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Experimental Investigation and Wear Characterization of Detonation-Sprayed TiMo (CN) and NiCrAlY+CeO_2 Coatings on EN45 Steel for Automotive Applications

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Abstract- This study presents a comprehensive examination of surface coating strategies to improve the wear resistance of EN45 steel using detonation gun (D-Gun) sprayed TiMo (CN) and NiCrAlY+0.4 wt% CeO_2 coatings. EN45 is commonly deployed in automotive suspension and axle systems but suffers from poor surface durability under frictional stress. Through X-ray diffraction (XRD), scanning electron microscopy (SEM), and Energy Dispersive X-ray Analysis (EDAX), the coatings were characterized for phase composition, morphology, and structural integrity. Pin-on-disc tests were performed under dry sliding conditions with varying loads to assess wear rate and frictional behavior. The results affirm that both coatings significantly enhance performance, with NiCrAlY+CeO_2 exhibiting superior wear resistance. These findings position detonation-sprayed coatings as viable upgrades for extending the service life of EN45-based automotive components.

Keywords- EN45 steel, Detonation gun spraying (D-Gun), Wear resistance, TiMo(CN) coating, NiCrAlY + CeO_2 coating.

I. INTRODUCTION

EN45 spring steel, used widely in truck and trailer axles, exhibits high mechanical strength but poor tribological endurance under high-load cyclic conditions. Surface modification through high-performance coatings has emerged as a powerful strategy to minimize material loss, fatigue cracking, and friction-induced failure. Detonation gun spraying—recognized for its ability to create dense, high-bond-strength layers—has shown promise in creating resilient surfaces on steels in various industrial applications [1][2]. This paper examines the application and performance of TiMo (CN) and NiCrAlY+CeO_2 ceramic–metallic coatings deposited on EN45 substrates.

II. MATERIAL SELECTION AND PRE-COATING PREPARATION

- Base Material: EN45 Steel The selected base material, EN45 steel, is a medium-carbon chromium alloy steel known for spring-back ability and high fatigue strength. Its chemical composition is verified prior to experimentation and documented for consistency.
- Sample Preparation Pins were machined into standard dimensions (20 mm × 15 mm × 5 mm) and polished in multiple grit stages up to 1000 grit for smooth coating adhesion. Final polishing produced a reflective finish ensuring proper bonding of coating particles during the thermal spraying process.

- Macrostructural Inspection Visual and photographic macrographs were taken to verify surface readiness, cleanliness, and integrity of prepared EN45 pins prior to the coating stage.

III. COATING DEPOSITION USING DETONATION SPRAY PROCESS

- **Coating Materials Based on tribological performance reported in literature [5][6][7][8], two powders were selected:**
- TiMo (CN): 72% Titanium, 18% Molybdenum, 10% Carbon.
- NiCrAlY+0.4 wt% CeO_2: Multi-phase composite including Nickel, Chromium, Aluminum, Cobalt, Carbon, Yttrium, and 0.4% Cerium Oxide.

Both powders are designed for high-temperature stability, resistance to abrasive wear, and strong bonding.

- Spray System The coatings were deposited at SVX Powder M Surface Engineering Pvt. Ltd., using the Awaaz D-Gun Spray system developed in collaboration with IPMS, Ukraine. Detonation spraying provides rapid heating and acceleration of powder particles, resulting in superior densification and adhesion.
- Spray Parameters and Optimization Spraying parameters including fuel gas composition (oxygen, acetylene), carrier gas flow, and spraying distance (150–180 mm) were controlled as shown in Tables 1 to 3. These parameters were tailored for each coating to achieve optimal particle velocity and thermal energy, critical to performance.

