long-lasting, able to transmit high power, and have a long service life. They're often found in heavy machinery, motorcycles, and bicycles.

Figure 8: A Chain Drive Mechanism

2.6.2 Belt Drive

A belt drive system transmits power between two or more spinning shafts using a flexible belt. Belt drives are quieter than chain drives and require less maintenance because they do not need to be lubricated or adjusted. Belt drives have lower power transfer capacities than chain drives and might slip or wear with time, limiting efficiency.

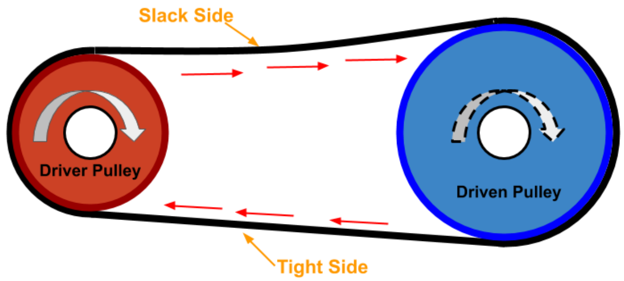

Figure 9: A Belt Drive Mechanism

2.7 Batteries

Batteries come in various shapes and sizes and whether they are rechargeable or for only one time usage. Because of their ease and environmental benefits, rechargeable batteries are a popular alternative for powering numerous sorts of gadgets and equipment. Rechargeable batteries, as opposed to disposable batteries, may be reused numerous times, decreasing waste, and saving money in the long run.

An ideal battery must satisfy specific characteristics, such as being highly efficient, long-lasting, safe, and cost-effective. The desirable characteristics are:

- High Energy Density
- Fast Charging
- Environmentally Friendly
- Cost Effective

A brief comparison among the batteries under consideration is given below:

Table 2: Comparison of Different Types of Batteries

Battery / Feature	Lithium-Ion (Li-ion)	Lead Acid	Lithium Polymer (Li-Po)
Energy Density	High	Medium	High
Cycle Life	Longer	Smaller	Longer
Maintenance Ease	Easy	Slightly Difficult	Easy
Self-Discharge Rate	Lower	Higher	Lower
Cost	Very High	Low	Very High
Environmental Friendliness	High	Low	High
Picture			

2.8 Motor

A direct current motor operates on the electromagnetic concept. It uses a magnetic field to convert electrical energy into mechanical energy.

Construction

A DC motor consists of a stator and a rotor separated by an air gap. The stator has field windings connected to a DC power supply, while the rotor has an armature with a wire coil. The direction of rotation is determined by the current passing through the armature coil, which changes direction as the commutator rotates. This allows the rotor to continue rotating in the same direction. The current must be reversed as the rotor revolves to keep it spinning continually. This is accomplished using a commutator, which is a split metal ring attached to the armature coil. Following are the types of motors.

2.8.1 Brushed DC Motor

A brushed DC motor is the most basic and widely used form of DC motor. It is made up of a rotor (spinning part) and a stator (stationary element), and it switches the direction of the current flowing through the motor using brushes and a commutator. The motor spins because the brushes make physical contact with the commutator.

Figure 10: A Brushed DC Motor

Advantages

1) Simple Design: Brushed DC motors are generally inexpensive due to their simple design and ease of construction.

2) High Starting Torque: Brushed DC motors provide high starting torque, which makes them suitable for applications that require high initial acceleration, such as power tools.
3) Easy to Reverse Direction: By switching the polarity of the input voltage, the direction of a brushed DC motor can be readily reversed.

Disadvantages

1) Limited Lifespan: Because of the wear and tear on the brushes and commutator, brushed DC motors have a limited lifespan.
2) High Maintenance: Brushed DC motors require frequent maintenance to ensure optimal performance and lifespan due to the wear and tear of the brushes and commutator.

2.8.2 Brushless DC Motor

In terms of basic components, a brushless DC motor is identical to a brushed DC motor, but it uses electronic commutation instead of brushes and a commutator. It is more efficient and reliable than a brushed motor, but it is also more expensive.

Figure 11: A Brushless DC Motor

Advantages

1) High Efficiency: Because brushes produce friction and electrical resistance, BLDC motors are more efficient than brushed DC motors. As a result, heat production is reduced while power output is increased.
2) Better Speed Control: BLDC motors can provide better speed control and precision because they use electronic commutation instead of mechanical commutation.

Disadvantages

1) Higher initial Cost: Because of its more advanced technology and electronic control needs, the initial cost of a BLDC motor is more than that of a brushed DC motor.
2) Requires Electronic Control: BLDC motors require electronic control circuits to function, which can increase the system's cost and complexity.

Motor Configuration

The motors can be further classified depending on the position of mounting. The two major types, however, are:

1) Axle Mounted Motor
2) Hub Motor

2.8.3 Axle Mounted Motor

Axle-mounted direct current (DC) motors are electric motors that are mounted directly on an axle, generally of a vehicle or machinery, to deliver rotational power to the wheels or other components. They eliminate the need for additional mechanical components such as gears, belts, and pulleys, which reduces the overall cost and complexity of the system.

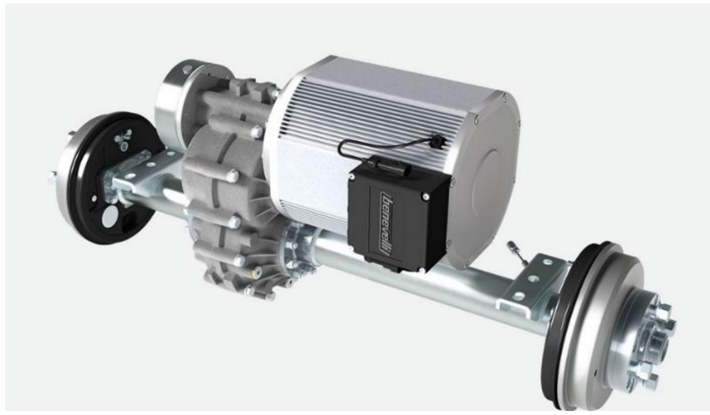

Figure 12: An Axle-Mounted Motor Configuration

Advantages

1) Efficient Power Transfer: Power is supplied directly to the axle via axle-mounted DC motors, eliminating energy losses that would occur if power was passed through a complex transmission system.
2) High Torque Output: Axle-mounted direct current motors may produce considerable torque at low speeds, making them excellent for heavy-duty applications requiring large power.

Disadvantages

1) Limited Speed Range: Axle-mounted direct current motors are designed to produce high torque at low speeds, limiting their speed range. They are not ideal for high-speed applications where speed is essential.
2) Limited Cooling: If axle-mounted DC motors are operated for an extended period of time, they may overheat and function poorly due to restricted cooling alternatives.

2.8.4 Hub Motors

Hub DC motors, also known as wheel hub motors, are electric motors that are built into a wheel's hub. This setup allows the motor to drive the wheel directly, eliminating the need for a separate transmission system. Electric vehicles and e-bikes frequently use hub DC motors.

Figure 13: A Hub DC Motor

Advantages

1) High Efficiency: Hub direct current motors are extremely efficient since they deliver power directly to the wheel without the use of a transmission system.
2) Reduced Maintenance: Hub DC motors contain fewer moving components than standard motor topologies, reducing maintenance and increasing reliability.
3) Improved Handling: Hub DC motors evenly distribute the motor's weight across the wheel, enhancing handling and stability.

Disadvantages

1) Limited Power: Hub DC motors are often smaller and less powerful than traditional motor topologies, therefore their use in heavy-duty applications may be limited.
2) Limited Mounting Options: Hub DC motors can only be put in the wheel hub, which may not be ideal for some applications that require other mounting options.

2.9 Braking System

Automobiles and railway vehicles employ braking for safety reasons. The fundamental function of brakes in railway cars is to controllably slow and stop the train. This is required to avoid crashes and derailments, which can damage the train and infrastructure as well as injure or kill passengers and staff.

The most common type of braking used in railway vehicles is given along with other potential braking mechanisms:

2.9.1 Disc brakes

Disc brakes are utilized in high-speed trains and other applications that require a lot of braking power. Disc brakes work by clamping down on the rotor with a caliper, providing a frictional force that slows the train. Disc brakes are more efficient and less prone to wear and strain than other types of brakes.

Figure 14:Disc Brakes

Advantages

1) High Performance: When compared to other types of brakes, such as drum brakes, disc brakes provide higher stopping power and performance.
2) Self-Cleaning: Disc brakes are self-cleaning by design, preventing the accumulation of dirt or dust that might degrade braking performance.

Disadvantages

1) Heat dissipation: During operation, disc brakes generate a lot of heat, which can cause thermal damage to other components of the vehicle or railway equipment.
2) Cost: Installing and maintaining disc brakes might be more expensive than other types of brakes.

2.9.2 Drum Brakes

Drum brakes are a sort of braking system that can be found in a variety of vehicles, including automobiles, motorcycles, and even railway uses. Drum brakes are made up of a cylindrical drum that rotates together with the wheel and a set of brake shoes that push against the interior of the drum to slow or stop the vehicle.

Working

When you press the brake pedal, hydraulic pressure is applied to the brake shoes, which causes them to press on the interior of the drum. Friction between the brake shoes and the drum slows the rotation of the wheel, lowering the vehicle's speed. The frictional heat is dissipated through the drum, which also serves to cool the brake shoes.

