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Investing Wear Resistance Of EN-45 Steel through Detonation - Sprayed Coatings : A Study Of Timo(CN)and NiCrALY+0.4 wt%CeO2

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Abstract
This research investigates the wear behavior of uncoated EN-45 steel and detonation-sprayed TiMo (CN) and NiCrAlY+0.4 wt%CeO_2 coatings on EN-45 substrates. The detonation gun spray process was utilized to successfully deposit the coatings, which were subsequently characterized by SEM, EDAX, and XRD analyses. Wear tests, conducted under normal loads of 40N, 50N, and 60N, revealed that coated materials exhibited significantly lower cumulative volume loss compared to uncoated samples. Among the coatings, NiCrAlY+0.4 wt%CeO_2 demonstrated superior wear resistance, lower cumulative volume loss, and higher bonding strength. These findings suggest that detonation-sprayed NiCrAlY+0.4 wt%CeO_2 coatings are highly effective in enhancing the wear resistance of EN-45 steel and can be applied in high-wear applications, particularly in the automotive industry for components like axles. Future research could explore the long-term performance and cost-effectiveness of these coatings in real-world applications.

1 Introduction

Wear resistance is a critical factor in the performance and longevity of mate- rials used in various industrial applications. Components that are subjected to high mechanical stresses, such as those in the automotive, aerospace, and manufacturing industries, require materials that can withstand wear and tear to maintain their functional integrity. Over the years, numerous studies have focused on developing coatings that enhance the wear resistance of base mate- rials.

EN-45 steel is widely used in applications requiring high wear resistance due to its excellent mechanical properties. However, uncoated EN-45 steel is prone to significant wear under harsh operating conditions. To address this issue, various coating methods have been explored to enhance its wear resistance.

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Among these methods, the detonation gun spray process has gained attention for its ability to deposit dense and durable coatings.
This study aims to evaluate the wear behavior of uncoated EN-45 steel and compare it with detonation-sprayed TiMo (CN) and NiCrAlY+0.4 wt%CeO_2 coatings. The detonation gun spray process is utilized for coating deposition, and the coatings are characterized using Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Analysis (EDAX), and X-ray Diffraction (XRD) tech- niques. Wear tests are conducted using a pin-on-disc apparatus under varying loads to assess the wear resistance of the coatings.

2 Literature Review

Numerous studies have explored the enhancement of wear resistance through various coating techniques. This literature review provides an overview of the key findings and methodologies in this field.

2.1 Wear-Resistant Coatings

Cueva (2003) investigated the wear behavior of different coatings and high- lighted the importance of using materials with high wear resistance in indus- trial applications. The study emphasized that coatings play a significant role in extending the lifespan of components subjected to harsh environments . Demir (2008) conducted research on coatings designed for wear resistance and con- cluded that selecting appropriate coating materials can significantly enhance the durability of substrates . The study also demonstrated the effectiveness of coatings in reducing wear rates under varying operational conditions. Samur (2010) reviewed various coating materials and their properties, focusing on the advancements in coating technologies . The research highlighted the potential of new materials in providing superior wear resistance and extending the lifespan of coated components.

2.2 Detonation Spray Coatings

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The detonation spray process has been extensively studied for its ability to deposit dense and durable coatings. Mohanty (1996) discussed the versatility of the detonation gun spray process in depositing coatings on various substrates, which significantly enhances wear resistance . Murthy & Venkataraman (2006) explored assessments of the coating's uniformity.

