CHAPTER 1
Introduction and Literature Review

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1.1 Introduction

As per the Indian government data, Indian Railways is 4th in the world's top 5 rail networks [1]. Railways have been the preferred mode of transportation for passengers and freight due to its reliability and affordability. Historically, track maintenance was done manually, which was labor-intensive and time-consuming. Manual methods faced challenges like difficulty in handling heavy track construction, limited working hours due to frequent train operations, safety concerns for maintenance crew and inconsistent quality of work. Mechanization of track maintenance in Indian Railways has changed the traditional way of managing railway infrastructure. For decades, track maintenance used to depend on manual effort, and the work was time-consuming; teams of trackmen performed tasks like inspecting, aligning, and replacing worn-out components. Though this process ensured maintenance of operational standards, its inherent limitations were observed in terms of speed, accuracy, and scalability. Indian Railways has ordered various mechanized solutions to address these problems. Its jobs, hitherto done purely manually, are being undertaken by the latest technologies such as Track Relaying Trains and Continuous Track Renewal Trains. Such equipment will lift, place, and lock tracks in positions no human could ever reach out for in a single day to cover a distance running into kilometers. The other important mechanized maintenance equipment are tamping machines & Ballast Cleaning Machines. Tamping Machines are used to pack ballast under railway tracks & Ballast cleaning Machines are used to screen the ballast. As opposed to manual packing, these machines use hydraulic arms to ensure uniform compaction of the ballast and prevent track misalignment while improving ride comfort and safety. Additional features of ballast cleaning machines include clearing debris and reviving the effectiveness of the ballast layer, as this is a critical role for drainage and stability purposes. Mechanizing this will enable Indian Railways to cut down on the time spent on ballast cleaning while increasing the durability of tracks. It further accelerates track maintenance activities with fewer manual interventions as the mechanized process increases less risk to worker safety [1]. The mechanized methodology will assist Indian Railways in maintaining more frequent and effective maintenance in alignment with the railway's goal to deliver safer and more dependable services. With continuous investments in advanced machinery and processes that are mechanized, the Indian Railways is erecting a modern and effective infrastructure that will cater for growing passenger and freight loads. Indian Railways has been adopting advanced equipment to help its workforce, minimize human error and streamline the process. The aim of upgrading the maintenance process is to upgrade technology and techniques and ultimately improve asset productivity, performance and reliability. The implementation of technology will enhance the dependability of motive power and rolling stock. Improved maintenance practices for tracks will also enhance train operating safety and reduce overall maintenance requirements.

Indian government is actively working to indigenize the maintenance machines which were being imported from foreign companies as the import cost was a huge burden [2]. To address this, efforts are being made to develop domestic track maintenance machines. Commonly used maintenance machines are:

i. Track Tamping Machines (for maintaining rail track geometry)

ii. Ballast Cleaning Machines (for regulating and cleaning the ballast)

Indian railways is suffering from heavy load due to its large rail network. The average number of trains running on a railway track and the total load on a single train whether it is a passenger or goods train is very high. This results in heavy dynamic forces, acting on a railway track. Due to heavy dynamic forces, in general, two types of faults happen on railway tracks:

i. Longitudinal

ii. Alignment

In longitudinal fault, the railway track goes down to its normal position in Y-axis direction as shown in fig.1.1 In alignment fault rail goes left or right from a straight line in Z-axis direction as shown.

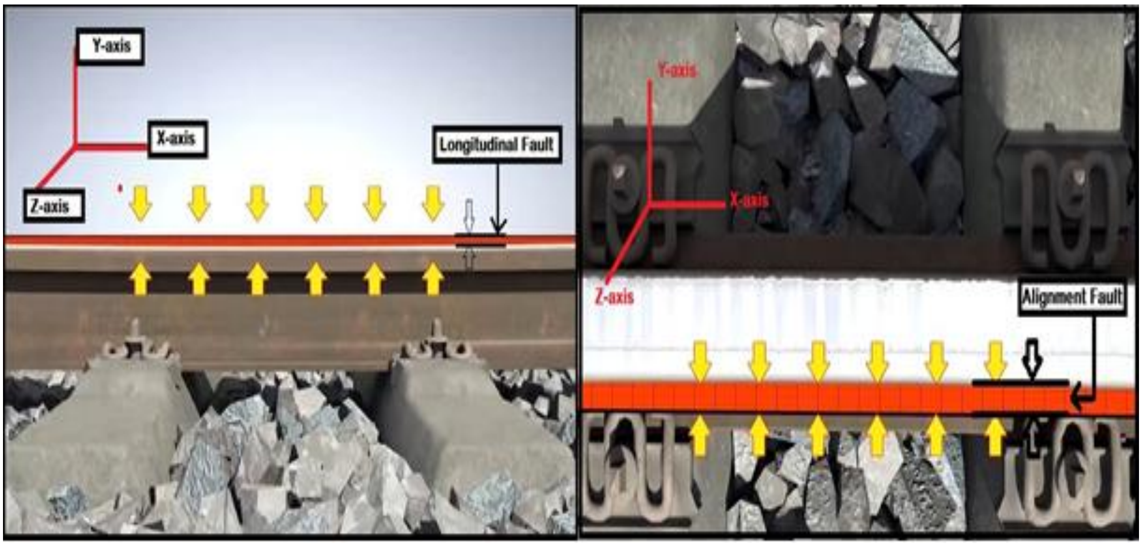


Fig.1.1: Railway Track Geometry Faults.

Above two faults are very serious and lead to accidents which may cause risk of life of human beings. Therefore, it is important to regularly check and to correct the fault. Many railway ballast reaction parameters may be acquired throughout the simulation procedure. The study investigated the permeability of ballast beneath railway sleepers during construction, since it can influence the carrying limit and stability of railway tracks. The permeability of railway ballast in different places varies throughout the tamping procedure. As part of this study, we used the simulation during the cleaning process to identify the permeability of railway ballast at the defined location, which is indicative of the evolution of the porosity of ballast beneath the middle sleeper during the tamping process. It deals with various types of machines for maintaining the railway track geometry by packing the ballast under the railway track. For effective machine operation, at least buffer of 150 mm of clean ballast should be there. For the necessary lift (around 20 to 25 mm in every tamping work) and packing retention following tamping, there should be enough ballast in the shoulders [3].

These loads are transferred by ballast from the sleeper to a large area of formation. Ballast is normally made up of crushed rocks with different particle sizes. It transfers the load from sleeper to subgrade and organizes it in a uniform manner as shown in fig. 1.2. When the train passes, it holds the sleepers in a firm position. It increases the elasticity of the railway track. It is designed to prevent longitudinal and lateral movement of sleepers.

