INDIGENIZATION OF INDIAN RAILWAY TRACK MAINTENANCE MACHINE PARTS

Thesis submitted in partial fulfillment for the Award of degree

Doctor of Philosophy

By

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Dedicated to…

My Beloved Parents

(Smt. Sharmila Pandey & Shri Dinesh Prakash Pandey)

&

Wife & Daughter

(Smt. Mamta Mishra & Shrinika)

'न चोरहार्यं न राजहार्यं न भ्रतृभाज्यं न च भारकारि!

व्यये कृते वर्धति एव नित्यं विद्याधनं सर्वधनप्रधानम्!'

"No one can steal knowledge, nor can the king snatch it. Education cannot be divided among brothers, nor is any tax or expenditure levied on it. The more knowledge is spent, the more it will grow."

(Source–Subhasitani)

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(Manas Pandey)

PREFACE

Ballast cleaning machines play a pivotal role in maintaining the stability and safety of railway tracks. The ballast cleaning operation involves transfer of ballast from the track and its redistribution on the track. However, the wear plates used in these machines are subjected to extreme conditions, making the assessment of their wear performance crucial. This study scrutinizes the wear performance of two distinct wear plate used in the ballast cleaning machines. The wear tests were conducted on a German grade steel wear plate used in the ballast cleaning machine and an indigenous grade steel used as alternative. Wear analysis uncovers pivotal insights, as indigenous wear plate consistently exhibits higher weight loss for both the ballast pin and disk under various loading conditions. In contrast, German Grade Plasser-wear plates demonstrate a declining average weight loss at higher loads, showcasing its superior wear resistance and resistance to indentation due to the presence of fine laths in the microstructure. The key factors contribute to this improved wear performance, includes relatively larger amount of high-angle grain boundaries, high dislocation density, small grain size, and variations in micro-alloying elements. The compositional analysis indicates a low amount of carbon in both wear plates. The microstructural analysis shows that both samples have a single Body-Centered Cubic (BCC) crystal structure, with a randomly distributed heterogeneous ferritic and cementite phase in a lath-bainitic microstructure. This comprehensive study provides valuable insights into the wear behaviour of these alloy steels, contributing to the optimization of wear plate materials for ballast cleaning machines.

The tensile test & fracture test was conducted on universal testing machine (100KN capacity) for evaluating the percentage elongation vs strength criterion for both the samples in which Plasser sample has UTS about 1270 MPa and % Elongation about

18% and RDSO sample has UTS about 1195 MPa and %Elongation about 21%. Fatigue crack growth rate (FCGR) test is conducted to evaluate the behavior of both RDSO and PLASSER sample to monitor the crack growth rate & fracture toughness of both the samples through compact tension (CT) test was done followed by fractography of CT samples were studied through Field Emission Scanning Electron Microscope which shows the kind of fracture morphology. A brittle mode of fracture was observed in the Plasser-samples whereas a comparatively fibrous failure was observed in the RDSO-samples. In contrast PLASSER sample showcase good properties due to higher proportion of high-angle grain boundaries, a high dislocation density and smaller grain size.

The focus of the present study is the analysis of the microstructure and mechanical properties of Boron Carbide (B4C) reinforced coating deposited over RDSO grade wear steel plate. Scanning Electron Microscopy (SEM), and optical microscopy were used for characterizing the coating. Mechanical properties were evaluated by Wear Tribology Pin on disk test. It was found that the B4C coating has a morphology that is well bonded to the substrate. The coating-substrate assembly exhibited better Wear Properties as compare to RDSO uncoated sample. Properties with a micro-hardness of 428 HV which is as per the requirement of maintenance purpose of railways. The coating being mostly brittle and the substrate behaving in a ductile manner.

Ensuring operational safety and effectiveness in relation to railways also means that the process of identifying and monitoring railway track locations has to be done with a high degree of accuracy. Other traditional methods of track inspection, such as manual check-ups and basic image-processing structures, are most of the times too slow, labor-intensive, and ineffective. In this paper, we present an artificial intelligence-based Railway Track Detection System as a way of making the process of railway track detection and analysis faster and easier using computer vision and deep learning techniques. A challenge in this system design is the need to discourage blocking of views of the track, detect how the track curved and situated with other tracks, and increase the ability to monitor in real time. Image classification and object detection is done in this system using convolutional neural networks (CNN), which enables the railway track detection system to work accurately even in real time video feeds of railway tracks. The image of a track in a given condition, per weather, lighting and environment, is obtained and used to train the model. This is done to make the model durable so image augmentation is one of the data pre-processing techniques employed and then the model performance is evaluated during validation and testing using precision, recall and score metrics of the model. System architecture allows it to be installed in edge devices as well as on the cloud thus real time processing is made flexible. The results show that the developed system is able to detect tracks with an accuracy greater than 95% which is a sightly lower than the false positive rate of the traditional approach. The AI-based system not only enhances the accuracy levels of detection but it also enables the provision of alerts automatically whenever there are any anomalies detected on the railway tracks thereby helping in quick railway response strategies. Although the model is highly effective, there are several problems observed such as processing time and dealing with rare edge cases. In the future, more effective model optimization techniques will be developed and the dataset improved, aiming at its generalization. The intelligent railway track detection system constitutes a big step in rail infrastructure monitoring. It is a solution that can be scaled up and it could change the way rail safety and maintenance is approached.