Advantages

1) Cost Effective: Drum brakes are less expensive to produce and install than other forms of brakes, such as disc brakes.
2) Self-Energizing: Drum brakes are designed to provide more braking force when the brake shoes press harder against the drum, resulting in self-energizing braking.

Disadvantages

1) Longer Stopping Distance: Drum brakes have a longer stopping distance than disc brakes because they need more time to dissipate heat and slow the car down.
2) Prone to Fading: Drum brakes can experience brake fade, which happens when friction heat causes the brake shoes to lose their efficacy.

2.10 Flaw detection mechanisms

Railway track flaw detection is done by numerous methods. Some of them include:

2.10.1 Human based detection

This is the most common method used to inspect if there are flaws in a railway line at a particular location. The staff designated to discharge its duties in patrolling railway lines uses different tools and also visually checks whether there is a defect in the railway lines or not.

Figure 15: A railway worker measures the distance between rails near Sukkur.

The main flaws that can be detected by this method include:

1) Misalignment of rails
2) Loose nuts/bolts in the track
3) Faulty/cracked sleepers
4) Cracked rails.
5) Scratched/worn-out rails.

However, the efficiency of this method remains the question as it includes a large degree of subjectivity by relying on human judgement. Also, it remains a largely superficial method with minimal information about within the rail structure.

2.10.2 AI-based flaw detection:

Machine learning algorithms, combined with computer vision techniques, offer a powerful solution for analyzing large amounts of track data and identifying potential flaws. This method can include usage of Data Acquisition, Image Processing and Feature

Extraction to train a machine learning model. Flaw detection using Artificial Intelligence can help increase efficiency, data-driven decision-making, and better maintenance.

2.10.3 Sensor based detection:

A sensor-based system can also be used to detect railway track flaws. This method includes incorporating a microcontroller such as Arduino or Raspberry Pi, along with some sensors which can return valuable information and the microcontroller can process the information and return the processed output to the user.

It is a small and precise sensor that can be used to determine the distance or proximity of an object. The sensor functions by producing an infrared beam and detecting the amount of light reflected. The distance to the object is then calculated using reflected light. The sensor has a 20cm to 150cm range and can be utilized to detect if the track has any cracks at a specific location. Whenever there is a crack or discontinuity in the railway track, the distance calculated by the sensor would change, thereby prompting an alert.

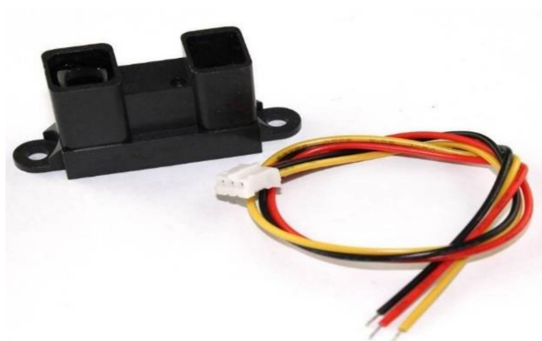

Figure 16: Sharp Infrared Distance Sensor GP2Y0A02YK0F

A brief comprison among the flaw detection mechanisms is presented in tabular form below:

Table 3: Methods and Features

Feature / Method	Human-based	AI-based	Sensor-based
Cost	Medium	High	Low
Reliability	Low	High	Medium
Fault detection capability	High	High	High
Accuracy	Medium-High	High	Medium
Types of faults detected	All	Limited	Limited
Fault classification	Yes	Yes	No

2.11 Link with SDGs:

The development of an electric railway patrolling vehicle can also contribute to the United Nations' Sustainable Development Goals (SDGs). The SDGs are a set of 17 goals established by the United Nations to address global challenges such as poverty, hunger, and climate change. The development of an electric railway patrolling vehicle can contribute to several of these goals.

Figure 17: Sustainable Development Goals

First, the use of electric vehicles can contribute to the SDG 7 goal of affordable and clean energy. The reduction of greenhouse gas emissions associated with the use of electric vehicles can help mitigate climate change and improve air quality.

Second, the development of an electric railway patrolling vehicle can contribute to SDG 9, which aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Finally, the development of an electric railway patrolling vehicle can contribute to SDG 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable. Efficient and reliable transportation systems are essential for achieving this goal, and the development of an electric railway patrolling vehicle can contribute to this effort.

3. CHAPTER 3: DESIGN AND ANALYSIS

Design and analysis of railway patrolling vehicles presented us with a unique opportunity of applying our theoretical concepts to the real world. As designing is an iterative process, we strived to ensure that we carry out maximum number of iterations for designing each part and hence satisfy reliability, durability, performance, and safety requirements. Furthermore, analysis of each component was done after it was designed to ensure that any anomalies and discrepancies are identified at an early stage and no error is carried forward. In this chapter, we aim to lay out the details of the design procedure we followed, with detailed insights into the design of every critical component, and the details of analysis we have done. Detailed results and the implications of our results are discussed in the following chapter, as here the focus is to specify the analysis procedure and techniques employed.

3.1 Design Methodology:

The methodology we used to design our project was based on iterative design procedure. We present a summary of our design procedure in the flow chart below:

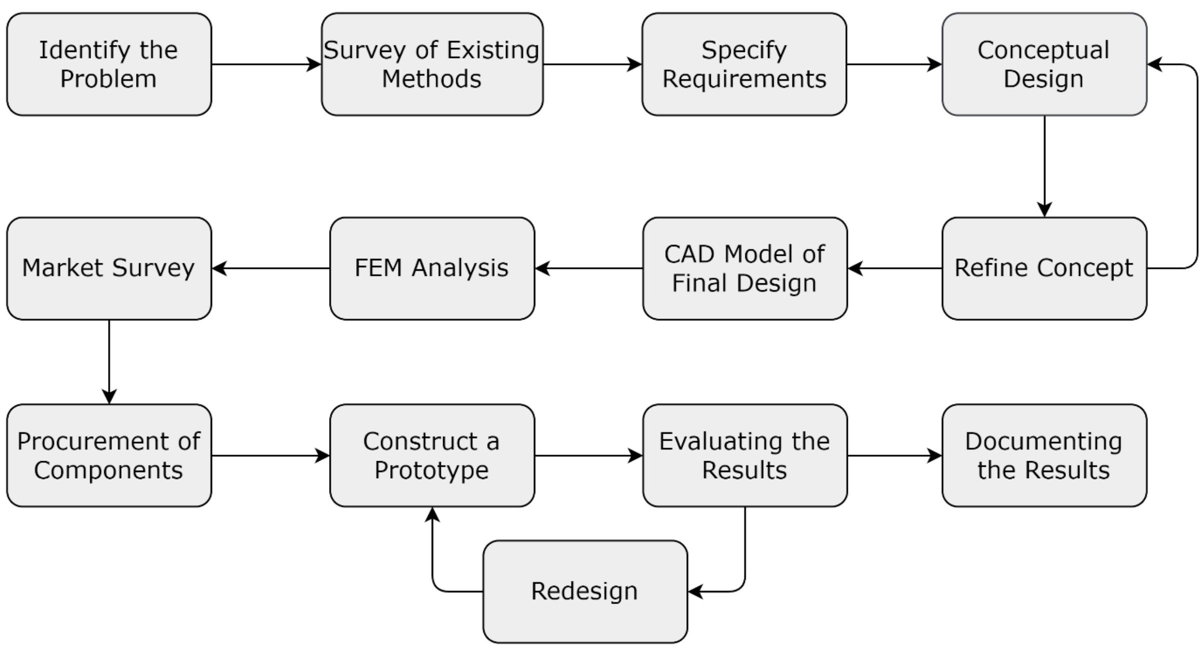

Figure 18: Flowchart Representing Design Methodology of the Project

Coming onto the detailed design, we had three separate but interlinked areas to design and analyze:

1. Mechanical
2. Electrical
3. Fault detection mechanism
4. Tracker design

We shall first cover the design of all these three areas and then their analysis in detail.

3.2 Mechanical:

In the mechanical side of the vehicle, we had some key components to design. The effective design of this area was extremely crucial for our project, so it was very carefully designed and then analyzed. The critical components in this design were :

3.2.1 Chassis:

A chassis is a very important part of a vehicle. Details of different types of chassis and their functions have been covered in the previous chapter. The chassis of our vehicle is shown in the image below:

Figure 19: Chassis with Bench Mounted

The details of our designed chassis are summarized in the table below:

Table 4: Summary of Designed Chassis

Sr.No	**Parameter**	**Value**
1	Type	Platform
2	Material	Wood
3	Dimensions	1524*1651*1397(mm)
4	Weight	150 kg

The platform type chassis offered us ample seating and tool carrying capacity. Moreover, the repair and maintenance work of this chassis type is easier as compared to other variants. In addition to this, hardwood was selected as the material for this chassis as it was the only material which ticked the three boxes of lightweighted Ness, cost effectiveness and strength. Finally, the dimensions of our track were constrained by the track width. However, ample considerations were given in ensuring that enough capacity is achieved in this vehicle.

3.2.2 Wheelset

In railway vehicles, it is a common practice to talk of wheelset rather than the wheel and axle separately. The main reason for this is that the wheels and axles both rotate simultaneously. It is not possible for one single wheel to rotate whilst the other is constrained. This is to ensure the prevention of derailment. Henceforth, we had to design the wheelset in a manner to ensure that it fulfills our requirements of resilience, toughness, durability, strength, and cost-effectiveness.