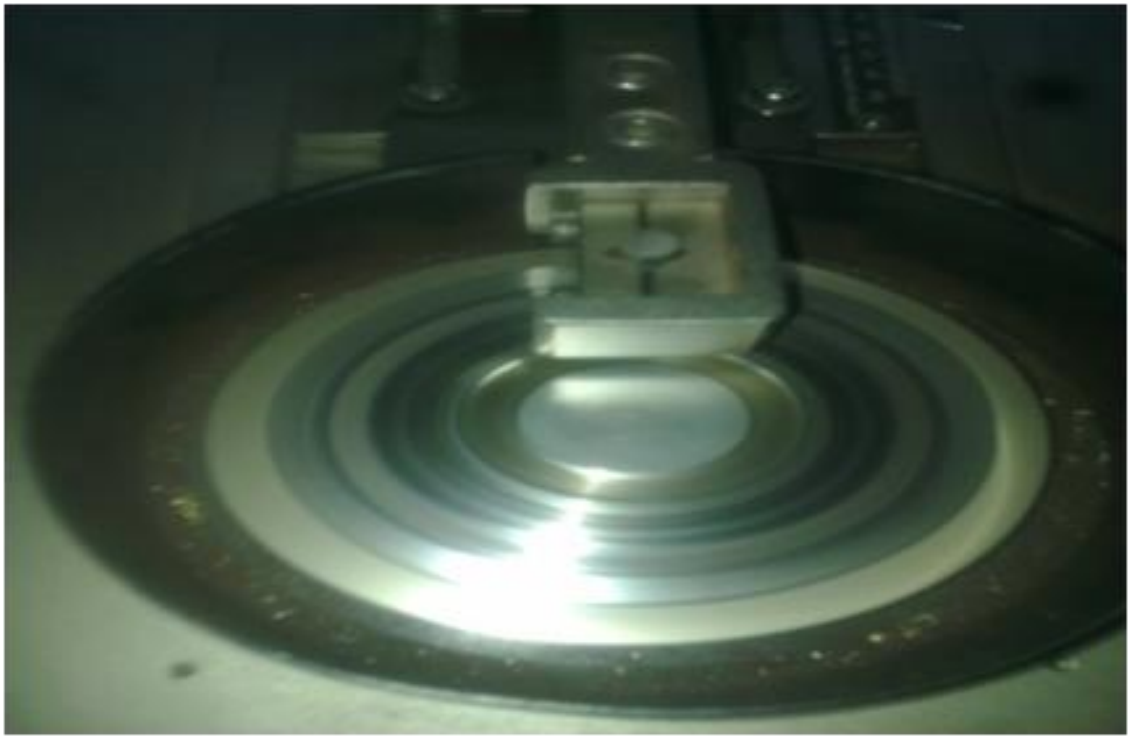
2.3 Wear Study Using Pin-on-Disc Machine

Wear tests were conducted under different loads using a pin-on-disc machine. The wear and friction characteristics were

examined for both uncoated and coated samples, providing essential insights into the coatings' effectiveness.

Table 1: Chemical composition (wt %) of the EN-31 carbon steel disc

Element	C	Si	Mn	P	S
Composition (wt %)	0.42 (max)	0.05-0.35	0.40-0.70	0.05 (max)	0.05 (max)



(a) Carbon steel disc with pin fitted into it

(b)Complete set-up of Pin-on-disc wear test machine with control unit and computer

Figure 1: (a) Carbon steel disc with pin fitted into it. (b) Complete set-up of Pin-on-disc wear test machine with control unit and computer.

3 Results

The results of wear tests are summarized in Table 2.

Table 2: Cumulative Volume Loss for Various Coatings

Coating	Load (N)	Time (min)	Initialwt. (gms)	Finalwt. (gms)	Cum. Wt. Loss (gms)	Cum. VolumeLoss (mm^3)
Uncoated	40	90	19.2276	14.5176	4.71	0.6
Uncoated	50	90	14.5176	9.0226	5.495	0.7
Uncoated	60	90	9.0226	3.1351	5.8875	0.75
TiMo (CN)	40	90	15.2202	12.1002	3.1	0.4
TiMo (CN)	50	90	12.1002	3.875	8.2252	0.5
TiMo (CN)	60	90	8.2252	3.9627	4.2625	0.55
NiCrAlY+0. wt%CeO2	40	90	10.7202	8.2002	2.52	0.3
NiCrAlY+0. wt%CeO2	50	90	8.2002	5.2602	2.94	0.35
NiCrAlY+0. wt%CeO2	60	90	5.2602	2.1522	3.108	0.37

4 Discussion

Selection of material, coating, and the wear behavior of uncoated EN-45 as well as detonation-sprayed TiMo (CN) and NiCrAlY+0.4 wt%CeO2 coatings have been discussed in detail. The TiMo (CN) and NiCrAlY+0.4 wt%CeO2 coatings have been successfully deposited on EN-45 substrates via the detonation spray process. SEM/EDAX analyses showed the presence of O and C on the surface, which may be due to the formation of carbide. XRD analysis supports the SEM results. The coated specimens showed significantly lower cumulative volume loss compared to bare materials under normal loads of 40N, 50N, and 60N.

