CHAPTER 6

Summary & Future Scope

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6.1 Summary of the Thesis

This thesis deals with manufacturing certain components and systems domestically, intending to minimize the importation of parts and technologies. As Indian railway is now working on high speed trains but average load on a single train is still very high therefore regular maintenance of railway track is very important for proper functioning of Indian railway. This maintenance if done manually, will take more time and work force required for this job will also be high. So mechanization of maintenance work is need of time. Indian railway had purchased many automatic & semi-automatic maintenance machines from 1990 to till now, but since average cost of an imported machine and its parts is very high so it is necessary to indigenize important parts of a maintenance machine in order to reduce the maintenance cost of a machine. This is very crucial for those countries whose objectives include enhancement of sustainability, cost efficiency, and technical resilience of their railway infrastructure. Ballast cleaning machines widely used as a track maintenance machines for screening the track ballast to maintain the rail track geometry. Wear plates are most crucial part of BCM and need to replace at very small intervals. In conclusion, this thesis discusses the need for more durable wear plates for ballast cleaning machines (BCM) as they are essential for maintaining the railway track. Using various techniques (optical microscopy, XRD, SEM and EBSD), the work arrived at extensive understanding of the wear performance of the Plasser and the RDSO wear plates. Therefore, this thesis examines the wear performance of Plasser sample S1 and RDSO sample S2 are compared to evaluate S1 and S2 as possible wear plates. Interesting results: XRD, SEM & EBSD analyses confirmed both were BCC single crystals (lath bainitic ferrite & cementite) Because of the BCC structure, however, features of the bainite could not be resolved from the alpha-ferrite phase in EBSD. While Plasser sample S1 possessed a greater hardness of 410 ± 10 HV as compared to RDSO sample S2, which was measured at 302 ± 10 HV. The friction coefficient (COF) for both Plasser sample S1 increased with load, but the for RDSO sample S2, it decreased with increase of load. Using Plasser sample S1 having higher content of carbon and silicon, a better wear resistance and indentation resistance was obtained in high load conditions. The results indicate that the contributing alloy composition of S1 from Plasser enhances wear resistance and indicate where wear plate materials and coatings can be further optimized to improve the durability and efficiency of ballast cleaning operations.

Higher carbon content in the steel determines the influence of the mechanical dispersions, wherein great strength, as seen in the Plasser sample, is counter nipped by ductility as seen in the RDSO sample for the existence of lower carbon concentration. As an interstitial solute, carbon appears in the iron lattice to create an excited ferrite crystal structure that may assume stronger harder types of supply such as martensite, cooled into certain conditions. In regard to heating and cooling, higher carbon content creates areas of weak ductility and, therefore, great fragility in the supplied samples.

Carbon strongly affects the mechanical properties of steel; higher carbon means greater strength but lower ductility as compared with a low carbon-type RDSO sample, whose carbon content is represented by the sample of Plasser. Carbon, which occurs as an interstitial solute in ferrite, disrupts the crystal lattice of iron, facilitating the formation of a stronger, harder phase such as martensite, along with specific set of cooling rates. With increased carbon levels, less ductility and toughness can be imparted, resulting in brittleness.

The comparative study of mechanical and fracture behavior and microstructural and wear properties highlighted the relative durability of these materials under the abrasive conditions characteristic of ballast cleaning processes.Fractography analysis shows that microstructure with high-angle boundary has a toughening effect because it bridged a crack. Still, low-angle boundaries are not very effective for this purpose. The grain structure and high density of dislocation of upper bainite (UB) provide a good combination of strength and toughness. Fractographs of the Plasser sample S1 shows transgranular facets in association with a granular bainite structure wherein microcracks cross over and propagate through the boundaries of the bainitic ferrite to the extent of causing brittle fracture. Crack propagation is therefore facilitated by hard, brittle phases, while ferrite helps blunt fracture formation, and these together drive the overall fracture behavior of the steel. Types of phases in terms of how each form once fracture progression occurs.

Additionally, the B4C coating has been explored on the RDSO wear plate substrate, which holds potential for improved life and wear resistance. The microstructural and mechanical characteristics of this coating were thoroughly analyzed, allowing to propose some modifications aimed at increasing the lifetime of wear plates applied in ballast cleaning machines. The wear performance of boron carbide (B4C) coated and uncoated RDSO samples for ballast cleaning machine has been evaluated in this study which are used in railway track. B4C has been shown to be an excellent coating material providing significant increases in surface hardness, wear resistance and stability as detailed in key findings. With a hardness of 430 ± 10 HV, which meets railway standards, the coated samples outperformed uncoated samples (302 ± 10 HV). In wear test also significant improvement was observed that at 10N load the COF of the sample was 0.33 (coated) vs. 0.64 (uncoated). The conclusion of these results also shows that carbide coatings provide benefits to service life and wear performance of wear plates in railway applications.

In conclusion, the development of an AI based ResNet-152 architecture for railway track identification shows the directions where railway maintenance may go in the fully automated mode. This deep learning framework seeks to automate the process of identifying railway tracks, thereby enhancing the effectiveness and safety of maintenance operations. On the whole, this paper addresses not only the improvement of wear plates intended for ballast cleaning machines but also tackles the issue of maintenance of the railway infrastructure as a whole by introducing out-of-the-box, artificial intelligence coupled, solutions.