After consulting relevant books and research papers and augmenting our knowledge with the practical experience of seasoned railway workers and employees, we set forth with the design procedures.

First, we selected the material for our wheelset which was cast iron. Secondly, the dimensions of the wheelset were to be found. It was split into two tasks, one to select the dimensions of axle and second to select dimensions of the wheels. With regards to the axle, the length of the axle was constrained by the track width being used in Pakistan.

However, we could always manipulate the diameter and we did so to ensure that torsion and bending of the axle did not occur. MDSolids software was used to calculate the diameter at which bending, and torsion were no longer a likely event.

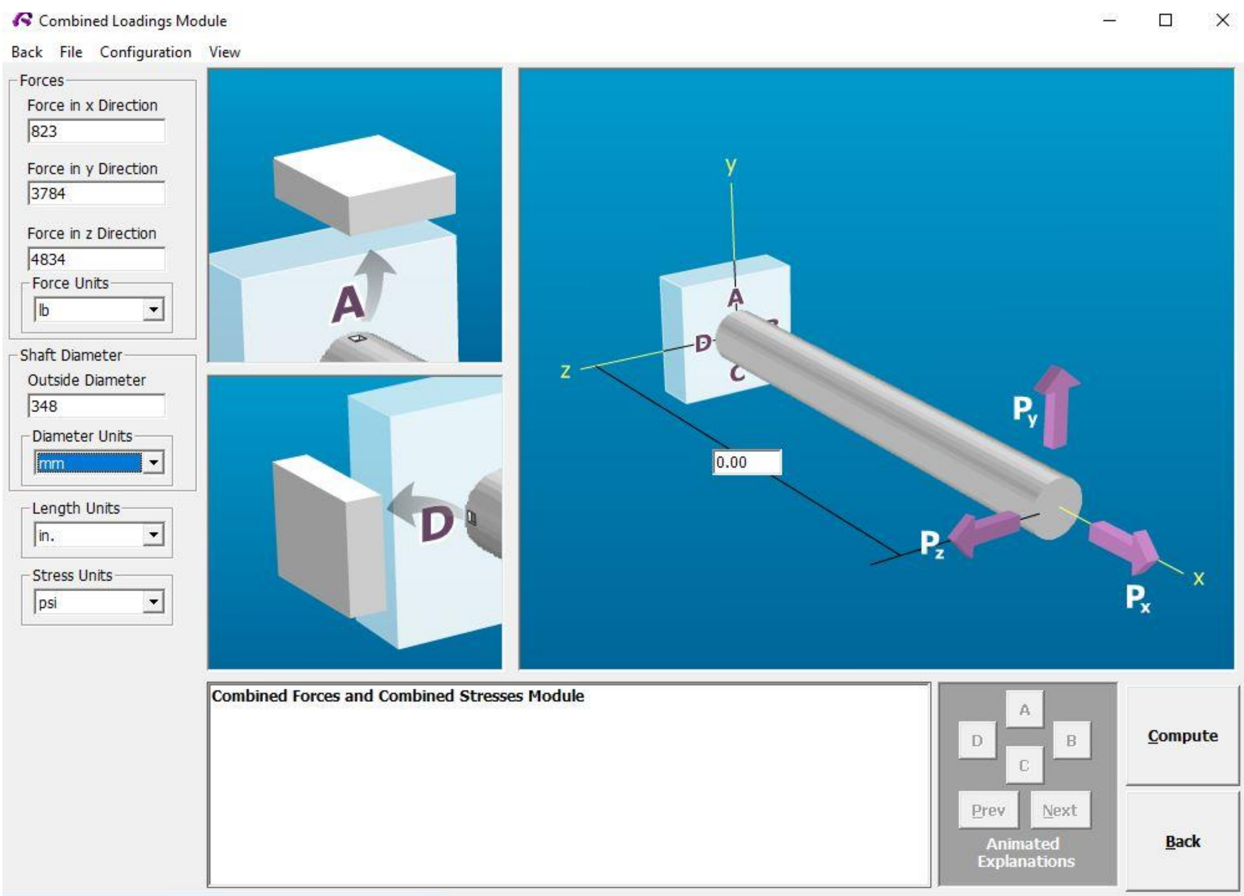

Figure 20: Calculating the diameter using MDSolids 4.0

Lastly, with regards to the wheels, we were faced with a complex task. Had they been wheels for road vehicles, the design would have been a walk through the park. However, railway vehicles require extensive wheel designing in three areas :

1. Wheel diameter
2. Flange depth
3. Tread width

Desired values of these three parameters were calculated using iterative processes and compared with the commercially available railway wheels' data. These wheels, present in scrap, not only made our vehicle more cost-effective but also ensured that standardized equipment is being used. The wheels bought were then riveted to the axle and the wheelset finalized.

Figure 21: A Wheelset

Figure 22: Wheelset view from below the chassis

3.2.3 Chain and sprockets design :

Chain and sprocket design was a very crucial juncture in our project. Effective teeth ratio to provide the necessary torque was to be calculated, which necessitated the selection of motor first. Hence, we carried out this step after selecting the MY1020 BLDC motor. After we had an idea of the torque being provided by the motor, we calculated the teeth ratio for our sprockets. Sprockets were then indigenously designed and manufactured as the ratio we aspired for wasn’t available commercially. The chain we selected was of the same pitch and had an ample amount of strength to ensure that it did not break during operation.

3.3 Electrical design:

The electrical design of our project can easily be termed as the ‘backbone’ of our project. Without effective electrical design, our vehicle would have neither operated nor carried out the fault detection and tracking tasks.

To begin with, the start of our electrical designing was the determination of the key parameters of our vehicle, such as weight, payload capacity and top speed. After achieving a consensus on these parameters, we carried out calculations to get the exact values of torque and rpm necessary to initiate and sustain this motion. Lastly, we selected from a list of available motors, the motor fulfilling our requirements. The electrical design finally concluded with selection and procurement of batteries.

3.3.1 Calculations:

To calculate the required motor rpms and power:

$\boldsymbol{Given\ data}$

$Vehicle\ mass = 105\ kg$

$Maximum\ inclination\ angle\ = \theta$

$= 2.29\ degrees\ (based\ on\ local\ conditions\ in\ Pakistan\ Railways)$

$Frontal\ area\ of\ the\ vehicle = A = 1\ m^2$

$Windage\ resistance\ factor = \ C_w = 0.55$

$Tire\ radius = R = 0.27\ m$

$Coefficient\ of\ rolling\ resistance = \ C_{rr} = 0.002$

$Density\ of\ air = \rho = \ 1.25\ \frac{kg}{m^3}\ at\ 20^oC$

$Gravitational\ acceleration = g = 9.81\ \frac{m}{s^2}$

$\boldsymbol{Design\ parameters}$

$Maximum\ payload = 700\ kg$

$Maximum\ mass\ carried = M = 850\ kg$

$Climbing\ velocity = 20\frac{km}{h}$

$Top\ vehicle\ speed = 60\frac{km}{h}$

We start with calculation of the total resistance experienced by the vehicle while climbing. After that we shall calculate total resistance on ground. The larger of these two values will serve as the required motor design parameter.

$\underline{\boldsymbol{Climbing\ resistance}}$:

$F_c = M * g * \sin\theta$

$= 850 * 9.81 * \sin(2.29)$

$= 336.58\ N$

$Rolling\ resistance\ while\ climbing$:

$F_r = M * g * \cos(\theta) * C_{rr}$
$= 850 * 9.81 * \cos(2.29) * 0.002$

$= 16.66\ N$

$Windage\ resistance\ at\ climbing\ speed\ \left(20\frac{km}{h}\ or\ 5.6\frac{m}{s}\right):$

$F_w = \frac{1}{2} * \rho * A * C_w * V^2$
$= 10.78\ N$

$Now\ we\ can\ find\ the\ total\ resistance\ while\ climbing$

$Total\ resitance\ while\ climbing\ , F_{climb} = F_r + F_w + F_c = 336.58 + 16.66 + 10.78$
$= 364.02\ N$
$Hence, required\ torque\ while\ climbing\ can\ be\ found\ out\ as$
$T_{climb} = F_{climb} * R = 364.02 * 0.27 = 98.28\ N\ m$

Type equation here.
$Now\ we\ shall\ find\ the\ total\ resistance\ on\ ground$
$Rolling\ resistance\ on\ ground = F_{rg} = M * g * C_{rr} = 850 * 9.81 * 0.002 = 16.67\ N$
$Windage\ resistance\ at\ Max\ speed\left(60\frac{km}{h} or\ 16.67\frac{m}{s}\right):$
$F_{w,max} = \frac{1}{2} * \rho * A * C_w * V_{max}^2 = \frac{1}{2} * 1.25 * 1 * 0.55 * (16.67)^2 = 95.52\ N$
$Hence\ total\ resistance\ on\ ground\ becomes$
$F_{ground,total} = F_{rg} + F_{w,max} = 112.19\ N$
$Thus, required\ torque\ on\ ground\ is$
$T_{ground} = F_{ground,total} * R = 112.19 * 0.27 = 30.29\ N\ m$