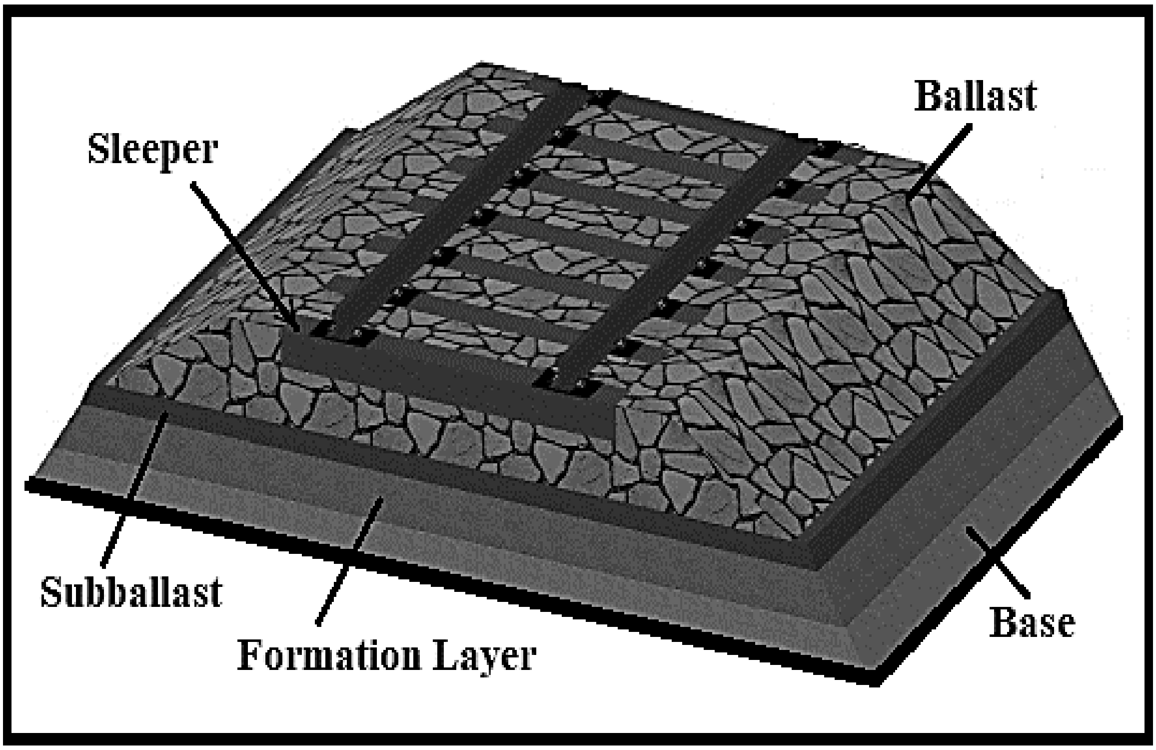


Fig.1.2: Railway ballast & track geometry

1.2 Machines for Ballast Cleaning & Handling

During various maintenance and renewal operations, ballast is handled by ballast cleaning and handling machines. By excavating existing crushed ballast and reinstalling clean ballast on the track while also getting rid of muck, the Ballast Cleaning Machine screens the entire cross-section of track ballast.

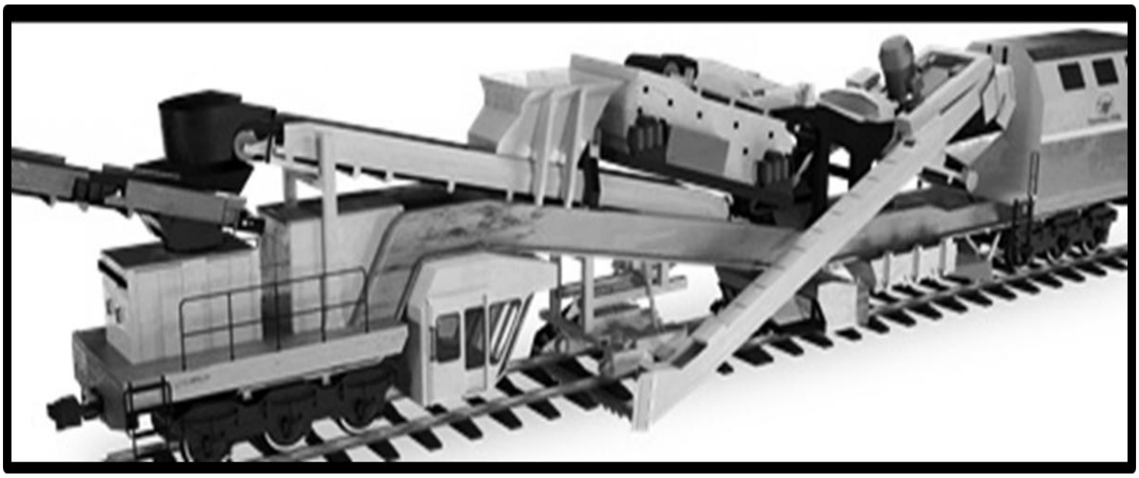


Fig.1.3: Schematic view of ballast cleaning machine

This enhances track resilience, drainage, and ballast bed elasticity. Shoulder Ballast Cleaning Machines clean only the shoulder ballast (outside the sleeper edge) by excavating, screening, and removing muck to improve track drainage as shown in fig. 1.3. Ballast Regulating Machines redistribute and profile the ballast along the track for optimal support. BCM loosen and excavate fouled ballast from the track's full cross-section including cribs, below sleepers, and shoulders [3]. Using an endless cutter chain, they collect and transfer ballast to vibrating screens that separate out muck, which is disposed of via a waste conveyor. Clean ballast is again returned to the track through a conveyor. Main Functions of BCM:

- Remove muck from the track and screen ballast that has become fouled.
- Boost the resilience of the ballast bed by restoring a clean ballast layer.
- Create a cross slope to ensure correct formation. Improve track drainage.

1.3 The main components of a typical Ballast Cleaning Machines:

Although a typical Ballast Cleaning Machine consists of many components, but some major components are given below:

- Engine: It is powered by two separate, air-cooled diesel engines. While the rear engine handles traveling propulsion and powers the excavation chain and screen drives, the front engine pumps hydraulic pumps for lifting mechanisms, conveyor belts, and propulsion [4].
- Excavating Unit: Equipped with an endless cutter chain of carbide/steel scraper blades. This chain excavates the ballast under the sleepers and along the shoulders, guiding it to the screening unit. The unit allows precise depth and slope adjustments for effective excavation and drainage.
- Screening Unit: A 21 m^2 screen with three mesh sizes (30 mm, 50 mm, and 80 mm) for grading ballast. It separates oversized ballast and removes muck, which is directed to waste conveyors. The system can be adjusted for super-elevated curves.
- Conveyor System for Ballast and Muck: Clean ballast is channeled back onto the track via distribution conveyors, while muck is moved away on an adjustable conveyor. The muck conveyor can be positioned horizontally and vertically to dispose of waste up to 7.5 meters from the track.
- Rail Track Lifting Unit: Modifies the depth of excavation and steers clear of track obstructions.
- Recording Unit: The latest BCM models (e.g., RM80 92U) include computerized recorders that log cross-level and longitudinal-level data before and after ballast excavation.
- Direct Brake: Operates while running controlled by hand valves on each driving

seat.

- Indirect Brake: Used when coupled with a coach or wagon, controlled by cabin valves.
- Emergency Brake: Engaged in emergencies, activated when connected to a KE valve.
- Parking Brake: Hand-operated for stable positioning.
- Safety Brake: Automatically applied when pressure of air falls below 3.5 bar.

1.4 Classification of BCM on Indian Railways tracks

Indian Railways utilizes three primary types of ballast cleaning machines for track maintenance, each with specialized features for different track configurations [5]:

1. Plain Track Ballast Cleaning Machine (RM80)

   It is manufactured by Plasser India and designed exclusively for deep screening on plain track sections; it cannot operate on turnouts. It has an excavating chain featuring scraper blades and five scraping fingers.