The present work proposes a rail track inspection system powered by artificial intelligence that enhances maintenance and safety surveillance along the railways. The system stands out with its accuracy, dependability, and cost effectiveness as most of its applications have been tested in the real world achieving over 96% defect detection while cutting down operational cost by more than sixty percent. The economic effect is quite substantial, particularly with the long-distance rail networks that have the potential of reducing costs by more than fourteen million dollars in a year. This advancement goes further than the reduction of emergency actions and wait times enhancing the safety of railways; it also speaks volumes about the application of artificial intelligence in monitoring vital infrastructures. Incorporating deep learning, modern neural networks, and sensor fusion allows the system to perform resilient inspection operations in any given condition on a real-time basis. The modular structure of the system, permits its incorporation with newly developed sensors and devices ensuring accommodation of all improvements in technology. This study provides evidence that AI-based monitoring attitudes can be adopted in other, more complex railway systems and even in other modes of transport and infrastructure. The present work thus represents a departure from traditional approach to infrastructure upkeep, which is primarily labor based, to a more technology driven model, where systems such as AI sensors, camcorders, and computer interfaces will be indispensable for maintenance of infrastructures globally.

6.2 Future Scope of Indian Railway Track Maintenance Machines& Track detection system

The use of AI, ML, and IoT can improve the processes of track maintenance. The capability of data collection and predictive capacity can result in the correction of the railway tracks before it gets damaged leading to safety and efficiency. Use of automated inspection systems such as drones and sensors to scan for faults will lessen the need of manual inspections and lower the chances of human faults. Along with the mechanization preventive maintenance in the railways is needed if you are to realize realistic benefits of operating more efficiently without higher B&M costs. A Belete model is one such forecasting model that can be used as a guide in predictive maintenance models of structures – rail tracks included to eliminate such surprises. As the high-speed rail corridors are coming up, there is no doubt that Indian Railways will require sophisticated and high-speed track maintenance equipment. These equipments should be designed for easy access to the lines, thus leading to minimal line occupancy on these vital lines. The high- speed machines allow management of the track work parameters without compromise on the high-speed rail work standards. Robotic technology will eliminate more physical jobs related to track repairs, such as ballast cleaning, rail welding, and sleeping changing. Mechano-manipulators fitted on drones and robots will make tasks in such areas easier, quicker, and safer. There is a higher awareness of how one uses the available resources. Electric and hybrid technologies should be adapted in the future track maintenance machine design to curb emissions. Perhaps machinery that uses batteries and has power-saving features will be aimed for more so in cities and areas with population concentration. Remote Surveillance and

Health Diagnosis: Instead of track geometry measurement systems, video cameras can be used in a real time track diagnostic base. Collected data might be relevant to the study of specific track defects allowing their fast reproduction and puck up of management of repair crews. New technology can facilitate better ballast regulation, reducing degradation and improving track stability. Specialized equipment fitted with predictors and automated ballast positioning controls ensures material is applied accurately, thus reducing material wastage while increasing the strength of the track. With expansion plans for the high-speed rail system for India, maintenance machinery designed for high-speed rail track standards will be needed. These machines will be required to accurately maintain the geometry of the track while withstanding loads and vibration dyanetics that are created due to the passage of high-speed trains geared to comfort and safety of passengers. Track and Rail Health Monitoring through Sensor Technology: There are sensors that can be fitted to the track and rail which can provide real time measurement of, temperature, pressure and even vibration. This will help in detecting structural fatigue and degradation even before it can lead to failure. In future, track maintenance machines of this nature may also be equipped to focus on specific areas that require urgent intervention. With advancement in technology comes training to enable the workforce handle and maintain these complex machines. Alliances with technology providers will prepare the staff of Indian Railways to adopt new maintenance solutions. Indian Railways track maintenance machines of the future have an eco-friendly integrated design that features high levels of automation. By embracing these improvements, the Indian Railways will enhance safety and efficiency while improving the maintenance activities for one of the massive rail networks in the world.

The progressive incorporation of artificial intelligence and Internet of Things into railway systems will allow for the constant monitoring and evaluation of track conditions. After reviewing long-term data trends, sophisticated machine learning algorithms are able to ascertain when exactly maintenance should be carried out in advance of a failure being experienced. This reduces the immobilization of the system and tries to ensure more efficient operations of the railways.

New systems may, for example, entail the use of autonomous drones or even robots fitted with vision systems backed by Al to carry out inspection of places where people cannot reach like certain portions of the track. Such autonomous systems can carry out depth checks thus helping in rapid detection of defects thereby eliminating the need for human inspectors in risky areas. An increasingly complex data set can be used to train in ai models to enhance performance by recognizing more types of defects (Fractures, dislocations and, wearing for example). The further construction of these deep learning systems may include more accurate and sophisticated architectures such as transformers and neural network systems that will enhance the capabilities of the system in terms of precision and range of defects that can be identified even when they are very fine and hard to detect. Defect management systems based on artificial intelligence could be embedded into the smart networks of railways through the development of digital twins of the infra-assets contained in the rail transportation systems. This is possible as it enables modelling of what would happen and how the operations will change with the presence of defects, when the repairs will be done, and even without doing repairs within the specified time frame, all of which assist the railway authorities in making sound decision