Now we calculate the required rpm on ground and while climbing.
$Required\ RPM\ at\ maximum\ speed = N_{max} = \frac{V}{R} * \frac{60}{2\pi} = \frac{16.67}{0.27} * \frac{60}{2\pi} = 589.63\ rpm$

$Required\ RPM\ while\ climbing = N_{climbing} = \frac{V_{climb}}{R} * \frac{60}{2\pi} = \frac{5.6}{0.27} * \frac{60}{2\pi}$
$= 189.07\ rpm$

Now motor power can be calculated for both the cases, the higher value shall be the limiting one.

$$Motor\ power\ on\ ground = N_{max} * T_{ground} * \frac{2\pi}{60} = 1867.34\ W$$

$$Motor\ power\ while\ climbing = N_{climbing} * T_{climbing} * \frac{2\pi}{60} = 1938.08\ W$$

Batteries calculation:

Required Voltage = 60 volts

Required Current = 33 amp

Voltage of 1 battery = 12 volts

Current Capacity of 1 battery = 20 ah

After connecting batteries in parallel as we know voltage add up and current remain same so after connecting 5 batteries in parallel:

Total Voltage = 5 * 12 = 60 volts

Minimum ride possible in single charge $= \frac{Ampere\ Hour\ of\ total\ batteries}{Amperes\ required\ by\ motor}$

$= \frac{20}{33} = .606\ h$

As we know, $S = vt$

Maximum distance $_{@maximum\ speed}$ = 60 * 0.606

= 36.36 km

After surveying commercially available motors, we eventually settled for 2000 W BLDC motor model called “Kun-ray MY1020”.

3.4 Motor specifications

Based on our calculations, we determined that our vehicle required a power output of 1921 watts at maximum. The nearest motor option available was to use a 2000 W BLDC motor. This motor was chosen to ensure that we would have sufficient power to operate our vehicle reliably and efficiently. Details of motor are as under in this table:

Table 5: Motor Parameters

Parameter	Value
Model	MOTOR MY1020
Motor Type	High-Speed BLDC brushless Motor
Output /W	2000W
Rated Speed	4500r/min (max:5400RPM)
Weight	about 4KG
Diameter	107mm (AS SIZE PICTURE)
Application Chain	25H/T8F Sprocket/Chain

3.5 Batteries Specification

To power the 60-volt motor, two options were available: using a single power source or creating a battery pack from multiple 12-volt batteries. After considering cost-effectiveness, the latter option was chosen.

To create the battery pack, a total of five 12-volt 20AH lead acid batteries were purchased. While dry batteries were also a possibility, the cost was higher compared to the lead acid batteries. The batteries were then connected in series, resulting in a total voltage output of 60 volts, which was sufficient to run the motor.

Overall, the decision to create a battery pack from multiple lead acid batteries was a cost-effective solution for powering the 60-volt motor. The use of lead acid batteries in the pack allowed for a cheaper alternative to dry batteries, while the series connection of the batteries ensured a sufficient voltage output to run the motor.

3.6 Sensors

Coming towards fault detection mechanism, two fault detection mechanisms are installed on the RPV to ensure that the track is effectively monitored and inspected.

1. Arduino based ultrasonic sensor mechanism:

Arduino UNO and HC-SR04 ultrasonic sensor is installed on the RPV.

Figure 23: An Arduino UNO

Figure 24: HC-SR04 Ultrasonic Sensor

The ultrasonic sensor is connected to Arduino UNO through jumper wires. Moreover, the Arduino UNO is also connected to a datalogger (with SD Card) and a buzzer. The working of this system is quite simple. We have pre-programmed the ideal vertical distance of the vehicle chassis from the rails. When that distance is exceeded, it is taken that an anomaly has occurred in the track profile and hence the buzzer is sounded. Moreover, for every 1 m the vehicle travels along the track, the sensor records 50 values of vertical distance in a text file in an SD card. This valuable data can then be post-processed, and a graph can be made which basically depicts the track profile. This way, track-profilometry can also be done using this vehicle.

3.7 Machine Learning

Detecting faults, such as cracks, on railway tracks is crucial for ensuring safe and reliable train travel. Traditional methods of inspection involve manual inspection by human experts or using specialized equipment, which can be time-consuming, labor-intensive, and expensive. However, with the help of modern technologies such as computer vision and machine learning, it is possible to automate this process and make it more efficient and accurate.

One effective method for detecting cracks on railway tracks is to use OpenCV, a popular open-source computer vision library, with the help of machine learning algorithms. This approach involves capturing video footage of the tracks using a camera with high frames per second (FPS) and then processing the footage using computer vision techniques to detect the presence of cracks.

To implement this method, the first step is to train a machine learning model using a dataset of images that contain examples of cracks. This can be achieved using a platform such as Roboflow, which provides tools for data preparation and annotation. The dataset should include images of different types of cracks, in various lighting conditions, and from different angles to ensure that the model can accurately detect cracks in real-world scenarios.

Once the model is trained, it can be integrated into an OpenCV-based software solution that captures video footage from the camera and processes it. The software solution will analyze the video frames, identify the areas that potentially contain cracks, and highlight them for further inspection by maintenance crews.

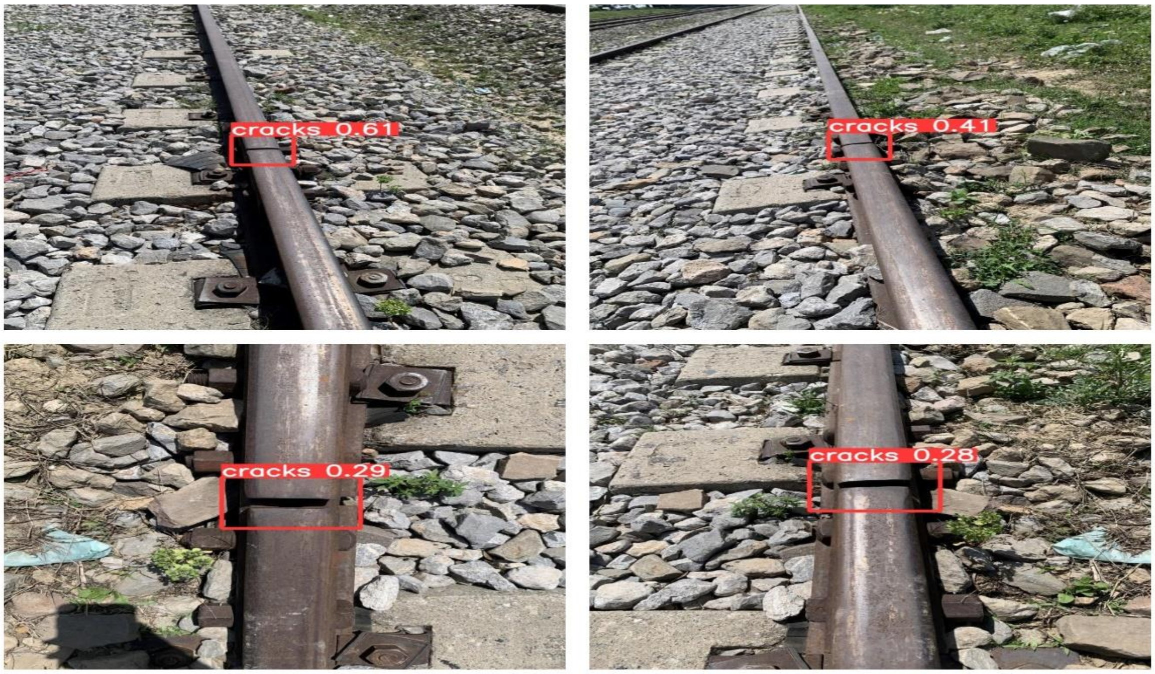

Figure 25: Machine Learning Identifying Cracks on Railway Tracks

3.7.1 Mounting the Drive

```
from google.colab import drive
drive.mount('/content/drive')
```

Mounted at /content/drive

3.7.2 Provide the path to folder inside Drive.

```
%cd /content/drive/MyDrive/ml_models
```

/content/drive/MyDrive/ml_models

3.7.3 Clone the Repository

```
# !git clone https://github.com/ultralytics/yolov5  # clone
```

Cloning into 'yolov5'...

remote: Enumerating objects: 15393, done.

remote: Counting objects: 100% (24/24), done.

remote: Compressing objects: 100% (18/18), done.

remote: Total 15393 (delta 9), reused 17 (delta 6), pack-reused 15369

Receiving objects: 100% (15393/15393), 14.31 MiB | 12.87 MiB/s, done.

