STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 1, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc

Research JoPC

Experimental Analysis of Residual Stress, Micro-Hardness and Corrosion Behavior of HVOF Sprayed Composite Coating

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Abstract

The utilisation of non-traditional composite coating materials, enhanced lubrication, and surface geometry optimisation have all contributed to the tribological performance. Piston rings are among the most crucial engine parts since friction causes between 40 and 45 percent of all energy loss. Fuel efficiency, power loss, and exhaust pollutants are all strongly impacted by the piston assembly's tribological performance. The present study's primary goal was to develop composite coating by using HVOF process. The composite coating's characteristics showed a notable improvement, as evidenced by an approximate 12.5% rise in micro-hardness and an 80% decrease in residual stress. A significant reduction in mass loss of the coated sample was also demonstrated by the corrosion test findings, with reductions of roughly 75.2% after 0.5 hours, 53.1% after 1.5 hours, and 42% after 2.5 hours of exposure. After a high-temperature wear test, the mass loss of the as-deposited composite coatings was measured using an electrochemical procedure that contained 3.5 weight percent NaCl for the corrosion test. The present study's primary goal was to use the HVOF technology to create a composite coating. The composite coating shows 320-380 HV micro-hardness and -10 to -55 MPa residual stress. The present observation is in line increase in the hardness of composite coatings. The production of carbide layers, and the development of oxides on the piston rings are all responsible for the abrupt increase in micro-hardness. Furthermore, as the temperature rises under test circumstances, thermal stress increases but structural stress decreases and compressive stress increases. Consequently, a decrease in residual stress is brought on by a rise in thermal stress.

Keywords: Composite; corrosion test; residual stress, micro-hardness, composite coating

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Received Date: September 03, 2024
Accepted Date: September 21, 2024
Published Date: December 05, 2024

Citation: Ankit Tyagi, Peeyush Vats, Rekha Nair, Sangram keshari Das, Mohd. Shahid, Amit Meena. Experimental analysis of Residual stress, micro-hardness and corrosion behavior of HVOF sprayed composite coating. Journal of Polymer & Composites. 2025; 13(Special Issue 1): S77–S82p.

INTRODUCTION

The utilisation of non-traditional composite coating materials, enhanced lubrication, and surface geometry optimisation have all contributed to the tribological performance. Piston rings are among the most crucial engine parts since friction causes between 40 and 45 percent of all energy loss. Fuel efficiency, power loss, and exhaust pollutants are all strongly impacted by the piston assembly's tribological performance. The literature indicates that surface modification, lubrication regimes, and surface topography optimisation are typically used to improve components performance [1-4]. The two most important techniques for lowering wear and friction are surface engineering and modification. Numerous surface modification approaches have been suggested by extensive research to enhance the tribological properties of piston rings [5-8]. The most well-liked techniques for creating composite coatings that improve the chemical, mechanical, and tribological qualities of the piston rings while maintaining their original geometry are thermal spray and HVOF deposition. The thermally sprayed nanocermets [9], multilayer composite coatings [10], and composite coatings, have recently been assessed using reciprocating and rotating testing. Studies comparing the plasma and flame spraying techniques show that the plasma spraying method offers better microstructural integrity, lower porosity, and higher particle velocity. Hard ceramic particles, diamond, SiC, and other materials can be added to the composite coatings to further improve their tribological and mechanical properties [11, 12].

Particularly at temperatures up to 700°C, plasma-sprayed CRC composite coatings—which are renowned for their high hardness, and low internal stresses, have drawn a lot of interest [13–16]. HVOF composite coating is especially preferred because it maintains low porosity while producing highly adherent composite coatings with less than 1% oxide content [17–19]. The aim present study:

1. Deposition of composite coating for wear resistance application
2. Evaluation of micro-hardness, residual stress, and corrosion test of composite coating.