4.1 Results Interpretation of EN-45 Uncoated

The cumulative volume loss data indicates that uncoated EN-45 steel exhibits consistent wear characteristics under different loads. Higher loads result in greater cumulative volume loss due to increased contact pressure and friction.

4.2 Comparison of Coatings

The data comparison highlights the superior performance of the NiCrAlY+0.4 wt% CeO2 coating. It showed the lowest cumulative Volume Loss (CVL) across all loads and time intervals. The TiMo (CN) coating also provided notable wear resistance, while the uncoated EN-45 steel exhibited the highest wear loss, indicating the importance of protective coatings.

The following graph illustrates the cumulative volume loss of various coatings under different loads:

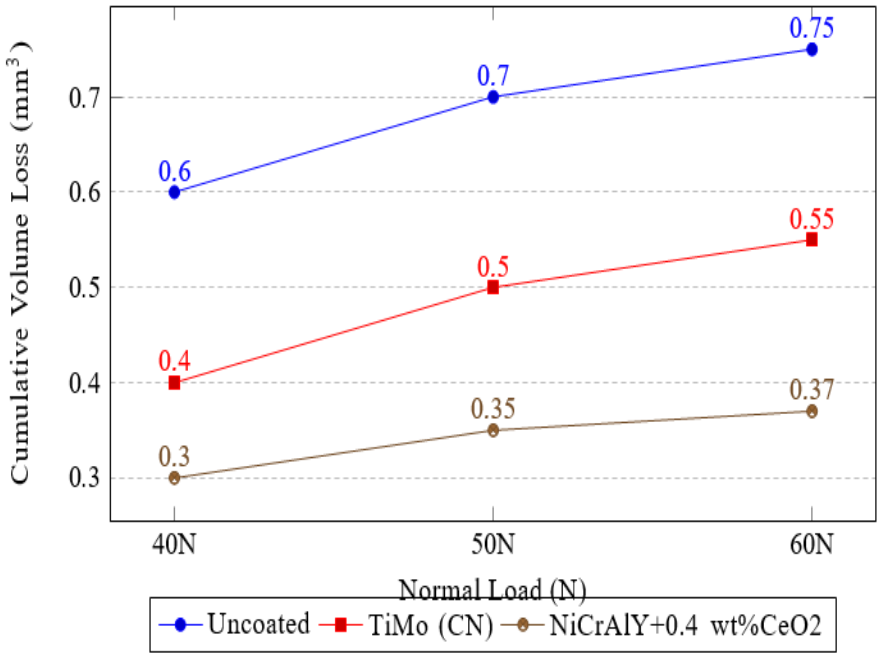


Figure 2: Cumulative Volume Loss of Various Coatings under Different Loads

4.3 Reasons for Preferring NiCrAlY+0.4 wt% CeO2 Coat- ing

1. **Superior Wear Resistance**: The NiCrAlY+0.4 wt% CeO2 coating sig- nificantly reduces wear and tear, extending the lifespan of the substrate material.
2. **Lower Cumulative Volume Loss**: The data clearly shows that this coating has the lowest CVL, making it the most effective in protecting the substrate.
3. **High Bonding Strength**: Ensures that the coating remains intact under high loads and stress, providing consistent protection.
4. **Material Composition**: The combination of Ni, Cr, Al, Y, and CeO2 creates a robust and durable coating that can withstand harsh conditions.
5. **Application Suitability**: Ideal for components that experience high wear, such as the axles of light trucks, due to its excellent wear resistance and bonding strength.

5 Conclusion

This research successfully demonstrated the benefits of using detonation-sprayed TiMo (CN) and NiCrAlY+0.4 wt%CeO2 coatings to enhance the wear resistance of EN-45 steel. The wear tests performed under various loads revealed signifi- cantly lower cumulative volume loss in coated specimens compared to uncoated ones. Among the coatings tested, NiCrAlY+0.4 wt%CeO2 exhibited the best performance, making it a promising candidate for high-wear applications such as automotive components.

6 Acknowledgments

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7 Appendices

7.1 Data Tables and Extended Results

Additional data supporting the findings reported in this study can be found in the following tables. This includes detailed measurements of wear tests across different loads and materials.

Table 3: Extended Data on Wear Resistance

Coating	**Load (N)**	bfTime (min)	**Initialwt. (gms)**	**Finalwt. (gms)**	**Cum. Wt. Loss (gms)**	**Cum. Volume Loss (mm^3)**
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