Resolving deltas: 100% (10523/10523), done.

```
%cd yolov5
!pip install -r requirements.txt  # install
```

/content/drive/MyDrive/ml_models/yolov5

Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/

Collecting gitpython>=3.1.30

3.7.4 Train Model on Custom Dataset for Cracks

```
# You can change the epochs for better results
!python train.py --img 640 --batch 16 --epochs 10  --data cracks.yaml --
weights yolov5x.pt
```

3.7.5 Inference in test Dataset

```
!python detect.py --weights runs/train/exp3/weights/best.pt --img 416 --conf 0.1 --
source /content/drive/MyDrive/ml_models/test
```

3.7.6 Display the results

```
#display inference on ALL test images
import glob
from IPython.display import Image, display

for imageName in glob.glob('/content/drive/MyDrive/ml_models/yolov5/runs/detect/ex
p/*.jpg'): #assuming JPG
    display(Image(filename=imageName))
    print("\n")
```

3.7.7 Inference on Video

```
!python detect.py --weights runs/train/exp3/weights/best.pt --img 416 --conf 0.4 --
source /content/drive/MyDrive/ml_models/test_vids
```

detect: weights=['runs/train/exp3/weights/best.pt'], source=/content/drive/MyDrive/ml_models/test_vids, data=data/coco128.yaml, imgsz=[416, 416], conf_thres=0.4, iou_thres=0.45, max_det=1000, device=, view_img=False, save_txt=False, save_conf=False, save_crop=False, nosave=False, classes=None, agnostic_nms=False, augment=False, visualize=False, update=False, project=runs/detect, name=exp, exist_ok=False, line_thickness=3, hide_labels=False, hide_conf=False, half=False, dnn=False, vid_stride=1

YOLOv5 🚀 v7.0-140-g1db9533 Python-3.10.11 torch-2.0.0+cu118 CUDA:0 (Tesla T4, 15102MiB)

Flow chart

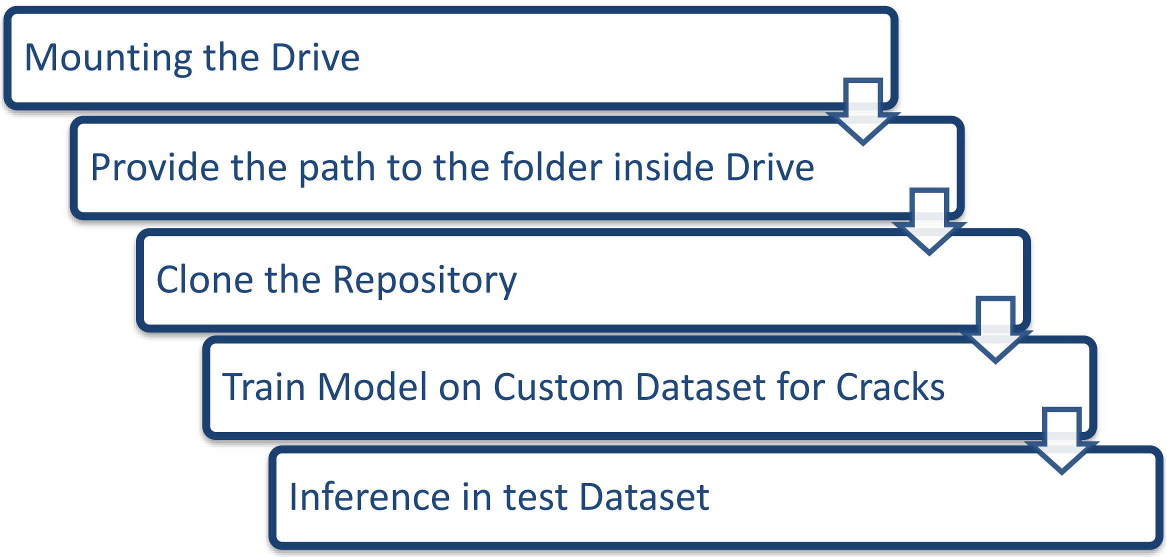

Figure 26: Flowchart Representing Path Followed to Apply Machine Learning

3.8 Analysis:

In this section we shall cover the methods we have used to analyze the components designed by us. As mentioned earlier, instead of discussing the results of analysis, we shall focus more on the methods and techniques used.

1. Mechanical components analysis:

We have analyzed the mechanical components designed using FEA (finite element analysis). For this purpose, the two critical components subjected to this technique, namely the chassis and wheelset were each subjected to the following stepwise:

1. Making of a CAD model
2. Mesh generation
3. Application of boundary conditions
4. Results interpretation

The CAD models were made using Creo software. They were subsequently imported in COMSOL Multiphysics software, which was used to do FEM analysis.

For our study, a physics-controlled mesh is generated. First a benchmark result is calculated using the coarser mesh elements. Once the benchmark results are obtained, the mesh element size is decreased consistently to study the effect of change in mesh size on the convergence or divergence of the results to benchmark value. Moreover, finer mesh elements are used at sharp edges and contours to cater for stress concentrations.

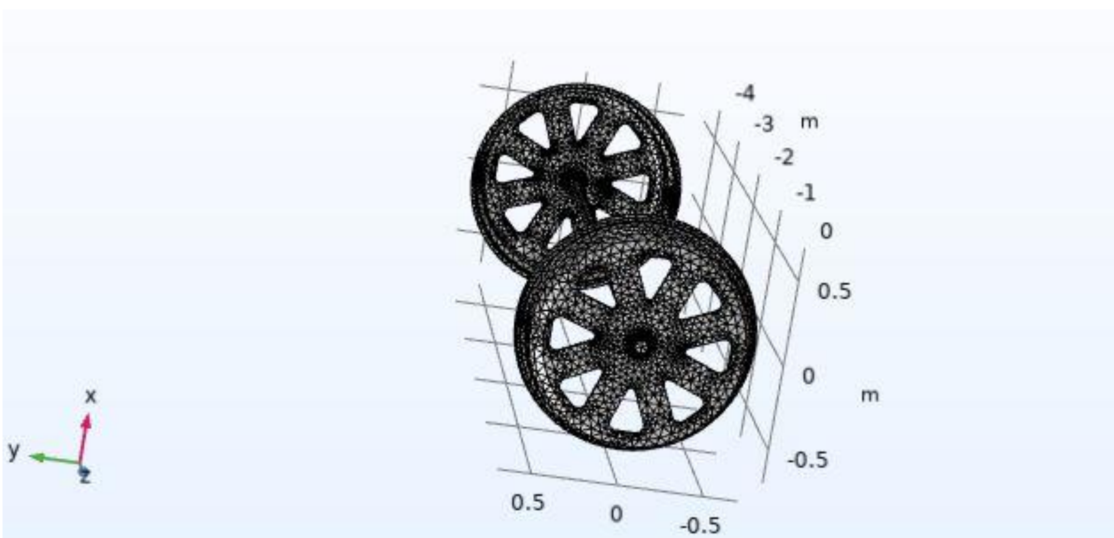

Figure 27: Meshing Applied on the Wheelset

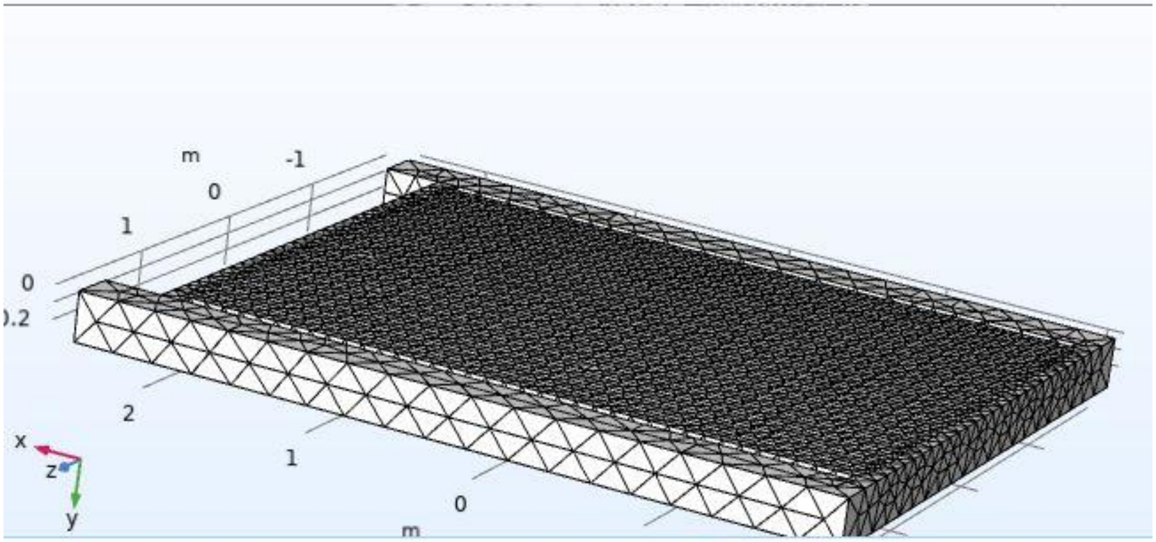

Figure 28: Meshing Applied on the Platform Chassis

As evident in the above pictures, we can see that hybrid mesh size is being used to ensure that both computational power and accuracy remain up to the mark.

Next step is the application of boundary conditions. Applying and correctly applying boundary conditions in Finite Element Analysis (FEA) is of utmost importance for accurate and reliable simulation results. Boundary conditions define the behavior of the system under analysis and ensure that the model represents real-world conditions. By accurately capturing the constraints and loading conditions, boundary conditions help in simulating realistic responses and predicting the structural behavior under different scenarios. Incorrectly applied boundary conditions can lead to erroneous results, compromising the validity of the analysis. Properly defined and applied boundary conditions ensure that the FEA model represents the physical system accurately and enable engineers to make informed design decisions, optimize structures, and ensure safety and performance.

Therefore, we have strived to replicate the actual conditions in applying boundary conditions. The boundary conditions applied on the chassis are:

1. Fixed constraint:
   The chassis movement is locked in the direction of movement of vehicle. However, it is **not** fixed in the vertical direction, and we need to keep it unconstrained vertically to learn the deflection that might occur vertically.