2. Ballast Cleaning Machine for Points and Crossing (RM76)

   It is Suitable for deep screening of both plain tracks and points and crossings without requiring dismantling of components. It includes a provision to extend the cutter bar using up to eight extension pieces (500 mm each), allowing a maximum 7.72 m width excavation. Scraper blades on this machine have two scraping fingers.

3. Plain Track & Points and Crossings Ballast Cleaning Machine (RM80 92U)

   It is similar to the RM76, with the added capability to manage heavier track structures. Using seven extension pieces, it reaches an excavation width of 7.78 m. Scraper blades have five scraping fingers for enhanced ballast removal.

1.5 Working Principle and Capabilities of BCM

Basic working principles of a BCM are as given below:

- Excavation Process: The machine's pentagon-shaped excavating chain digs through the ballast bed, transporting the ballast and debris to a screening unit via chain guides. Linear vibration from the screen separates clean ballast from muck, which is then discarded via a slew able waste conveyor belt. Clean ballast is redistributed over the ballast profile using a system of conveyor belts.
- Width of Excavation: Excavation should ideally span the full width of the ballast bed to ensure proper drainage. Cutter bars of 2150 mm and 1950 mm allow for cutting widths of 4282 mm and 4030 mm, respectively. For constrained spaces, such as bridge locations, the cutter bar's elbow can be folded to reduce required width from approximately 5000 mm to under 4500 mm. For points and crossings, additional 500 mm extension pieces increase the excavation width up to 7.78 m.
- Excavation Depth: The cutter bar typically cuts about 280 mm deep. With the bar positioned 20 mm below the sleeper, the total excavation depth reaches approximately 300 mm, which can be adjusted by lifting the track during screening to avoid damaging the formation layer.
- Track Lifting and Slewing: Machines on Indian Railways can lift the track up to 100 mm and slew it laterally by ±300 mm in one pass.
- Muck Disposal: Thanks to the waste disposal conveyor belt, which swings 70 degrees in each directions and extends up to 5 meters from the track center, muck can be disposed of at roughly 7.5 meters along the cess.
- Screening Capacity: Machines can handle up to 550 cubic meters of ballast per hour. Reduced longitudinal movement speed may be necessary to ensure thorough screening in tracks with higher ballast volumes.

- Controlled Ballast Distribution: A distribution conveyor belt that sways laterally to guarantee uniform ballast placement returns screened ballast to the track. Ballast placement is adjusted by guide plates above the screen, particularly for curved tracks.
- Total Excavation Capability: By pulling back the ballast guide plate, the BCM can get rid of both ballast and muck at once. This way, the excavated material will fall straight onto the main conveyor belt and then outside the track.
- Screening of Points and Crossings: For deep screening, RM76 and RM80-92U models can increase the cutting width using 500 mm extension pieces attached on the right-hand side of the machine's working direction. To ensure even track resilience, any unexcavated areas should be completed manually to prevent running deterioration.

Each machine is optimized to maintain ballast quality and track integrity, providing Indian Railways with the necessary tools to sustain safe and efficient train operations across diverse track configurations [6].

During, before & after the installation of ballast cleaning machines, a number of tasks must be completed. Generally, a DTS and a tamping machine should be used in the same block as the ballast cleaning machine. To efficiently manage the track's length under speed restrictions, it is recommended to use a DTS, at least one tamping machine, and several BCMs. To guarantee adequate planning and execution of all activities prior to, during, and following the work, the best working plan for deploying multiple BCMs should be decided upon beforehand and shared with all pertinent parties. To ensure high-quality work, it is crucial to plan ahead and fulfill requirements before screening the track ballast [7]. A thorough project report that addresses the following process and takes into account location-specific requirements should be written. In order to determine the needs for ballast recoupment, a field survey should be carried out to evaluate the track's current profile, formation, and availability of clean and caked ballast cushion. In accordance with the pertinent clauses in the Indian Railways Permanent Way Manual and Schedule of Dimensions, the suggested longitudinal profile should be completed. Either by hand or with the aid of the proper software, a longitudinal section showing the formation level, current rail levels, and proposed rail levels should be plotted on graph paper [8]. A channel under the track may need to be made by the cutter bar if the total (clean and caked) ballast cushion is less than 250 mm. Thus, it is best to avoid cutting the formation. Cutting the formation should therefore be avoided. In order to avoid cutting the formation during operation, the BCM has the ability to raise the track up to 100 mm either permanently or temporarily if the cushion is not enough. Lifting will require evaluation and careful thought. The proposed lifting must be taken into consideration when calculating the total ballast requirement. It's crucial to use permanent reference pillars to indicate the start and finish of transitions as well as circular curves [9]. The track should have these pillars spaced every 30 meters, and their alignment and levels should be recorded for future use. Overhead equipment masts should be recorded with the intermediate pillars since they can also be used as reference points. A foot-to-foot survey of the section should be conducted to evaluate the state of the track's components and the amount of land available for muck disposal. The main goal should be to locate any visible or hidden obstacles along the track that are within a 4500 mm width. This can be accomplished by looking up information on boulders or rubble that has been disposed of for breach restoration in the section register and by looking for cables, rail pieces, signals, and other foundations. This will assist in organizing steps to remove obstacles, guaranteeing a working environment free of obstacles and the best possible BCM output.

If the track cannot be temporarily slewed, any encroaching pucca drain walls should be disassembled.

It will be necessary to combine machine operations in those areas with manual labor if some obstacles cannot be removed. All damaged and broken sleepers ought to be swapped out. When necessary, hogged or battered joints should be addressed by end cropping or reconditioning. Before or while the machine is operating, approaches to bridges that the machine is unable to screen should be manually screened. All parties involved must be informed of the specifics of the plan, including the number of BCM and other machines to be deployed, their stabling locations, the station from which they will travel to the work site, the station to which they will return after the work is completed, the length of blocks, and lighting arrangements for night work [10]. Line blocks and other details must be planned and arranged by the operating department to guarantee the best possible use of the tamping machines. OHE staff availability is the responsibility of the electrical department. Providing signal personnel for disconnection, reconnection, and other duties as needed, particularly for cable protection, axle counter removal and refit, and screening points and crossings, is the responsibility of the S&T (The Signal and Telecommunication) department. As BCM advances, make sure that sufficient plans are in place for a consistent supply of ballast and training. Before deep screening starts, the ballast pockets that are out of the cutter chain's reach should be drawn within its cutting width. To enable the cutting chain to move freely in electrified sections, the distance between the track center and the mast foundation must be precisely measured. It is best to temporarily remove any cables, signal rodding, or OHE connectors that could interfere with the work. To make it easier for machines to operate, level crossings should be opened beforehand. Any obstacles in the cutting zone on the level crossing road should be located and removed before the block. At the level crossing, sleepers should be set up to replace any that aren't working. During ballast excavation, sleepers must have all fittings in place to avoid any coming loose and getting in the way of the cutter chain. To cut through any obstacles that could entangle and obstruct the cutting chain, such as rail pieces, pipes, or buried foundations, gas cutting equipment and a concrete breaker should be on hand. When working in station yards with numerous lines, cuttings, or tunnels where it is impractical to dump spoil along the cess, spoil disposal units—a unique kind of wagon—should be ready to be attached to the machine. Any adjacent track that needs to be used for waste disposal must also be closed to traffic. To make room for the cutter bar to be inserted into the track, a trench that is about 30 cm deep and one meter wide should be made [11]. This can be accomplished by either removing one sleeper or rearranging the sleepers. The Long Welded Rails Manual of Instructions must be followed when working in Long Welded Rail (LWR) territory. Due to the track's significant decrease in lateral ballast resistance following screening, temporary de-stressing at higher or lower temperatures may be required to avoid excessive stress buildup. Before work starts and throughout the project, engineering speed indicators should be positioned and arranged in accordance with IRPWM guidelines. Making sure S&T and electrical personnel are available when needed is crucial. The safety of employees working close to the machine must be ensured, and the worksite must be secured. To warn employees of any trains on nearby lines, there should be a hooter on the premises and on the machines. When the machine arrives at the site, the cutter bar unit should be lowered into the trench, and both ends of the cutter bar should be connected to guides using links. If the cutter bar is already on-site (left outside the track after the previous block), it can be inserted before the machine arrives, provided all necessary precautions are taken [12]. As the machine begins operation, one person should accompany the machine on either side to monitor for any obstructions to the cutter chain, allowing for immediate stoppage of the machine if needed.