VI. CHARACTERIZATION OF COATINGS

- Coating Thickness Measurement Thickness was monitored in real time using a Minitest-600B gauge with ±1 μm accuracy. Uniform thickness across each sample face indicated consistent deposition and process stability.
- X-Ray Diffraction (XRD) Analysis XRD analysis confirmed the presence of crystalline phases unique to each coating. TiC and Mo_3C_2 phases dominated TiMo (CN), whereas NiO, Cr_2O_3, and Al_2O_3 phases were observed in the NiCrAlY+CeO_2 coating—indicative of high-temperature oxide stability [3].
- Scanning Electron Microscopy and EDAX SEM images highlighted dense coating layers with uniform distribution of sprayed particles. Cracks and voids were minimal, validating the mechanical integrity of coatings. EDAX spectra showed elemental homogeneity and verified the presence of Ce, Mo, and Ti, which are crucial for hardness and crack resistance [9].

V. WEAR TESTING PROTOCOL

- Pin-on-Disc Setup Wear behavior was tested using a DUCOM TR-201 pin-on-disc apparatus. EN31 hardened steel discs served as counterfaces, with known composition and hardness (62–65 HRC). Testing was conducted at a track radius of 40 mm and constant sliding velocity of 1 m/s.
- Test Conditions Three loads (40 N, 50 N, and 60 N) were applied across all samples. A sliding distance of 5400 m was achieved over a total test duration of 90 minutes, in cyclic intervals. Tangential force and frictional force were recorded throughout.
- Wear and Friction Measurement Wear volume loss was calculated using recorded mass loss, with specific wear rate W=δw/(L·ρ·F)W = \delta w / (L \cdot \rho \cdot F). Coefficient of friction (μ\mu) was determined as μ=Frictional Force/Normal Load\mu = \text{Frictional Force} / \text{Normal Load}.

Results indicated 30–50% reduction in wear volume for coated pins compared to the uncoated baseline. NiCrAlY+CeO_2 consistently outperformed TiMo (CN), especially under high loads.

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VI. POST-WEAR SURFACE ANALYSIS

- Visual Examination Coated samples exhibited minimal wear scar formation, while uncoated EN45 showed noticeable deformation and material displacement.
- SEM of Worn Surfaces Worn surfaces of coated specimens showed compact oxide layers acting as secondary protection against abrasion. EDAX confirmed elemental stability post-wear, indicating chemical resilience under test conditions.

VII. CONCLUSION

This investigation confirms that detonation-sprayed coatings offer a robust solution to the wear limitations of EN45 steel. Both TiMo (CN) and NiCrAlY+CeO_2 coatings improved mechanical resilience under dry sliding conditions. The Ni-based composite coating demonstrated superior wear resistance due to oxide reinforcement and enhanced microstructural uniformity. These coatings show strong potential for extending the life of EN45-based axles and springs under automotive conditions.

REFERENCES

1. Kumar, A., Singh, R., and Bansal, V., "Wear behavior of thermal spray coatings: A review," Surface Engineering, 35(5), 351–366, 2019.
2. Palaniappan, S., Suresh, K. S., and Venkatesan, P., "Evaluation of detonation gun sprayed Cr_3C_2–NiCr coatings," J. Mater. Eng. Perform., 29(10), 6980–6992, 2020.
3. Goyal, H., and Chawla, A., "Microstructure and wear behavior of NiCrAlY coatings reinforced with CeO_2," J. Alloys Compd., 812, 152086, 2020.
4. Sharma, R., and Jain, V. K., "EN45A spring steel characterization," Materials Today: Proceedings, 46, 8784–8789, 2021.
5. Samur, F., "Comparative study on D-Gun and HVOF coatings," Coatings Technology, 204(6), 756–762, 2010.
6. Demir, A. G., "Processing and performance of thermal sprayed coatings," Journal of Thermal Spray Technology, 17(5), 668–676, 2008.
7. Murthy, L. N., and Murthy, B. S., "Microstructure and wear resistance," Surf. Coat. Technol., 201(9–11), 5085–5092, 2006.
8. Sundararajan, G., et al., "Tribological properties of ceramic coatings," Mater. Sci. Eng. A, 379, 361–368, 2004.
9. Mehta, R. K., and Ghosh, S., "Microstructure-wear correlation in carbide coatings," Surface and Coatings Technology, 337, 195–204, 2018.
10. ASTM