2. Applied loads:
   We have applied vertically and horizontally the forces that are exerted on the chassis. Vertical forces include the weight of the payload and the bench, while horizontal forces include the jerk that might be exerted when the vehicle is brought to a sudden halt or suddenly started.

Similarly, the boundary conditions applied to wheelset include:

1. Fixed constraint: Movement of the wheels with respect to one another and the axle is fixed.

2. Applied loads: The loads applied are treated as concentrated loads being applied on the axle edges.

4. CHAPTER 4: RESULTS AND DISCUSSIONS

Results and discussions mostly pertain to the mechanical testing and secondly to the sensors' part.

4.1 Mechanical:

Results of the FEM analysis of chassis and the wheelset are presented below.

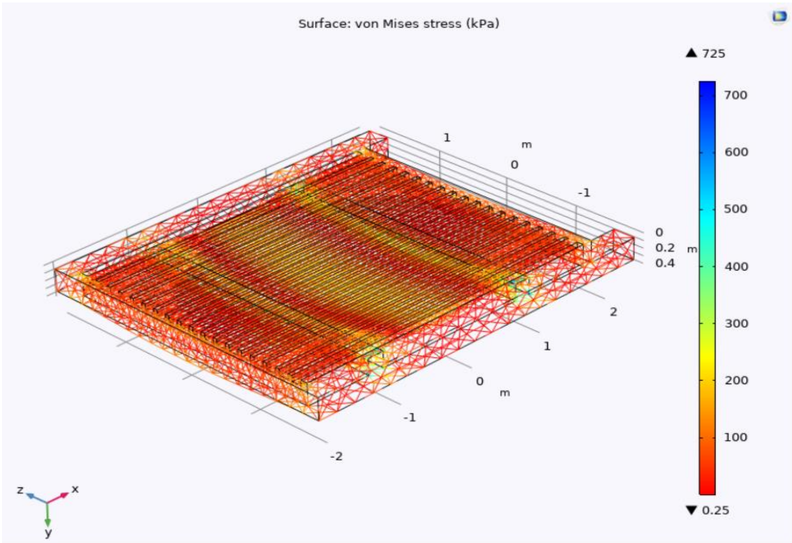

Figure 29: Finite Element Analysis of Chassis

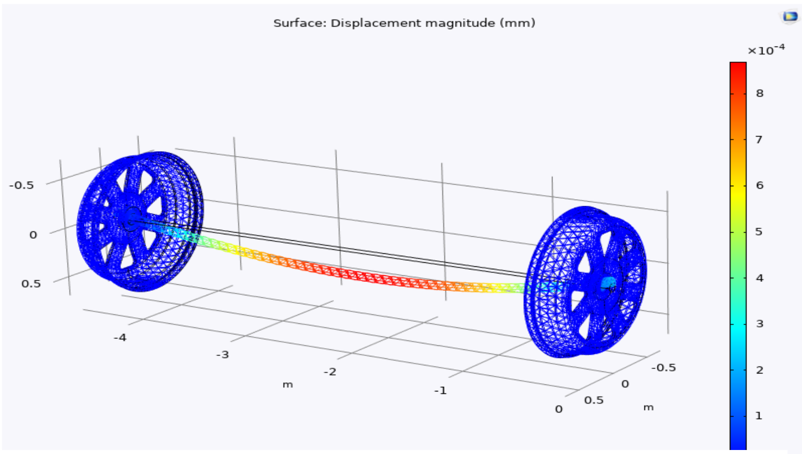

Figure 30: Finite Element Analysis of Chassis

The FEM analysis conducted on the chassis of the railway patrolling vehicle yielded valuable results in terms of Von Mises stress and modal frequencies. Von Mises stress is a widely used measure in FEM analysis to assess the structural integrity and failure potential of a component. It combines the effects of normal and shear stresses to provide a single scalar value representing the equivalent stress state. By examining the Von Mises stress distribution across the chassis, we can identify areas that experience high stress concentrations and potential failure points.

In the case of the railway patrolling vehicle chassis, it is crucial to ensure that the Von Mises stress values remain below the failure stress of the material, considering the material used is wood. By comparing the Von Mises stress obtained from the FEM analysis with the material's failure stress, we can evaluate the structural robustness of the chassis. The fact that the Von Mises stress values are below the failure stress threshold indicates that the chassis design can withstand the applied loads and operating conditions without experiencing material failure.

Additionally, the FEM analysis provided modal frequencies of the chassis, which are essential for assessing the dynamic behavior of the structure. Modal frequencies represent the natural frequencies at which the chassis vibrates when excited by external forces. It is crucial to ensure that the modal frequencies of the chassis do not coincide with the operational frequencies of the motor installed in the vehicle. Resonance between the motor's frequencies and the natural frequencies of the chassis can lead to excessive vibrations, compromising the vehicle's performance, stability, and overall structural integrity.

By analyzing the modal frequencies, we can identify any potential resonance issues and make design adjustments if necessary. The goal is to ensure a sufficient separation between the modal frequencies and the motor's operating frequencies, thereby minimizing the risk of resonance. This ensures the chassis remains stable and does not experience excessive vibrations that could negatively impact the vehicle's functionality and structural integrity.

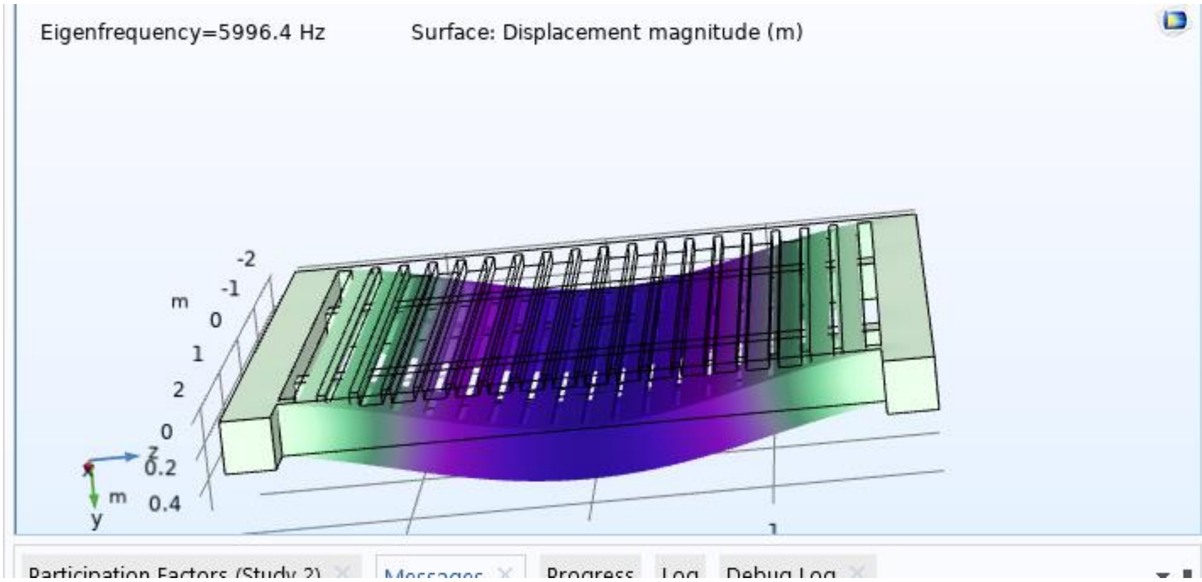

Figure 31: Surface Displacement of Chassis

In conclusion, the FEM structural railway patrolling vehicle chassis provided valuable insights into the structural behavior and performance. The examination of Von Mises stress distribution allowed us to identify areas of potential concern and verify that the stress values remain below the material's failure stress for the chosen wood material. The evaluation of modal frequencies helped ensure that the chassis does not resonate with the motor's operating frequencies, thereby ensuring stability and performance. These results guide the design process, ensuring the chassis is robust, reliable, and capable of withstanding the operational loads and vibrations encountered during railway patrolling operations.

4.2 Wheelset:

The FEM analysis conducted on the wheelset of the railway vehicle aimed to assess its structural integrity and evaluate its ability to withstand specified loading conditions. This analysis involved applying loads representative of the operating conditions and evaluating various parameters to ensure the wheelset's performance and reliability.

One of the key parameters examined in the FEM analysis was the von Mises stress distribution within the wheelset. The von Mises stress is a scalar value that combines the effects of normal and shear stresses, providing a measure of the equivalent stress experienced by the material. By analyzing the von Mises stress distribution, we could identify regions of high stress concentration that may indicate potential failure points within the wheelset.

The results of the analysis indicated that the von Mises stress values in the wheelset were well below the material's failure stress. This finding suggests that the wheelset can withstand the specified loading conditions without experiencing material failure. It provides confidence in the structural integrity of the wheelset and assures its ability to carry the required loads safely.

Additionally, the FEM analysis considered other critical factors such as deformation and displacement. By examining these parameters, we gained insight into the behavior of the wheelset under loading conditions. It allowed us to assess the magnitude and distribution of deformations, ensuring that they remained within acceptable limits and did not compromise the overall performance and functionality of the wheelset.

Furthermore, the analysis included a study of the contact pressure between the wheelset and the rail. The contact pressure distribution is crucial for ensuring effective load transfer and minimizing wear and damage to both the wheelset and the rail. By examining the contact pressure distribution, we could identify any areas of excessive pressure or uneven loading, which could lead to premature wear or failure. Adjustments and optimizations could then be made to improve the contact pressure distribution and enhance the longevity and reliability of the wheelset.