The gates for clean ballast beneath the screen should be closed right away if the machine stops moving while you're working on it. This will keep extra ballast from building up in one area. Tasks like filling ballast behind the BCM and putting in and taking out the cutter bar require labor in BCM operations [13]. To guarantee that the BCM's advancement is not impeded, a sufficient number of personnel should be allocated. In the absence of a tamper positioned behind the BCM, notably during comprehensive checks of junctions and passages, additional labor might be required for manual track loading to ensure train operation following the block's release. In infrequent instances when the tamper is delayed, manual packing could be essential to reach speeds of approximately 40-45 kilometers per hour. For the BCM to be properly wound up, for DTS to tamp and consolidate, if available, and for the machines to be moved back to the station, screening should stop well before the traffic block ends. The removal of the cutter bar, proper re spacing of the sleepers, filling of the ballast, and packing of the cutter bar area must all be done before the block is cleared. It is not advisable to put ramps in areas like curve transitions, girder bridge approaches, or level crossings. They ought to be placed two rail lengths or more away from these locations. BCM work must cease if the tamping machine breaks down, and any untamped track must be manually fixed before it can be made accessible to traffic while following the IRPWM's speed limits. Ballast in cribs and shoulders should be properly profiled by BRM or by using enough workers both during and after machine operations. To avoid running into electrical masts or signal posts, the waste conveyor's movement must be carefully controlled. Always keep the safety switch that detects the mast in the "ON" position. All employees using the machine must wear masks to prevent dust inhalation, safety helmets, and suitable footwear.

1.6 Trial of En19 & En24 Steel for certain Parts of Indigenized Maintenance Machines

Before 1945 maintenance activities were carried out manually which involved a heavy workforce. It took large time to carry out maintenance manually. Indian railways started mechanization of railway track maintenance by importing various tamping machines from an Austrian company Plasser & Theurer. This company was having the patent for a long time on maintenance machines so the average import cost was so much high even now [14]. Because of high import costs, Indian railways started making important tamping units & parts of maintenance machines in India. Indigenization process is done with the help of reverse engineering. Any reverse engineering approach aims to create a three-dimensional mapping of the product in CAD file. Part digitization, feature extraction, and CAD modeling are the three processes of reverse engineering. A variety of contacting and non-contacting digitizers are used to digitize parts. Typically, feature extraction is accomplished by segmenting the digitized data and extracting surface characteristics like edges. As per the reverse engineering process railway workshop firstly took the individual parts of a typical tamping unit which is imported & follow the steps as given below in fig. 1.4

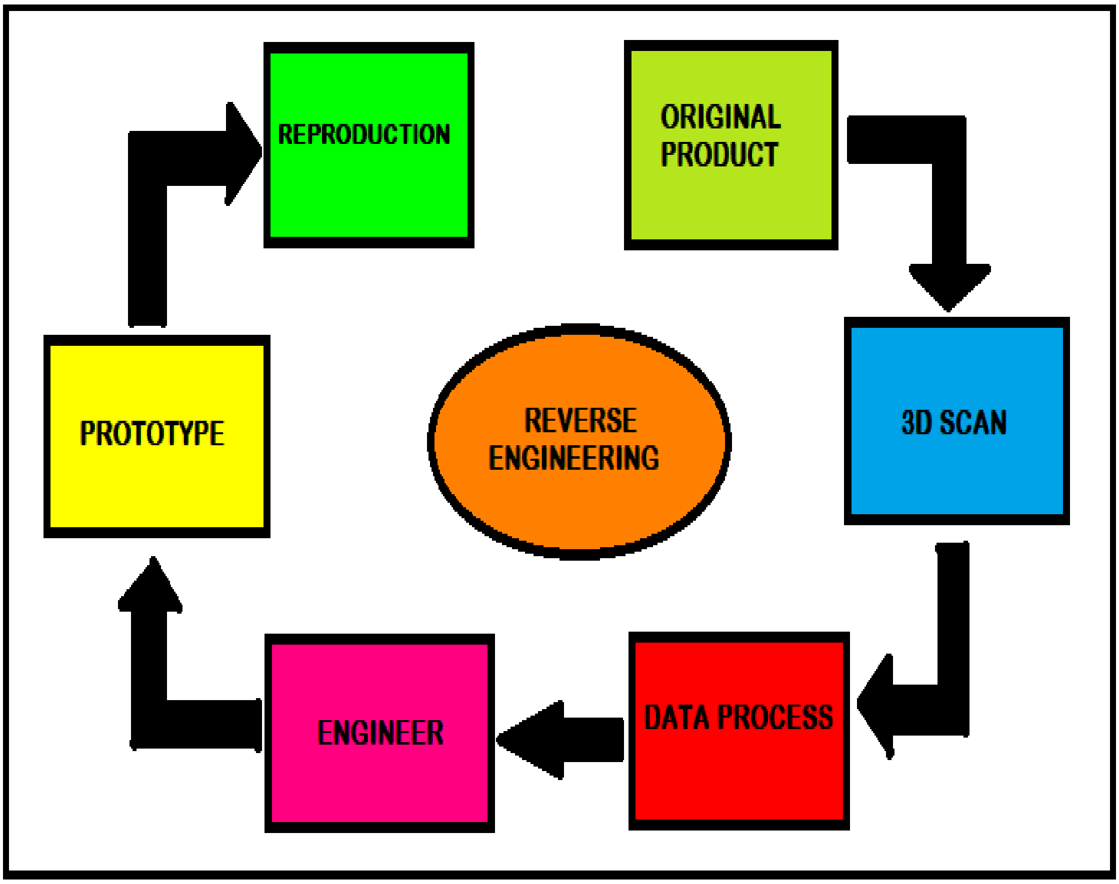
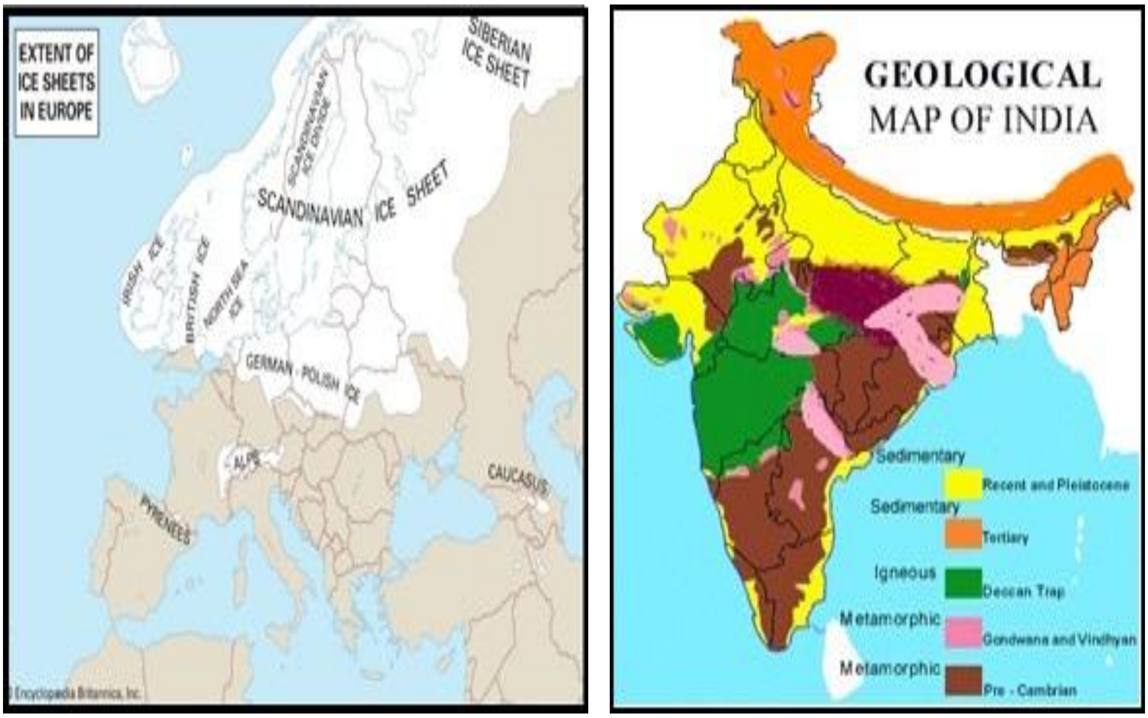