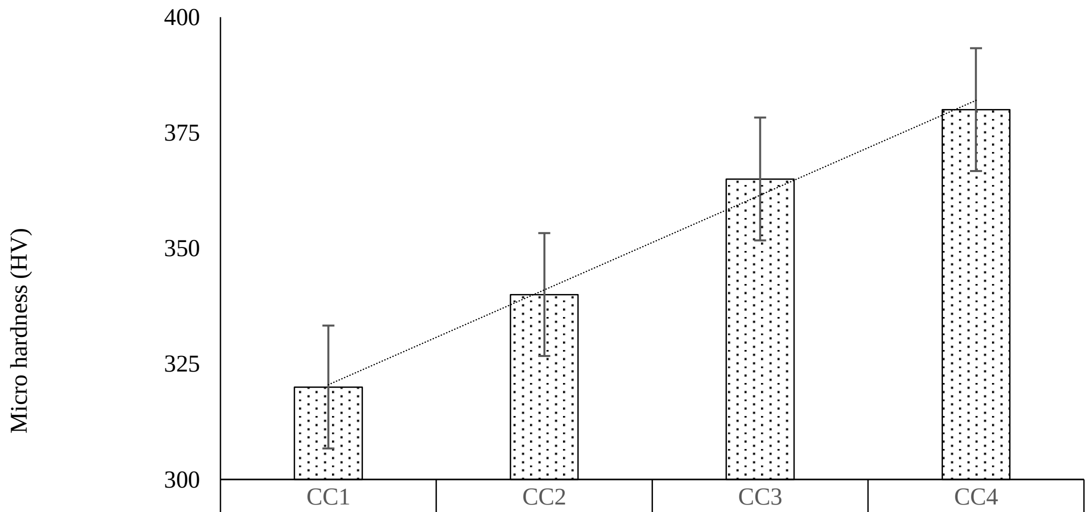
EXPERIMENTAL PROCEDURE

Initially, 500–3000 grit sandpaper was used to cut and polish steel plates with dimensions of 750 × 75 × 3 mm. Next, SiC additive layers were applied using the PR-9182 type pressure blaster manufactured by MEC. The composite coating was subsequently developed by depositing the resultant composite powder using a HIPOJET-2700M HVOF system, which sprays at supersonic speeds. A Vickers hardness tester was used to determine the composite coatings' microhardness, and a stress analyser was used to evaluate any internal residual stresses. Using an electrochemical approach in an electrolytic solution, the mass loss of the composite coatings was calculated for the corrosion test.

EXPERIMENTAL RESULTS

Micro-Hardness

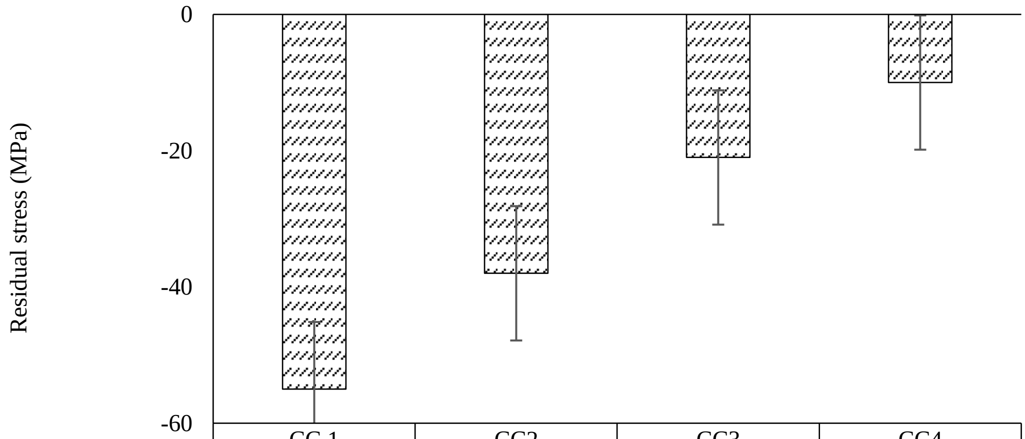
According to Figure 1, which depicts micro-hardness of composite coatings, which quickly increased from 320 HV to 380 HV as the testing parameters were raised. A 12.5% improvement was found in the micro hardness test results. The present observation is in line with the research conducted by Tyagi et al. [20]. increase in the hardness of composite coatings. The production of carbide layers, and the development of oxides on the piston rings are all responsible for the abrupt increase in micro-hardness [21-22].