Overall, the FEM analysis provided valuable insights into the structural behavior of the wheelset under specified loading conditions. By considering parameters such as von Mises stress, deformation, displacement, and contact pressure, we could assess the wheelset's performance and confirm its ability to withstand the applied loads safely. The analysis results guided design decisions, allowing for improvements in load distribution, material selection, and overall wheelset design. This ensured a reliable and robust wheelset that meets the required performance and safety standards in railway operations.

In conclusion, the FEM analysis conducted on the wheelset of the railway vehicle demonstrated its ability to withstand specified loading conditions without failure. The examination of von Mises stress, deformation, displacement, and contact pressure provided valuable information on the structural behavior of the wheelset. The analysis results guided design improvements and optimizations, leading to a reliable and efficient wheelset design that ensures safe and efficient railway operations.

4.3 Sensors

Results of ultrasonic sensors are:

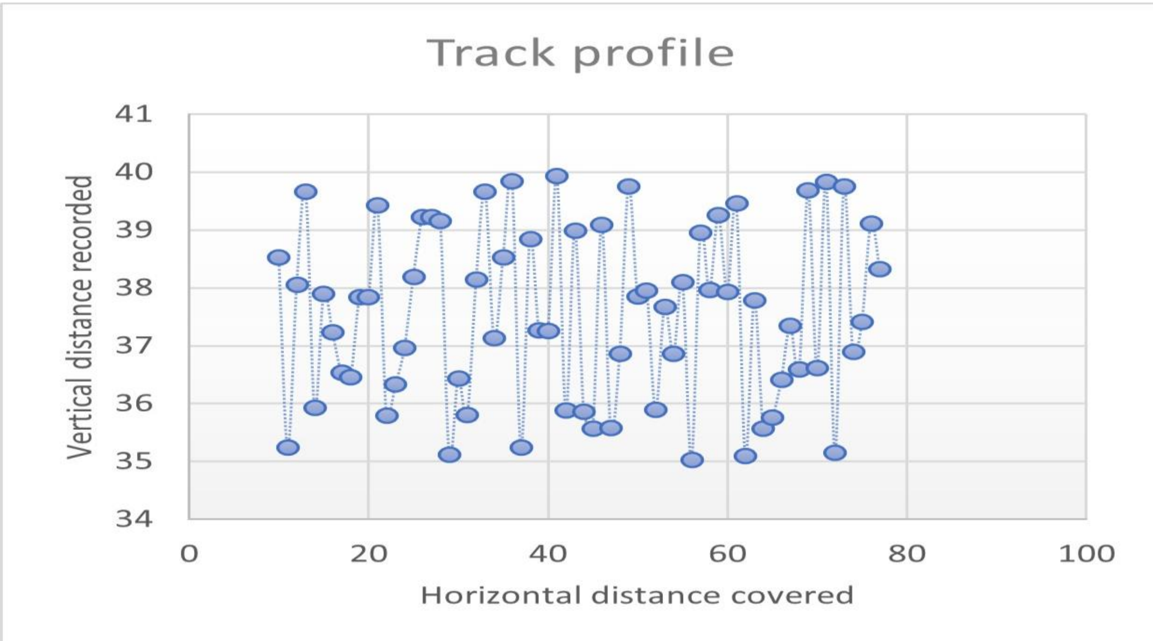

Figure 32: Graphical Repesentation of Track Profile

The ultrasonic sensor is utilized to detect the track profile by emitting sound waves and measuring the distance they travel. It is mounted on the chassis at a height of 35cm with a tolerance of 5cm. If the measured value exceeds this limit, an alert is triggered, indicated by a buzzer sound, signaling the presence of a crack or an object on the railway track. This system ensures timely notification and enhances safety during patrolling operations.

4.4 Machine learning

Crack detection relies on the powerful capabilities of OpenCV, a computer vision library. To facilitate this process, a camera is strategically mounted on the chassis, facing downwards towards the track. The camera diligently records video footage, capturing the surface details for analysis. The recorded video is then passed through the implemented code, which leverages OpenCV's algorithms and functions. This code meticulously examines the video frames, seeking out any visible cracks or anomalies on the track surface. Through advanced image processing techniques, the code identifies and distinguishes cracks from the surrounding area. The crack detection algorithm then generates precise and accurate results, indicating the presence and locations of any cracks detected. This method offers a reliable and efficient means of monitoring the condition of the track, enabling prompt maintenance and safety measures. By employing OpenCV's comprehensive features and the camera's perspective, the system ensures effective crack detection and evaluation. Results are as under:

Figure 33:Machine Learning Results

Overall, this setup provides a valuable tool for maintaining track integrity and ensuring optimal safety for all users.

5. CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion:

In conclusion, this project successfully addressed the challenge of limited functionality and budgetary constraints in developing a railway patrolling vehicle. The working prototype of the electric vehicle demonstrated the feasibility of integrating commercially available components to detect faults and improve overall performance. This project also highlights the importance of innovation and creative problem-solving in developing practical solutions for real-world problems. Overall, this project represents a significant step towards improving the safety and efficiency of railway patrolling vehicles and serves as an example of how innovative thinking can lead to practical and impactful solutions.

5.2 Recommendations:

Our project successfully achieved its goals of developing a functional railway patrolling vehicle within a limited budget, utilizing commercially available components. However, there are some limitations that were encountered during the project, such as the vehicle's limited speed and range. These limitations can be addressed by replacing the current batteries with higher ampere hour batteries to increase the distance it can cover and the speed at which it can operate.

Moving forward, there are several recommendations that can be implemented to enhance the functionality and reliability of the vehicle. For instance, a full covered body can be added to make the vehicle suitable for use in tough weather conditions. Additionally, disc brakes can be used to improve the braking system, ensuring the safety of the vehicle and its occupants.

Another potential improvement could be the addition of solar panels to charge the batteries, making the vehicle more environmentally friendly and reducing the need for frequent battery charging. Moreover, adding cameras for back vision can enhance the safety and maneuverability of the vehicle.

Finally, integrating cameras for AI fault detection can further improve the vehicle's functionality by allowing for real-time fault detection and preventative maintenance. These recommendations have the potential to significantly enhance performance.

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6. APPENDIX I: ARDUINO EQUIPMENT AND CODE

Arduino based ultrasonic sensor mechanism:

Arduino UNO and HRC SR-04 ultrasonic sensor is installed on the RPV.

Figure 34: Arduino

Figure 35: Ultrasonic Sensor

Arduino code:

```
#include <Wire.h>

#include <SD.h>

const int triggerPIN=4;

const int echoPIN=3;

const int chipSelect=10;

int distance;

long duration;

unsigned long microsecs;

unsigned long seconds;

void setup() {

  Serial.begin(9600);

  // put your setup code here, to run once:

   if (!SD.begin(chipSelect)) {

      Serial.println("Card failed, or not present");

      // don't do anything more:

      return;
```

```
  } else
  Serial.println(F("Card initialized!"));
}
void loop() {
 microsecs=micros();
 delay(1000);
 seconds=microsecs/1000000;
 // put your main code here, to run repeatedly:
 distance=getDistance();
 File dataFile = SD.open("times.txt", FILE_WRITE);
 Serial.print(distance);
 Serial.print(F(" cm at "));
 Serial.print(seconds);
 Serial.print(F(" \n"));
 if (dataFile) {
  dataFile.print(distance);
  dataFile.print(F(" cm at "));
```

```
    dataFile.print(seconds);
    dataFile.print(F(" \n"));
    dataFile.close();
  }  }
int getDistance () {
    digitalWrite (triggerPIN, LOW);
    delayMicroseconds (2);
    digitalWrite (triggerPIN, HIGH);
    delayMicroseconds (10);
    digitalWrite (triggerPIN, LOW);
    duration = pulseIn (echoPIN, HIGH);
    distance = duration * 0.034 / 2;
    return distance;
}
```

7. APPENDIX II: ENGINEERING DRAWINGS

To design a railway patrolling vehicle, crucial parameters like chassis, bench, axle, and wheelset must be considered. These components play a vital role in ensuring the vehicle's performance and functionality. Detailed drawings are available for reference to facilitate the design process. By carefully designing each parameter, an efficient and reliable patrolling vehicle can be developed for railway maintenance and monitoring.