Fig. 1.4 Block diagram of process of reverse engineering

In the process of localizing the tamping unit of all types of tamping machines by replacing the German standard materials by the Indian standard materials by following a set of processes.

1.7 Challenges with German Standard part in India

Indian railway has purchased various tamping machines for plain tracks tamping and for point & crossing [15]. In tamping machine, the part which periodically needs to change is the tamping unit because tamping unit directly comes in the contact with ballast while performing tamping operation. In tamping unit mostly parts (tamping arm, squeezing cylinder & tamping bank) are made of 42CrMo4 (European grade) steel by Plasser & theurer except tamping tool. Typically, this steel is utilized in the design of dynamically stressed components in engineering practice. We are aware that the "42" in 42CrMo4 refers to its 0.42% average carbon content. In general, 42CrMo4 steel is supplied hot-rolled or annealed, with a hardness below 241HB.



(a) (b)

Fig. 1.5 Types of rocks founded in Europe (a) & India (b) for ballast material. Reprinted from [15] with permission of pmf, ias 2016.

In the European countries the type of ballast is different than that of Indian ballast. Due to diversity in India, Igneous rock is founded in southern region, in Himalayan region metamorphic as well as igneous rocks are found and in middle & west India sedimentary rocks are found therefore this directly affect the tamping unit. So same material which is used for tamping arm, squeezing cylinder & tamping bank cannot be used in Indian scenario in same manner as given in figure 1.5. Another important factor for replacing German grade is the lesser cost when material with approximately similar grade used in wearable components. High import cost also forced Indian railway to Indigenize the parts. When it comes to replacement of this grade by a cheaper and similar property material then En19 is most suitable one as show in table 1.1

Table 1.1 Difference between European standard & British standard

No.	Constituents	42crMo4	En19
1	C	0.38-0.45%	0.35-0.45%
2	Mn	0.6-0.9%	0.5-0.8%
3	Si	≤ 0.4%	0.10-0.35%
4	S	-	0.02-0.04
5	P	≤ 0.025	≤ 0.025
6	Cr	0.9-1.2%	0.9-1.5%
7	Ni	-	-
8	Mo	0.15-0.30%	0.2-0.40%

1.8 En19 & its desirable properties in Railways

While indigenizing the tamping arm, the most commonly used material is En19. American SAE 4140 circular bar is also known as En19 steel brilliant round bar. The chemical composition of the material taken by the Indian railways is given in the table 1.2.

Table 1.2 Chemical configuration of En19 steel used by Indian railway [17]

No.	EN No.	EN 19
1	C	0.43
2	Mn	0.65
3	Si	0.23
4	S	0.016
5	P	0.019
6	Cr	0.96
7	Ni	-
8	Mo	0.23

For Tensile Strength a tensometer determined the ultimate stress in tension, breaking load. The tensometer in question was made by Kudale. It makes use of a 20 kN load cell. The tensometer's lowest count is 0.1mm. Elongation varies from 0-500mm. The tensometer can handle a minimum load of 10N. The tensometer has an accuracy of 1%. A370-E8 was the ASTM standard for the tensometer that was utilised. The sample whose tensile strength has to be determined is fixed between the tensometer's two jaws. The moveable jaw then moves while the tensometer is activated until the specimen splits in half. Braking load & ultimate stress of En19 are given in details in table 1.3.

Table 1.3. Ultimate Stress & Breaking Load of EN19 Steel Alloy

Sample	Breaking Load (N)	Ultimate Stress(N/mm2)
general	6628.00	527.69
Anealed	6158.00	490.31
Normalized	7138.00	738
Quenched (Oil)	16259.00	1295
Quenched (Water)	10218.00	1357
Quenched (Brine)	18147.00	1423

Bright round bar is a 1% chromium–molybdenum medium hardenability special - purpose high tensile steel that is often hardened and tempered with in tensile limit of 850–1000 MPa. It is used when better mechanical qualities than carbon steel are required. Axles, good strength bolts, drive shaft, crankshaft connecting rods, studs, propeller shaft joints, and crankshaft rifle barrels, are some of the most common applications [1]. The process of heat treatment involves heating and cooling steel to achieve certain results. Young's modulus, hardness, toughness, and yield of a component must all be achieved. Tempering & Hardening, on the other hand, are two of the most common heat treatments used to enhance the microstructure and mechanical properties of steel. The purpose of steel hardening is to improve both strength and wear resistance. It is important to note that adequate carbon and alloy are the most important requirements for hardening steel. A material with enough carbon can be toughened immediately. A tempering process improves toughness, hardness, and relieves internal tensions. The hardness of the specimen after tempering is determined by the tempering temperature and time. Hardness was measured using the HRC scale following HT, which revealed a significant increase in hardness As given in table 1.4. Therefore, tempering plays a critical role in modifying mechanical properties and microstructure characteristics of materials.

Table 1.4. Properties of En19

Properties (Mechanical)	Metric	Imperial
Properties		
Tensile Stress	655.00 MPa	95000.00 psi
Yield Stress	415.00 MPa	60200.00 psi
incompressibility	140.00 GPa	20300.00 ksi
Modulus of rigidity	80.00 GPa	11600.00 ksi
Young's modulus	200.00 GPa	27557.00 ksi
coefficient de Poisson	0.28	0.28
Elongation at break	25.7%	25.7%
Brinell hardness	197.00	197.00
Knoop hardness	219.00	219.00
Rockwell scale B	92.00	92.00
Hardness, Rockwell C	13.00	13.00
microhardness	207.00	207.00
Machinability	65.00	65.00

Tempering temperatures for EN19 alloy steel range from 205 to 649°C, depending on the desired hardness. Lower temperatures can increase hardness.