The inclusive investigations on the railway track maintenance machine parts in the present thesis are given below:

- To indigenize the wear plate of Ballast cleaning machine and to resolve the challenges associated with that.

- Microstructural & Wear investigation of Plasser & RDSO wear plate sample of Ballast Cleaning Machine (OES, Optical, SEM, XRD & Pin on Desk Wear Testing).
- Mechanical & fracture behavior of both samples & their Comparative Analysis.
- Microstructural characterization and mechanical properties of boron carbide (B4C) coating on RDSO (Research Design & Std. Org.) steel Sample.
- Artificial intelligence based railway track defect detection system.

The thesis is organized in 6 different chapters. A brief description of these chapters and their important results are as follows:

Chapter 1: A foundation for basic definitions, terms and concepts Indian railway track maintenance machines and their important parts have been given in this chapter. This chapter explains the changing scenario of Indian Railway Track Maintenance from manual to automation. All machines which are imported from Austrian companies Plasser & Theurer are explained. Due to high German standards, some parts of Indigenized machines, which need to replace after some intervals, having the higher cost. This leads to indigenizing those important parts. A brief literature review of previous investigations on indigenization of track maintenance machines & their important parts. Review investigated the materials which Indian railway is using for manufacturing parts of these machines. The objectives of the thesis are listed at the end.

Chapter 2: The research presented in this chapter focuses on the microstructural & wear performance of two types of ballast cleaning machines wear plates, namely the Plasser and RDSO sample plates. Specifically, the Plasser sample was used as the wear plate in the ballast cleaning machine; RDSO sample was used as a domestic counterpart of the wear plate. Microstructural examination conducted by Electron Backscatterer Diffraction (EBSD) is seen to establish that the crystal structure of the two samples had a single Body-Centered Cubic (BCC) crystal but the morphology had heterogeneous ferritic and bainitic phases. No doubt, the wear analysis provides certain important realizations; for instance, the RDSO sample loses weight more than the ballast pin and RSDO disk under the stress. In other words, as load increase Plasser sample average weight loss decreases indicating that its resistance to wear and indentation is greater.

Chapter 3: This chapter proceeds with a brief introduction of evaluation of Mechanical & Fracture behavior of two distinct wear plates used in ballast cleaning machines. This study helps in evaluating the mechanical and fracture behavior of two distinct wear plates used in ballast cleaning machines. The tensile test & fracture test was conducted on universal testing machine (100 KN capacity for tensile test and 25 KN capacity for fracture Test) evaluating the percentage elongation vs strength criterion for both the samples. Fatigue crack growth rate (FCGR) test is conducted to evaluate the behavior of both RDSO and PLASSER sample to monitor the crack growth rate & fracture toughness of both the samples through compact tension (CT) test was done followed by fractography of CT samples were studied through FESEM which shows the kind of fracture morphology. PLASSER sample showcase good properties like high fracture toughness & high tensile strength due to higher proportion of high-angle grain boundaries, a high dislocation density and smaller grain size.

Chapter 4: This chapter briefly introduces coating on RDSO steel samples using a thermal spraying technique. Microstructural examinations were performed using scanning electron microscopy (SEM) and optical microscope to characterize the coating's homogeneity, adhesion, and interfacial bonding with the steel substrate. Mechanical tests, including hardness testing, tensile strength, and wear test were conducted to understand the coated sample's performance compared to the uncoated counterpart. This comparative analysis suggests that B4C-coated RDSO wear plate steel is a promising railways for wear plate applications in ballast cleaning machines, providing increased lifespan and better performance.

Chapter 5: This chapter proceeds with a brief introduction to an artificial intelligence-based Railway Track Detection System, which uses computer vision and deep learning techniques to make the process of railway track detection and analysis faster and easier. Image classification and object detection is done in this system using convolutional neural networks (CNN), which enables the railway track detection system to work accurately even in real time video feeds of railway tracks. The image of a track in a given condition, per weather, lighting and environment, is obtained and used to train the model. This is done to make the model durable so image augmentation is one of the data pre-processing techniques employed and then the model performance is evaluated during validation and testing using precision.

Chapter 6: This chapter summarizes the main findings of the research work carried out for the present PhD thesis and lists a few important suggestions for future investigations.

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ABBREVIATIONS

BCM	Ballast Cleaning Machine
TRT	Track Relay Trains
CTRT	Continuous Track Renewal Trains
DTS	Dynamic Track Stabilizer
SEM	Scanning Electron Microscope
EBSD	Electron Backscatter Diffraction
XRD	X-Ray Diffraction
OHE	Overhead Equipment
LWR	Long Welded Rails

NOTATION

Symbols

ΔK	Stress Intensity Factor
Δa	Fatigue Crack Growth
E	Elastic Constant
Hz	Hertz
b	Unbroken Ligament
j	Plane stress fracture toughness