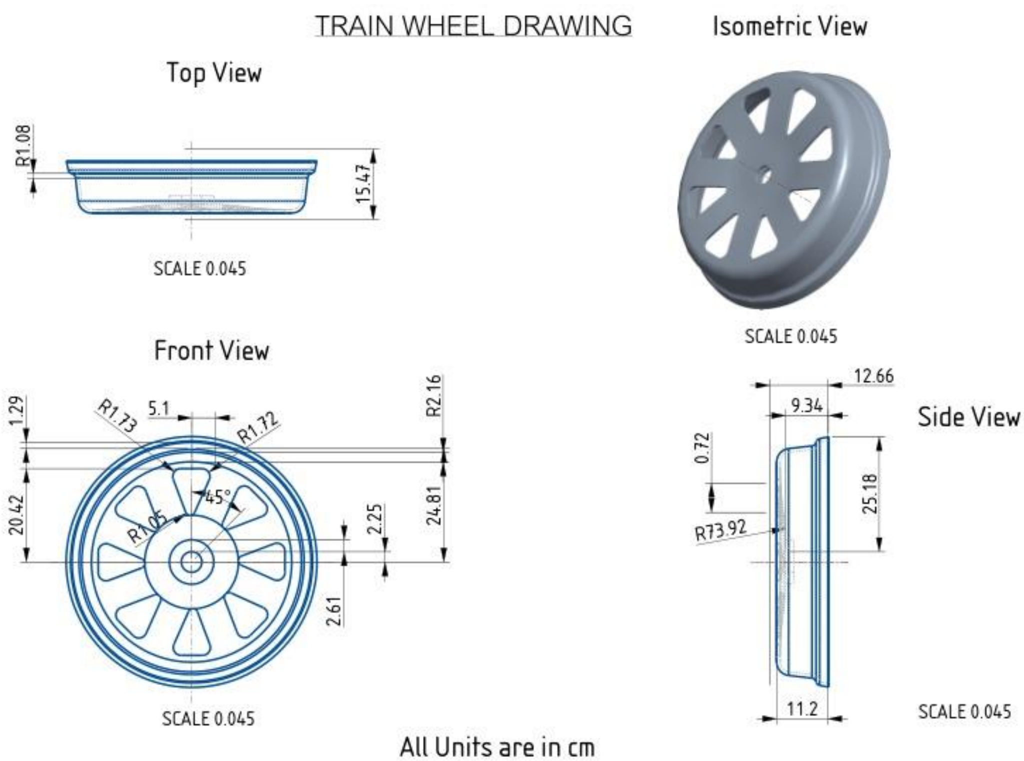

Figure 36: CAD Drawing of the Wheel

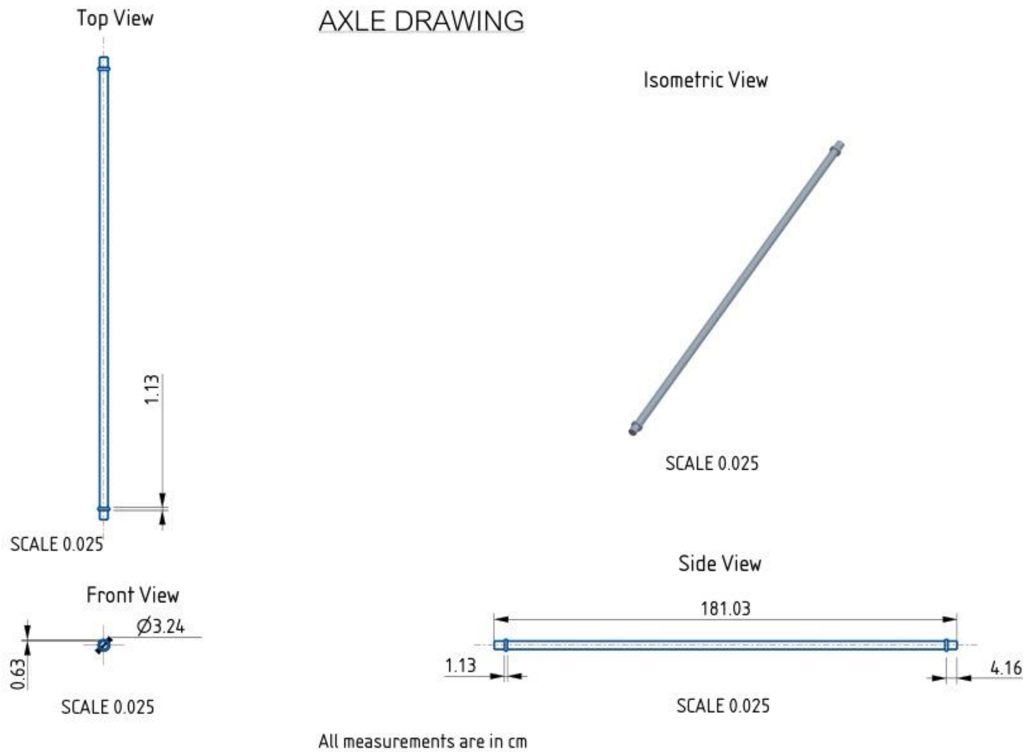

Figure 37: CAD Drawing of the Axle

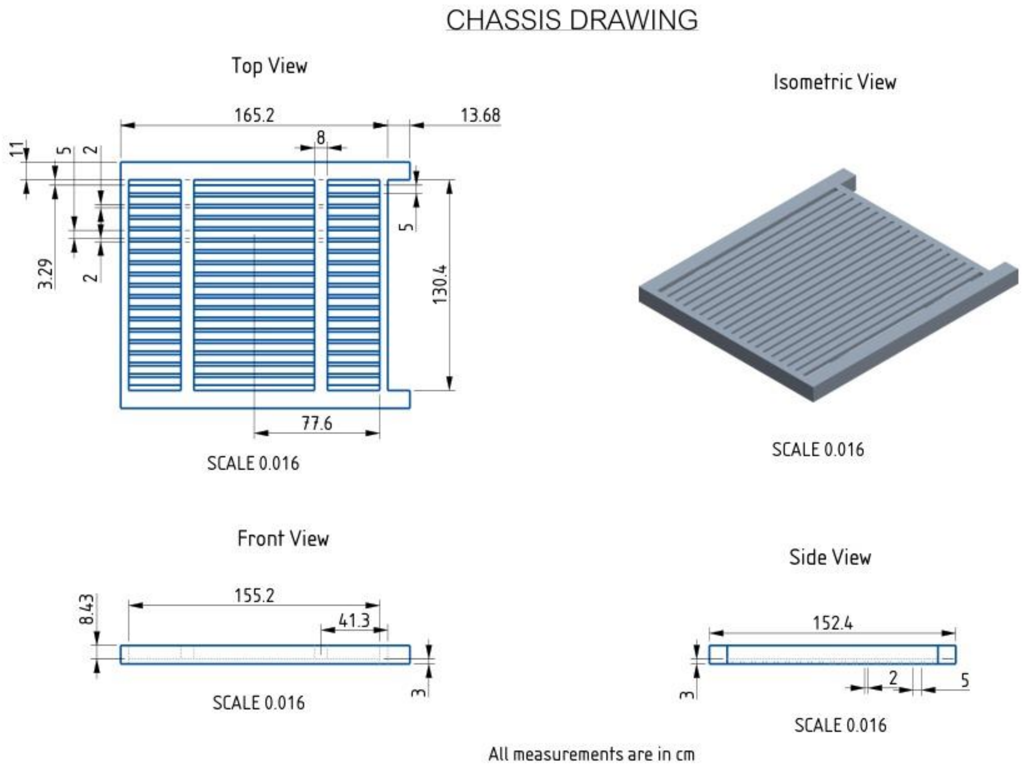

Figure 38: CAD Drawing of the Chassis

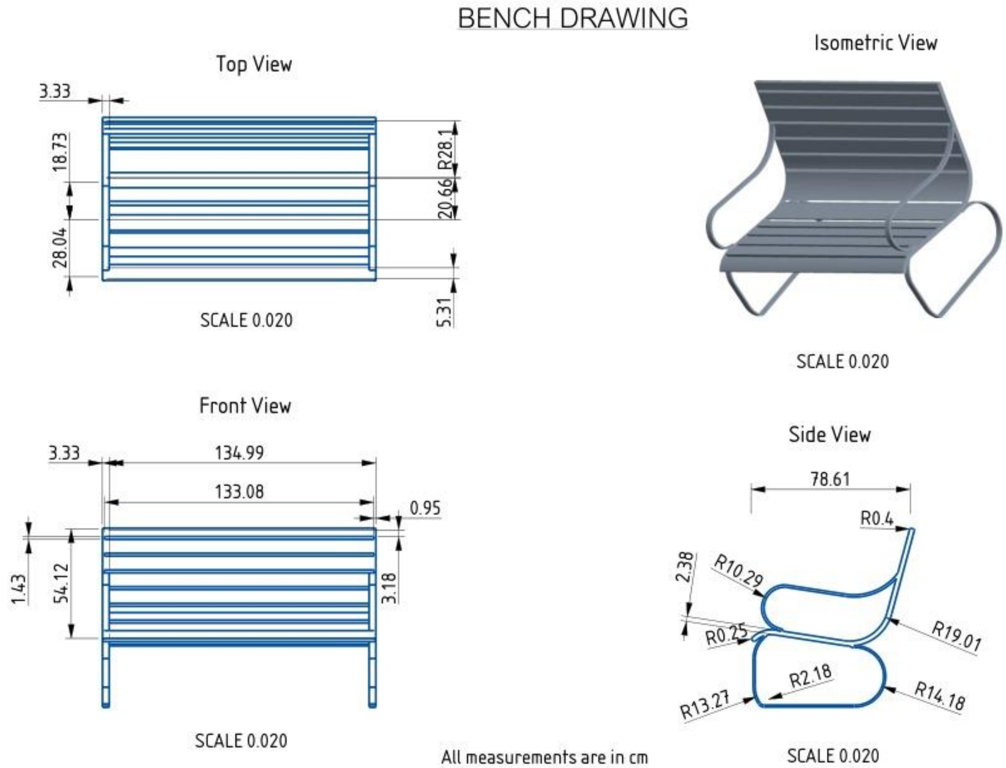

Figure 39: CAD Drawing of the Bench