1.9 En24 & its Application in Indian Railway Maintenance machines

En24 is generally used in hardened and tempered condition to achieve optimum mechanical properties. Before heat treatment, EN24 consists mainly of ferrite and bainite. Different treatments change the matrix/phase structure. These changes affect the mechanical properties of alloy steel EN24. Despite En24's microstructure being quite similar to the prior specimen, it exhibits improved tensile strength, yield stress, % elongation, and hardness properties after stress relieving treatment. En24 was categorized as a wrought steel for autos and aircrafts when it initially became popular in the early 1900s, and it was used to make a variety of products and materials for these industries [17]. It is most often known as En24T, and it is frequently employed in the industrial industry due to its strong tensile qualities in T state. Some of application are gears for power transmission and other gears that require maximum toughness, crankshafts, axles, propeller shafts, and gearbox shafts with high tensile characteristics. It also finds application in connecting rods, cranks, and other elements must be rigid while being extremely durable. En24 is nickel-chromium-molybdenum alloy steel which provides high tensile strength, wear resistance and toughness even in larger cross sections [18].

Both the steels EN19 and EN24 provide the necessary strength, durability, and resistance to fatigue, well adapted for hostile, high-wear environment typical of railway maintenance machines. The kind of steel used depends upon tensile strength, impact strength, and fatigue life in a part of the machine. A brief literature survey has been done as given below in table 1.5.

Table.1.5: Literature Review

S. No.	Title	Output parameter	Conclusion
1.	Indian Railways Institute of Civil Engineering[8]	To optimize the ballast cleaning process by following certain operations before during and after.	Description about various process of ballast cleaning.
2.	Design of Advance Compacting Tools for Railway Track : A Review[6]	Wear plates of BCM & Tamping tool of Tamping machines are need to be replaced after certain intervals.	Some Parts of maintenance machines needed to be change after certain interval.
3.	Track Maintenance machines [10]	Plasser & theurer maintenance machines	Key manufacturer and supplier of all track maintenance machine to Indian Railway.
4.	Report No.24 of 2015 (Indian Railways) Volume II [1]	Review on 'Procurement and Utilization of Track Machines in Indian Railways.	Indian Railway have targeted full Mechanization of railway Maintenance.
5.	The metallurgical properties of polished tungsten carbide	Fatigue experiment was performed of En19 Steel before & after the heat	After heat treatment the material En19 showed an improvement in

	inserts were compared using En19 steel [19].	treatment on the fatigue testing machine.	fatigue life & hardness increased from 16 to 45 hardness rockwell C.
6.	Micro structured carbide inserts for En19 alloy steel machining [20].	Micro structures in the form of holes and slots were created by laser-radiating the rake faces of cutting tools.	The tool life of structured cutting tools was extended by 15% over standard material and by 36% over unstructured cutting tools.
7.	Liquid pure tin was used to evaluate liquid metal embrittlement of En19 steel specimens during tensile testing[21].	Each of the samples was subjected to a metallographic investigation.	Temperatures ranging from around 400 C for low-strength steels to around 480 C for high-strength steels.
8.	The effects of partial and intense cryogenic treatment on En 19 steel tribological Behavior[22].	A SEM was used to analyze the nanostructures of CHT, SCT, and DCT samples.	Wear resistance has increased by 118.38 percent for SCT specimens and 214.94 percent for DCT samples.
9.	Optimization of machining parameters to achieve the desired technological parameters [23].	Using response surface methodology, parameters such as surface roughness, tool radial vibration, and material removal rate were measured.	Surface roughness is largely affected by feed rate (72.19 %), followed by effect of cutting speed (10.69 %) and by feed rate (1.86 %).
10.	The polymer	The microstructure of	Quenching polymers

	quenching assessment of medium carbon low alloy forged steels [24].	specimens quenched in 10 percent and 30 percent polymer solution was examined using a Carl Zeiss microscopy.	would increase ductility, toughness, and impact strength.
11.	Fatigue behavior of En19 on heat treatment [25].	Fatigue experiment was performed on the fatigue testing machine.	En19, the number of cycles after heat treatment for fatigue failure increased.
12.	Parametric optimization under cryogenic machining of En19 steel [26].	Integrated Taguchi-present worth method.	Applied to the maintenance system in total quality management.
13.	Wear in high-speed turning of low carbon steel [27].	After a series of machining tests, a few important relationships have been discovered.	Using uncoated carbide tools, high speed machining can lead to a near-merging of wear zones.
14.	A study of the effects of heat treatment on the microstructure of En19 steel [28].	Observe and compare the changes in the microstructure, strength after the heat treatment.	A specimen's strength is improved by quenching, and its toughness is improved by tempering.
15.	Plasma nitriding of low alloy steel and its physico-mechanical properties [29].	The pulse plasma technique can be applied to the hardening, coating or etching of surfaces.	Samples are shortly achieved very good mechanical & metallurgical properties and the observed Physico-mechanical properties.
16.	Analyze grey	The material removal rate	In dry machining,

	relational to optimize multi-response objectives when machining En24 steel [30].	and surface roughness are validated by grey relational analysis.	spindle speed is ranked first, feed rate is ranked second, and depth of cut is ranked third.
17.	Graphite mixed EDM of En-24 alloy steel [31].	An in-depth examination of the machined surface was conducted to determine whether the concentration of graphite powder during the machining process affected the final surface.	Both material removal rate and peak current, gap voltage, and graphite concentration increased with a higher voltage.

1.10 Inferences drawn from literature review

Ballast Cleaning Machine is an important Track Maintenance Vehicle manufactured by Ms Plasser & Theurer, Austria but as a process of Indigenization, it had started Purchasing Some most important parts of both Machines from local Indian Manufactures. Those parts need continuous replacement because of failure, therefore if these parts would be imported from outside countries then the average cost will be much higher. The most important parts which are purchased by Indian railways from local vendors are wear Plates as shown in fig. 1.6.

