NLC INDIA LIMITED

(Formerly Neyveli Lignite Corporation Limited)

NATIONAL INSTITUTE OF TECHNOLOGY TIRUCHIRAPPALLI

THE INDIAN INSTITUTE OF SCIENCE

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PROJECT COMPLETION REPORT ON

"PREVENTION OF PREMATURE FAILURES AND ENHANCING LIFE OF BOTTOM ROLLERS USED IN BUCKET WHEEL EXCAVATORS"

(Code: MT175)

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ABSTRACT

The project aimed to enhance the performance and longevity of bottom rollers used in Bucket Wheel Excavators (BWEs) through material development, heat treatments, and surface engineering techniques. The study conducted several tests, including hardness, wear, and corrosion resistance assessments, focusing on new alloy compositions and advanced surface treatments like nitriding and nitrocarburizing.

1. **Alloy Development**:

   - Three new alloys (NA1, NA2, NA3) were developed based on modifications to out of base alloy, 42CrMo4. These modifications include adjustments in carbon, chromium, molybdenum, and other alloying elements addition such as nickel and vanadium, aimed at enhancing hardness and wear and corrosion resistance.

   - The wear resistance of NA1 and NA2 significantly improved compared to the existing bottom roller material, with volume losses of 117.06 mm^3 and 116.98 mm^3, respectively. NA3 showed inferior wear resistance with a volume loss of 184.65 mm^3.

2. **Heat Treatment Process**:

   - Two primary heat treatments, nitriding, and nitrocarburizing, were applied to improve surface hardness and wear resistance.

   - Nitriding enhanced surface hardness and Both treatments increased the hardness of the material, which had a hardness of 480 HV.

   - In terms of wear resistance, the nitrocarburized samples demonstrated the best overall performance, with the lowest wear volume (129.92 mm^3). This was followed by nitrided samples (171.51 mm^3), both of which outperformed the existing untreated roller material (192.83 mm^3).

3. **Three-Body Abrasion Test**:

   - The three-body abrasion tests revealed that NA1 and NA2 alloys exhibited significantly improved wear resistance under abrasive conditions, making them more suitable for high-duty applications. The untreated base material demonstrated higher wear rates, confirming that surface treatment and alloy composition play a critical role in enhancing performance.

   - Nitrocarburizing offered the most balanced solution, combining wear resistance and surface hardness, making it the most promising heat treatment for long-term durability in abrasive environments.

4. **Corrosion Resistance**:

  - The corrosion tests highlighted that nitrocarburizing not only improved wear resistance but also offered enhanced corrosion resistance, making it suitable for applications in harsh environments where both abrasion and corrosion are significant concerns.
  - Nitriding also provided moderate improvements in corrosion resistance.

The combination of advanced material development and surface engineering processes, particularly nitrocarburizing, has shown the potential to significantly extend the operational lifespan of bottom rollers in Bucket Wheel Excavators. The development of new alloys, coupled with nitriding and nitrocarburizing treatments, has resulted in substantial improvements in wear and corrosion resistance, surface hardness, and overall performance under harsh operating conditions. Nitrocarburizing stands out as the most balanced solution for enhancing the durability and efficiency of bottom rollers, making it the preferred treatment for high-demand applications. Further testing and real-world applications are recommended to validate the laboratory results and ensure optimal performance in the field. The performance comparison of existing rollers and new alloy rollers are shown in table 47.

Table 1 Alloy combination and results

Property	**Existing bottom roller**	**New alloy 1**	**New alloy 2**	**New alloy 3**	**Nitriding**	**Nitro carburizing.**
Hardness (HV)	450 HV	540 HV	560 HV	565 HV	578 HV	585 HV
Three body abrasion tests (mm^3)	192.83	117.06	116.98	184.65	171.51	129.92
Wear rate at 25-75N	0.127-0.524 mm^3	0.051-0.333mm^3	0.064-0.333 mm^3	0.269-0.524 mm^3	0.152-0.456 mm^3	0.102-0.328 mm^3
Corrosion rate	Moderate	Enhanced performance	Enhanced performance	Excellent	Very Good	Extraordinary

1. **Proposed new alloy and heat treatments:**

- ❖ Incorporating the 9 alloy combinations, their applications, and segments:

Table 2 Heat treatments, applications and their industrial segments.

Sl. No	Alloy/Process	Characteristics	Applications	Segments
1	**NA1 (Induction Hardened)**	Moderate wear resistance	Conveyor belt drum shafts, Cable reel drum shafts	Automotive and General Engineering
2	**NA2-N (Nitrided)**	High corrosion resistance	Track drive/idler wheel shafts	Mining
3	**NA3-NC (Nitrocarburized)**	High durability and wear resistance	Gearbox solid shafts, Track rollers	Heavy Engineering and Earthmoving
4	**NA4 (Induction Hardened)**	Enhanced wear resistance	Conveyor pulleys, Chain drive sprockets	General Machinery
5	**NA5-N (Nitrided)**	Excellent corrosion resistance	Hydraulic cylinder rods, Mining drill components	Mining and Industrial Equipment
6	**NA6-NC (Nitrocarburized)**	Balanced wear and corrosion resistance	Coupling shafts, Axle shafts	Rotational Systems and Mining
7	**NA7 (Induction Hardened)**	Superior surface hardness	Heavy-duty rollers, Structural supports	Construction and Mining Equipment
8	**NA8-N (Nitrided)**	Exceptional corrosion resistance	Oil seal sleeves, Bucket shafts	Mining
9	**NA9-NC (Nitrocarburized)**	High stress and wear resistance	Track cams, Bearing sleeves	High-Stress Applications

2. **Usage of proposed new alloy/heat treatments for the other Mining components.**

- ❖ The above table also offers valuable insights into diverse applications. Based on the operational conditions of the mining environment and its applications, components can be tailored, produced, and deployed effectively in other mining operations.

3. Commercial leverage:

1. New Vendor development opportunities:

- ❖ Promotion of MSME participation in mass production of components, creating localized and cost-efficient supply chains.

2. Market Expansion:

- ❖ Sharing these research findings will encourage more industries to explore innovative product developments.

3. Standardization:

- ❖ Develop technical specifications for manufacturing of this specific components, ensuring quality consistency and broad applicability.

4. Patent filling:

- ❖ The research findings can be very well patented.

4. Cost analysis for New bottom rollers

Table 3 : Cost analysis of New bottom rollers

Type of roller	Cost per Roller (Rs.)	Remarks
Already existing bottom roller	44,800	-
New alloy (1/2/3)	55537	Induction hardened
New alloy (1/2/3) Heat treated	87,203	Nitrided
New alloy (1/2/3) Heat treated	92870	Nitrocarburized

Note:

The cost of the nitrided and nitrocarburized compared to existing bottom rollers are high due to addition of heat treatment cost. Since we have heat treated only 3 nos of bottom rollers each in nitriding and nitrocarburizing the unit cost of heat treatment was very high. If we heat treat bulk quantities (full load capacity of the HT furnace) and if the soaking time of heat treatment has been reduced, the cost of heat treatment will be approximately 10% of the unit cost.