	CC1	CC2	CC3	CC4
Micro-hardness	320	340	365	380

Figure 1. micro-hardness Vs composite coating graph

Journal of Polymer & Composites
Volume 13, Special Issue 1
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)



	CC 1	CC2	CC3	CC4
Residual stress	-55	-38	-21	-10

Composting coating

Figure 2. Residual stress Vs composite coating graph

Residual Stress

The composite coatings' residual stress data are shown in Figure 2, which shows a sharp decline in residual stress from -55 MPa to -10 MPa. An eighty percent reduction in residual stress was shown in the test findings. Furthermore, as the temperature rises under test circumstances, thermal stress increases but structural stress decreases and compressive stress increases [20-24]. Consequently, a decrease in residual stress is brought on by a rise in thermal stress. The distribution using different colour combinations shows residual stress concentrations is depicted in Figure 3. The present observation is in line increase in the hardness of composite coatings.

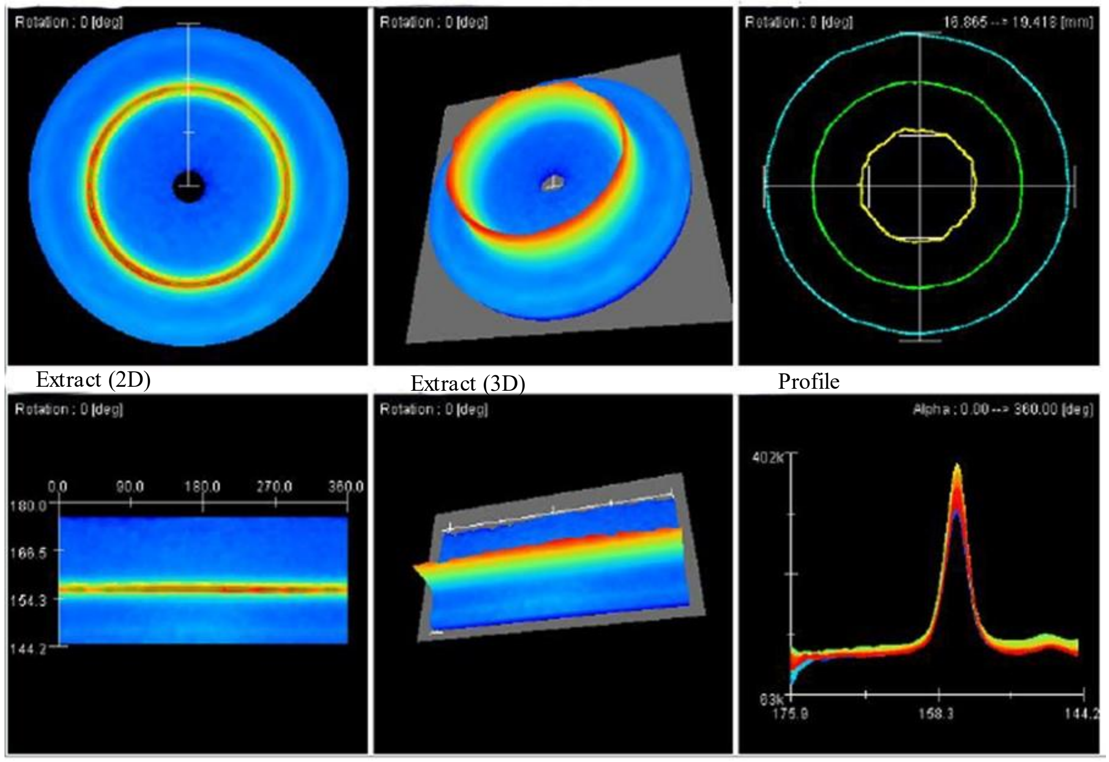


Figure 3. Residual stress distribution.