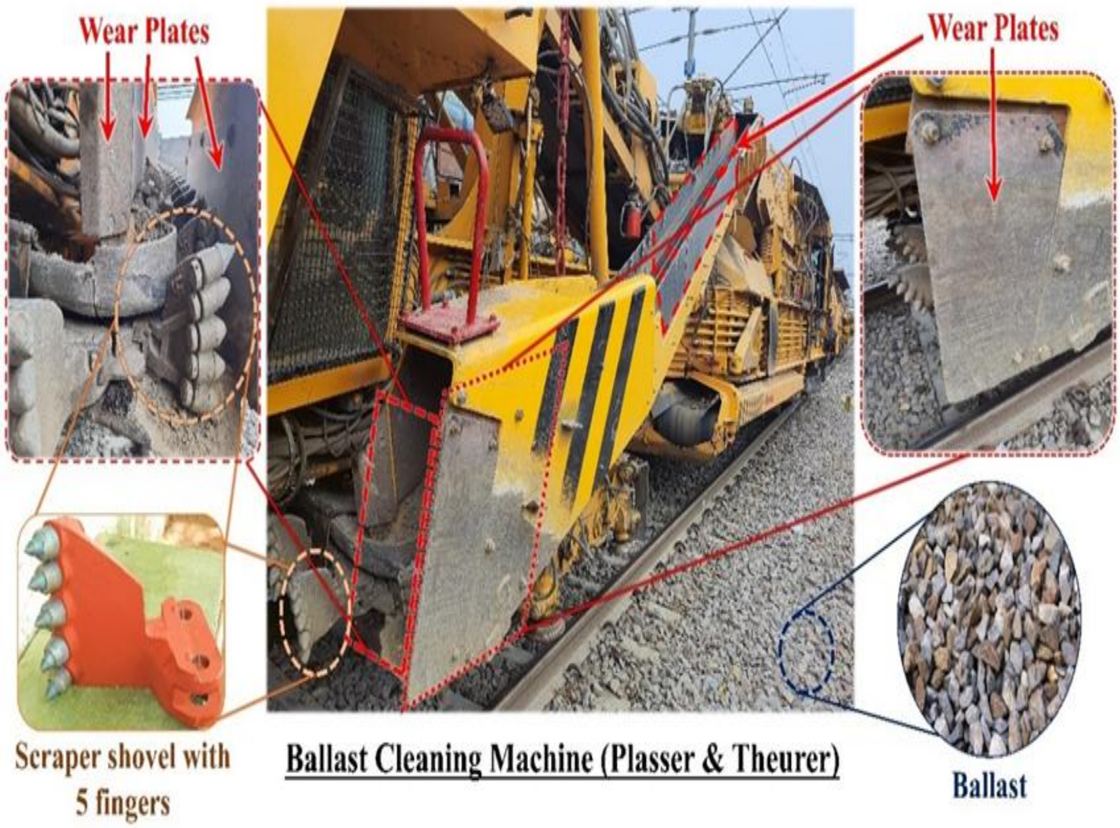


Fig.1.6: A typical Ballast cleaning machine with its important parts

The ballast bed is first accessed by the BCM which uses excavating chains or cutters positioned underneath the railway tracks. The figure 1.7 Shows the movement of ballast over the machine. These tools strip away ballast from the track bed inclusive of fouled piles and degraded material. Conveyors or scooping mechanisms then transport the excavated ballast to the cleaning unit. The ballast collected conveys to the cleaning unit where vibrating or rotating screens are available. At this location, the purpose of the screens is to separate out from the individual particles of ballast other contaminants such as soil, small stones and any other. The use of vibrations on the ballast ensures that all small waste particles fall through the screens while the larger stones which need to be reused are held in place.

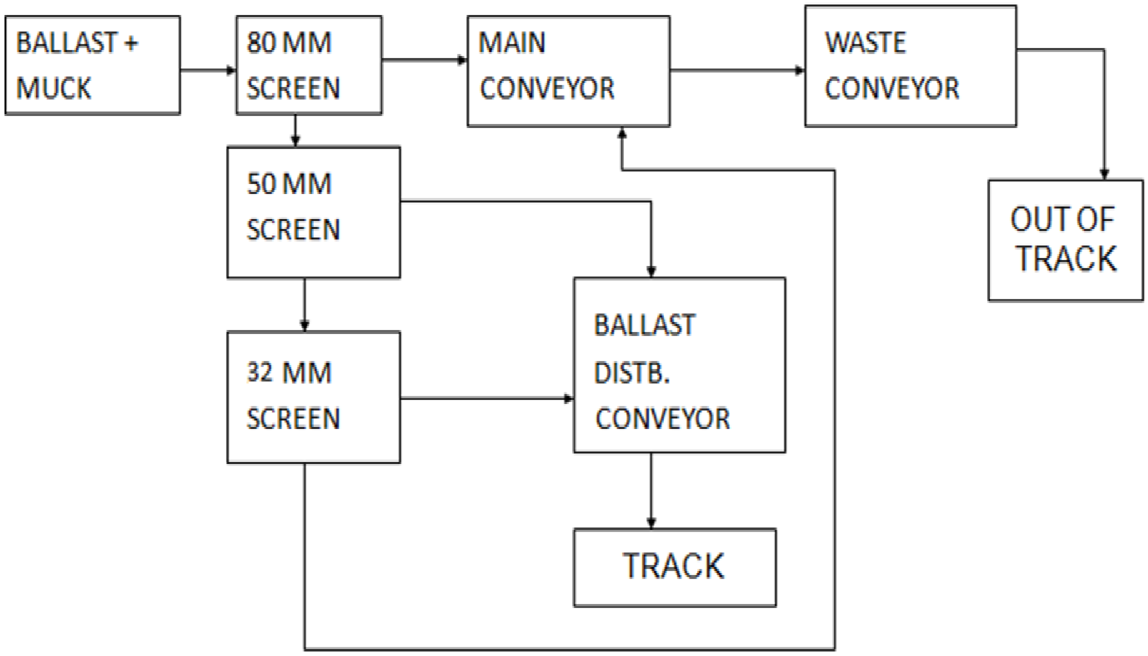


Fig. 1.7: Ballast movement flow diagram on ballast cleaning machine

The fines and dust wastes are directed to a disposal conveyor or hopper and the screw in the forward direction pushes the grit over the screen. Spreading of ballast is usually carried out in a systematic manner which moves it to the desired position targeting evenly spread ballast, this is done by slewing of the spout. Rubbish and small pieces of debris which are segregated from ballast particles are disposed of to the waste bin or disposing conveyer [33].

A layer of grit or crushed stone of size is placed under the railway track to transfer the vertical force to the underlying soil to manage the vertical load on railway tracks. Due to the accumulation of fine dust, mud, and sand, this ballast layer becomes compacted and rigid over time, hence proper track maintenance with the help of track tampers is not possible. This requires regular cleaning and screening.

