



GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી

(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

Accredited with A++ Grade by NAAC

Abstract of the Thesis



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Discipline/Branch: Mechanical Engineering

Title of the Thesis: Investigations on Characteristics and Tribological Performance of Graphene Nanoplatelets and Nano-CeO₂ Reinforced Cr₃C₂-NiCr Coatings

Abstract

• **Content of the Abstract**

This investigation focuses on improving the microstructural, mechanical, and tribological performance of HVOF-sprayed Cr₃C₂-NiCr coatings by incorporating graphene nanoplatelets (GNP) and Ceria-based nano-reinforcements. The research investigates the effects of different reinforcements on coating characteristics, such as porosity, surface roughness, microhardness, fracture toughness, and tribological parameters, including coefficient of friction and specific wear rate.

• **Research Problem**

Cr₃C₂-NiCr coatings can potentially serve as a substitute option for WC-Co-based coatings. However, they face challenges such as decarburization of carbide phases, porosity, and inadequate hardness and fracture toughness, which can limit wear performance. Therefore, reinforced Cr₃C₂-NiCr coatings need to be developed with improved microstructural integrity, mechanical properties, and resistance to severe tribological conditions.

• **Methodology followed for research**

- Five Cr₃C₂-NiCr coating compositions were developed using GNP, nano/micro-CeO₂, and Y₂O₃-doped nano-CeO₂ reinforcements.
- A novel powder-mixing process involving ultrasonication, magnetic stirring, oven drying and 3D tumbling was developed to obtain uniform reinforcement dispersion. The coatings were deposited on SS304 substrate using HVOF, with identical spray parameters.
- Feedstock powders and coatings were characterized using FE-SEM/EDS, TEM, XRD, Raman spectroscopy, and optical profilometry.
- Coating properties such as porosity, surface roughness, microhardness, and fracture toughness were evaluated. Dry sliding wear tests were performed using a ball-on-disc tribometer, followed by FE-SEM/EDS analysis of worn surfaces to determine the prevailing wear mechanisms.

• **Outcome of the research**

The study demonstrated that nano-reinforcements can significantly improve the performance of Cr₃C₂-NiCr coating by:

- Successful mixing of coating powders and nano-reinforcements with uniform dispersion



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- Coating deposition of the composite feedstock powders with the conventional method and spray parameters
- Refining the coating microstructure and reducing decarburizing and porosity, also improving hardness and fracture toughness.
- Providing reinforcement-specific strengthening and toughening mechanisms
- Providing solid lubrication through the layered structure of GNP and promoting protective tribo-oxide film formation during sliding.
- Demonstrating that nano-sized reinforcements are more effective than micro-sized reinforcements.
- Showing a synergistic improvement in properties and wear performance with combined GNP and nano-CeO₂ reinforcement.

• Application

The developed reinforced Cr₃C₂-NiCr coatings have potential for use in engineering components exposed to severe wear conditions, particularly in turbines, valves, boilers, and aerospace systems. Improved wear and friction behaviour in these components can consequently lead to longer component lifespan, higher productivity, energy savings, and reduced CO₂ emissions.

This PhD Thesis would be useful for providing a practical approach for developing a mixing process to blend the different combinations of coating powders and nano-reinforcements with uniform dispersion and for depositing the coatings with existing conventional HVOF spray deposition set-up. The investigation also exhibits that the developed reinforced Cr₃C₂-NiCr coatings demonstrate improved coating properties and tribological performance, which places the coating as potential alternate to the WC-Co-based coatings. The study also presents the underlying mechanisms through which the nano-reinforcement materials enhance the coating performance.

List of Publications:

- 1) H. R. Chauhan, A. Solanki, S. Variya, and S. Saladi, "Investigating the Tribological Performance of Cr₃C₂-NiCr Coatings Reinforced with Nano-Yttria-Doped Ceria," Transactions of the Indian Institute of Metals, vol. 78, no. 7, p. 156, 2025, doi: <https://doi.org/10.1007/s12666-025-03633-8>.
- 2) H. R. Chauhan, A. Solanki, S. Variya, and S. Saladi, "Development of Graphene Nanoplatelets Reinforced HVOF Sprayed Cr₃C₂-NiCr Coatings," Journal of Thermal Spray and Engineering, vol. 4, p. 81-86, 2024, <https://doi.org/10.52687/2582-1474/401>
- 3) H. R. Chauhan et al., S. Saladi, S. Variya, A. Solanki, S. Tailor, K P Sooraj, M Ranjan, S Joshi, "Role of micro-and nano-CeO₂ reinforcements on characteristics and tribological performance of HVOF sprayed Cr₃C₂-NiCr coatings," Surface and Coatings Technology, vol. 467, p. 129684, 2023, doi: 10.1016/j.surfcoat.2023.129684.