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Enhancing Wear Resistance of EN45 Steel Axles for Lightweight Trucks Using Detonation Sprayed Coatings

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Abstract- This study investigates the enhancement of wear resistance in EN45 steel axles, widely used in lightweight trucks but limited by poor surface durability under abrasive and fatigue conditions. The application of advanced detonation-sprayed coatings—specifically TiMo (CN) and NiCrAlY+0.4 wt% CeO_2—is explored to improve mechanical performance. Systematic wear testing and microstructural characterization aim to establish a foundation for integrating these coatings in automotive axle applications.

Keywords- EN45 steel, Axle applications, Wear resistance, Detonation gun spraying (D-Gun), TiMo(CN) coating.

I. INTRODUCTION

Lightweight truck axles are exposed to repetitive loading, frictional contact, and environmental degradation. While grey cast iron has been traditionally used, it shows limitations in wear resistance. EN45 steel, with higher tensile strength and toughness, offers a more robust structural alternative but still lacks the surface resilience necessary for long-term performance. This study investigates the application of ceramic–metallic detonation-sprayed coatings to improve the wear resistance of EN45 axle-grade components.

II. LITERATURE REVIEW

The need for superior wear-resistant coatings for steel components in transport and mechanical systems is well established. Kumar et al. [1] provided a comprehensive overview of thermal spray coatings, emphasizing the dominance of tungsten carbide (WC), chromium carbide (Cr_3C_2), and oxide ceramics such as Al_2O_3 for improving durability. These materials are selected based on their high hardness and thermal/oxidation resistance.

Several advanced coating techniques have emerged in recent years. Among them, detonation gun (D-Gun) spraying and High Velocity Oxy-Fuel (HVOF) have drawn considerable attention due to their ability to produce dense, low-porosity coatings [2], [6]. Palaniappan et al. [2] compared HVOF and detonation methods, revealing that D-Gun-sprayed Cr_3C_2–NiCr coatings offered higher hardness and bonding strength than traditional coatings, especially under dry sliding conditions.

Goyal and Chawla [3] demonstrated that NiCrAlY coatings reinforced with CeO_2 provided significant improvements in wear resistance due to microstructural grain refinement and increased oxide layer formation. This aligns with observations from Mehta and Ghosh [8], who stressed that grain uniformity, carbide phase dispersion, and minimized porosity are critical for reducing abrasive wear and fatigue under cyclic loading.

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Despite extensive work on thermal-sprayed coatings on steels like AISI 1045 and mild steel, studies addressing EN45 steel remain scarce. Sharma and Jain [4] evaluated EN45A spring steel properties under different heat treatments, identifying its high potential for fatigue and wear applications—especially when surface-treated.

Senthilkumar and Muthukumaran [5] compared APS and HVOF coatings applied to EN steel. Their analysis showed that surface hardness, coating thickness, and adhesion varied considerably with technique, impacting tribological performance. Still, their study did not include detonation coatings or EN45 substrates, indicating a gap this work aims to address.

Patel and Bhatt [7] called for greater application of coatings in commercial transport components, citing increased lifecycle costs from untreated surface wear. Voyer and Watkins [10] further emphasized how wear resistance in axle steels can directly reduce failure incidents in logistic and freight applications.

Thermal spray pioneer Berndt [9] identified detonation spraying as one of the most promising technologies for future work in structural and fatigue-critical environments—particularly where operating pressures, thermal fluctuations, and surface loadings vary drastically.

These insights collectively shape the direction of this research, which aims to evaluate the microstructure–wear behavior relationship for detonation-sprayed coatings applied to EN45 steel, addressing a clear literature gap.

III. METHODOLOGY

- Problem Formulation The wear challenges in axle systems stem from sliding contact, abrasive debris, and cyclic fatigue. Grey cast iron lacks resistance to these effects. While EN45 steel offers a stronger baseline, this research investigates how detonation-sprayed coatings can significantly elevate its surface resilience.

Objectives

- To select suitable ceramic–metallic coatings (TiMo (CN), NiCrAlY+0.4 wt% CeO_2).
- To apply these coatings using detonation spraying techniques.
- To test coated and uncoated EN45 under identical sliding and load conditions.
- To evaluate microstructure and chemical uniformity through SEM, EDS, and XRD.
- To correlate performance trends with microstructural findings.

Research Questions

- How do D-Gun coatings affect the wear behavior of EN45?
- What are the key structural factors influencing wear resistance?
- Which coating offers the optimal balance of hardness, durability, and adhesion?

VI. EXPERIMENTAL PROCEDURE

Sample Preparation

- EN45 steel cylindrical pins were cut and surface-polished with emery paper to prepare for coating.
- Each pin was cleaned ultrasonically in ethanol to remove surface residues.

Coating Process

- TiMo (CN) and NiCrAlY+0.4 wt% CeO_2 powders were deposited using the detonation spray method.
- Process parameters were kept consistent across samples to minimize variability.

Wear Testing

- Pin-on-disc tribometer used to evaluate wear resistance at 40 N, 50 N, and 60 N loads.

- Testing environment was kept dry and room temperature.
- Data recorded: wear volume loss, friction coefficient, and surface temperature rise.

Microstructure Evaluation

- Scanning Electron Microscopy (SEM) for surface morphology and crack tracking.
- Energy Dispersive X-ray Spectroscopy (EDS) for phase and element mapping.
- X-ray Diffraction (XRD) for crystal structure analysis and oxide dispersion characterization.

Data Analysis

- Wear rates and friction coefficients of each sample were statistically analyzed.
- Microstructure properties correlated against wear performance.

V. FACILITIES REQUIRED

- Detonation Gun Coating Unit
- Pin-on-Disc Tribotester
- Scanning Electron Microscope with EDS
- X-ray Diffraction Machine
- Sample polishing and preparation kits

VI. EXPECTED OUTCOMES

- Substantial improvement in wear resistance for coated EN45 over uncoated samples.
- Clear evidence of microstructural refinement, grain densification, and oxide dispersion.
- Comparative performance data to guide industrial coating decisions for axles and springs.
- Practical recommendations for commercializing D-Gun coating applications in automotive sectors.

VII. CONCLUSION

This work seeks to establish detonation-sprayed coatings as a viable enhancement strategy for EN45 steel axles. By combining systematic testing with detailed microstructural evaluation, it will provide valuable insights for both academic researchers and automotive engineers seeking improved component life under high-load conditions.

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