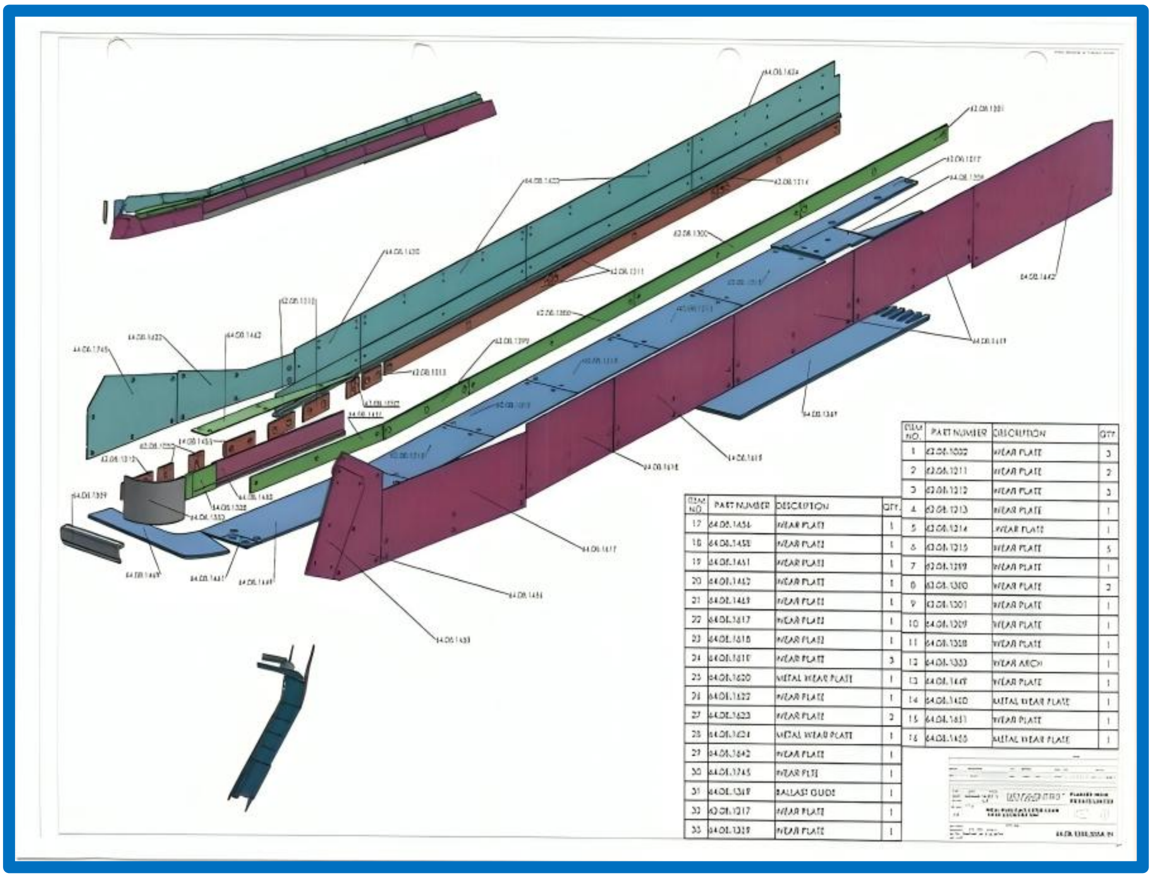


Fig.1.8: Wear plates of ballast cleaning machine

The Ballast Cleaning Machine is one of the key track maintenance vehicles designed to clean this ballast. This machine removes the ballast under the track with a cutter bar and transports it through a chain conveyor system known as the TURF, shown by the red arrow with the direction of ballast movement. The TURF body is protected by a host of wear plates as given in fig. 1.8 from wearing away continuously between the contact of ballast, chain, and wear plates; these wear plates have wearing away properties and, eventually, have to be replaced once in a while so as not to bring down machine functionality, as the machinery cannot work without them.

Table 1.6: List of all wear plate with their life calculated on real time basis

Ballast cleaning machine wear plates details with their estimated Service life				
S. No	**Part name**	**Part No.**	**Quantity**	**Life in Km**
1.	Wear plate	60.08.1032	5	2
2.	Wear plate	60.08.1181	1	5
3.	Wear plate	64.08.1209	1	2
4.	Wear plate	62.08.1215	5	2
5.	Wear plate	62.08.1226	1	5
6.	Wear plate	64.08.1328	1	2
7.	Wear plate	64.08.1329	2	7
8.	Wear plate	64.08.1333	1	10
9.	Wear plate	64.08.1335	1	10
10.	Wear plate	64.08.1369	1	4-5
11.	Wear plate	64.08.1449	1	4-5
12.	Wear plate	64.08.1450	1	4-5
13.	Wear plate	64.08.1455	1	2
14.	Wear plate	64.08.1456	1	4-5
15.	Wear plate	64.08.1461	6	4-5
16.	Wear plate	64.08.1462	1	8-10
17.	Wear plate	64.08.1469	1	8-10
18.	Wear plate	64.08.1617	1	8-10
19.	Wear plate	64.08.1618	1	8-10
20.	Wear plate	64.08.1619	3	8-10
21.	Wear plate	64.08.1620	1	4-5
22.	Wear plate	64.08.1622	1	4-5
23.	Wear plate	64.08.1623	2	4-5

24.	Wear plate	64.08.1624	1	8-10
25.	Wear plate	64.08.1626	1	8-10
26.	Wear plate	64.08.1635	1	8-10
27.	Wear plate	64.08.1636	2	4-5
28.	Wear plate	64.08.1637	1	4-5
29.	Wear plate	64.08.1642	1	4-5
30.	Wear plate	64.08.1683	1	8-10
31.	Wear plate	64.08.1745	1	4-5
32.	Wear plate	64.08.1746	1	4-5
33.	Wear plate	62.08.8032	2	4-5
34.	Wear plate	64.10.4287	1	8-10
35.	Wear plate	64.10.4288	1	8-10
36.	Wear plate	64.10.4289	1	8-10
37.	Wear plate	64.10.4290	1	8-10

Wear plates are used in ballast cleaning machines for protection of the body of the machine against abrasive rubbing that happens continuously as the ballast moves in case of track maintenance. table 1.6 explain about all types of wear plates use in BCM. Consequently, these plates experience extreme wear and have to be changed constantly. These wear plates are always imported and have lots of implications: they are costly, take long, and depend on foreign suppliers. The benefits of indigenizing its wear plates production for the company are as follows:

- Local production can do away with almost 100% of import duties, shipment costs, and risks associated with foreign exchange risks. This makes replacement parts easy to get at a reasonable cost. Shortening of supply chain, local sourcing reduces turnaround times for ballast cleaning machines' replacement wear plates.

Downtime is thus minimized as well as track maintenance to be done much more effectively.

- Indigenization would allow the wear plates to be manufactured locally in whichever size is needed within certain fields, according to requirements of different sizes of ballasts or soil conditions. Lastly, local production allows for strictly controlled quality as well as strict testing towards improved durability.
- Manufacturing of wear plates would greatly improve domestic self-reliance in railway maintenance kits componentry and support domestic enterprise development and employment.
- Identify the locally available high-wear-resistant materials, such as specialized alloy steels, which can resist the wear and pressure of the ballast. Laboratory test material strength, wear resistance, and durability for validation.
- Work with local manufacturers to modify the wear plate design to improve its ease of production in the region without sacrificing performance. This could include minor changes to durability or compatibility with existing machine types.

Pilot test selected ballast cleaning machines with these wear plates for field performances and make changes based on the obtained field data in order to perfect the design and material choice. Once validated, step up mass production and incorporate these wear plates into routine cleaning machines' maintenance programs for all ballast cleaning machines. The adoption of indigenized wear plates would assure railway operators the opportunity of cutting costs, improving operations efficiency, and promoting manufacturing capabilities locally within the frameworks of track maintenance at a high standard.

1.11 Objectives of the Thesis

Ballast cleaning machine is one of the important machine used for railway track maintenance. The general objective of this thesis is to indigenize the wear plate of ballast cleaning machine and proposing an Resnet 152 algorithm for Artificial Intelligence based railway track detection system. The specific objectives of the thesis are as follows:

1. The optical, XRD, SEM, and EBSD analysis provided a holistic understanding of the performance of wear plates.
2. The present study delves into the wear characteristics of materials used in these machines, focusing on wear plate samples (Plasser sample and RDSO sample) designed to withstand the abrasive forces inherent in ballast cleaning operations.
3. Hardness and wear performance has been evaluated and being compared with the synergic.
4. Comparative analysis of Mechanical & fracture behaviorof Plasser sample & RDSO sample.
5. Nature of fractured surface of both the samples Plasser sample and RDSO sample during fracture toughness testing.
6. To Study the Process of B4C coating on the RDSO wear steel plate substrate.
7. Investigating Microstructural properties of the coating and its substrate.
8. Investigation of wear properties of coated RDSO wear Plate.
9. The Artificial Intelligence based system automates the process of railway track detection using deep learning and computer vision.