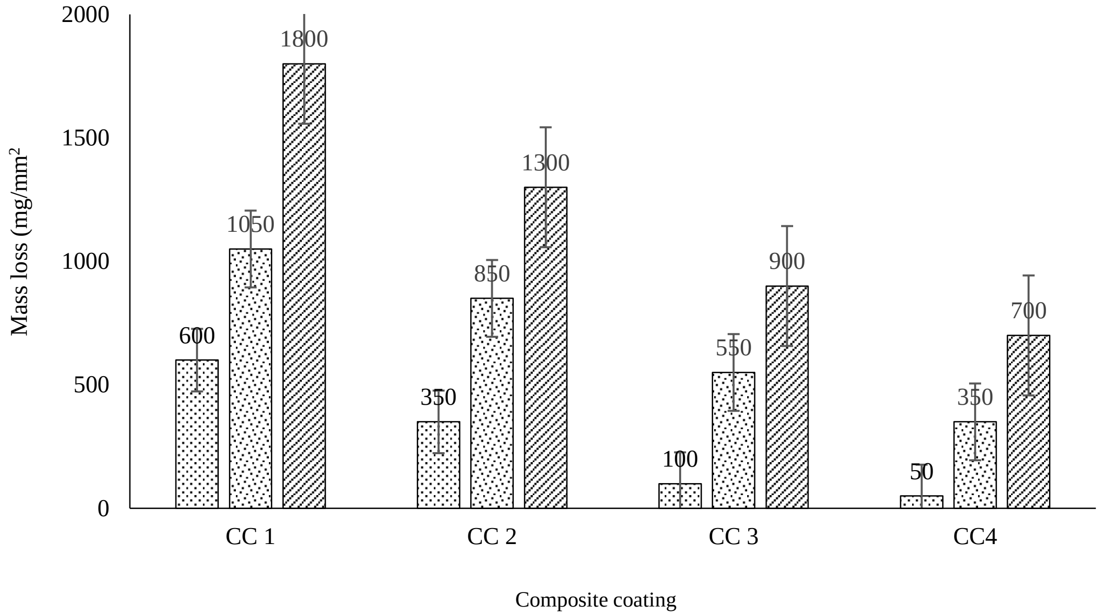


Figure 4. Corrosion test result

Corrosion Test

After a high-temperature wear test, the mass loss of the as-deposited composite coatings was measured using an electrochemical procedure that contained 3.5 weight percent NaCl for the corrosion test. Figure 4 displays the experimental findings from the wear test. Coatings with a crystalline structure have been found to provide better corrosion resistance than those with an amorphous structure, as reported by Ali et al. [25]. Hukovic et al. [26]. and Singh et al. [27]. According to the corrosion test results, the as-deposited sample's overall mass loss per unit area dropped by roughly 75.2% after 0.5 hours, 53.1% after 1.5 hours, and 42% after 2.5 hours of exposure.

CONCLUSIONS

The present study's primary goal was to use the HVOF technology to create a composite coating. The composite coating shows 320-380 HV micro-hardness and -10 to -55 MPa residual stress. The composite coating's characteristics showed a notable improvement, as evidenced by an approximate 12.5% rise in micro-hardness and an 80% decrease in residual stress. A significant reduction in mass loss of the coated sample was also demonstrated by the corrosion test findings, with reductions of roughly 75.2% after 0.5 hours, 53.1% after 1.5 hours, and 42% after 2.5 hours of exposure. The production of carbide layers, and the development of oxides on the piston rings are all responsible for the abrupt increase in micro-hardness. Furthermore, as the temperature rises under test circumstances, thermal stress increases but structural stress decreases and compressive stress increases. Consequently, a decrease in residual stress is brought on by a rise in thermal stress.

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