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Microstructure Characteristics and Properties of NiCrMoFeCoAl-30%SiO_2 Composite Coating on T22 Boiler Tube Steel

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Abstract

In the present investigation, the NiCrMoFeCoAl-30%SiO_2 composite coating was sprayed on T22 bare steel with the HVOF technique. HVOFtechniqueallows the production of dense, excellently structured coatings with smoother surfaces and enhanced mechanical properties of the boiler materials. The produced coatings are characterized for their microstructure, and corrosion resistance by high-temperature corrosion.The specimen microstructure has been characterized by SEM/EDS and XRD methods. The coating thickness, porosity, microhardness, and coating density have been assessed.

Keywords: *SEM/EDS Technique, Thermal spraying*

1.0 Introduction

As a result, the variables of porosity variability and heat treatment are related to the values of microhardness [1]. Premkumar and Balasubramanian [2] were investigated the behaviour of HVOF-sprayed (27% Cr_3C_2-23% Ni-50% Cr) coatings on SA 210 Grade C boiler material at high temperatures and their mechanical characteristics. The characterization of coatings is porosity, microstructure, coating thickness, and microhardness. SEM/EDS and XRD methods are employed to examine the as-sprayed coatings. Thermal spraying is considered effective to install a preservative coating, without affecting any other material of the material [3-6]. The carbide ceramic peak has a substantial effect on wear resistance, but the NiCr matrix allows for corrosion resistance [7]. Senthilkumar et al. [8] studied the effect of thermal cycle on HVOF sprayed NidCr coating in boiler tubes. NiCr nanostructured coatings revealed higher metallurgical and mechanical properties than conventional coatings. According to the findings of the experiments, the nanostructured coated samples had a denser and more uniform microstructure than the traditional ones. XRD, HR-TEM, microhardness test, and SEM/EDAX techniques are used to characterize the HVOF coated sample and feedstock powder. Several investigations have evaluated entire coating designs [9-13]. Song et al. [14] studied the high-temperature oxidation behaviour and microstructure of HVOF (gas and liquid-fuelled) sprayed Ni50Cr coated ASME P92 alloy in thermal power plants. The kinetics of the oxidation were examined by thermogravimetric analysis. The porosity and microstructures of the two coatings were investigated using oxygen content analysis, mercury intrusion porosimeter, XRD, and SEM/EDAX methods. In high-temperature environments, HVOF coatings exhibit great durability, strong

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bond strength, and corrosion resistance [15-16]. Vasudev et al. [17] studiedthe bi-layer Alloy-718/NiCrAlY coated grey cast iron substrate's high-temperature oxidation and erosion behaviour was observed using HVOF spraying. The oxidized products are characterized using microhardness tests, SEM/EDAX, and XRD methods. Various studies have recommended that hot-rolled cermet with a high fine-grained carbide can have better wear and tear [18]. Zhang et al. [19] investigated the Isothermal Oxidation of the HVOF (kerosene-fuelled) sprayed Ti_2AlC coatings. SEM, optical microscope, and XRD techniques investigated coatings' cross-sectional microstructure and surface morphology.

The present work used the HVOF technology to produce the NiCrMoFeCoAl-30%SiO_2 composite coating on T22 steel. The as-sprayed coatings were characterized using XRD and SEM/EDS techniques. The primary goal of this research was to find a suitable covering for protecting bare T22 steel.

2 Experimental Section

2.1 Substrate Material

In the present examination, T22 steel has been identified as the bare material. Specimens for exposure experiments were sectioned from T22 substrate steel in square (25mm × 25mm × 5mm) forms. Before HVOF formulation, sectioned specimens were grit blasted with Al_2O_3. During spraying, the drum jigs were turned on a turntable to achieve uniform coating with a minimized edge effect. The nominal chemical composition of T22 substrate steel is shown in Table 1.

2.2 Formulation of the Coating

The HVOF technique was used to apply a composite coating of NiCrMoFeCoAl-30%SiO_2 on the T22 bare steel. The particle size of the coating powder is –45+15 m. Steel tubes used in boiler construction are subjected to high temperatures [37]. Table 2 lists the powder compositions used in the present investigation.Throughout the coating process, all of the usual spray parameters and the spray distance were kept constant. The achieved average coating thickness was 197 µm.The coatings were applied to the basic metal's six edges.The grit blasting was done to achieve a fine surface roughness and encourage the greatest possible adherence between bare and coating.The specimens' microstructure and compositions are premeditated using SEM and EDS techniques.The coating phases were examined using the XRD method.

2.3 SEM Analysis NiCrMoFeCoAl-30%SiO_2 Powder

Figure 1 depicts the SEM morphology and surface composition distribution of the powders based on EDS investigation.With certain bigger crystallites, the typical particle size distribution varies from 15 to 55 µm. The EDS mapping shows the distribution of elements in the particles, with Ni, Si, and Cr being the most abundant.

2.4 Coatings Characterization Techniques

Based on ASTM B 276 and an image analyzer (Metaplus software), the porosity of the composite coatings is calculated. The porosity of coated steel was calculated for each sample using the mean value of the eight values. A cross-sectional micrograph of coating was made possible with the aid of the SEM. The coating thickness is assessed using an inverted metallurgical microscope (Olympus BX53M Upright metallurgical microscope). The Micro Vickers Hardness tester (VH1102) was used to measure the microhardness of the coatingat eight distinct points on the coated cross-section sample under a 300g load. The samples were sectioned, mounted in transoptic powder, and polished after the surface characterization procedures. A mirror finish was made possible

Table 1: Chemical composition (wt%) of T22 bare steel

Fe	Ni	Cr	Ti	Al	Mo	Mn	Si	C
Bal.	-	2.55	-	-	1.10	0.52	0.43	0.14

Table 2: Chemical composition (wt. %) of the composite coatings

HVOF coating	Ni	Cr	Mo	Fe	Co	Al	SiO_2
NiCrMoFeCoAl-30%SiO_2	39.9	15.4	2.1	4.9	4.2	3.5	30

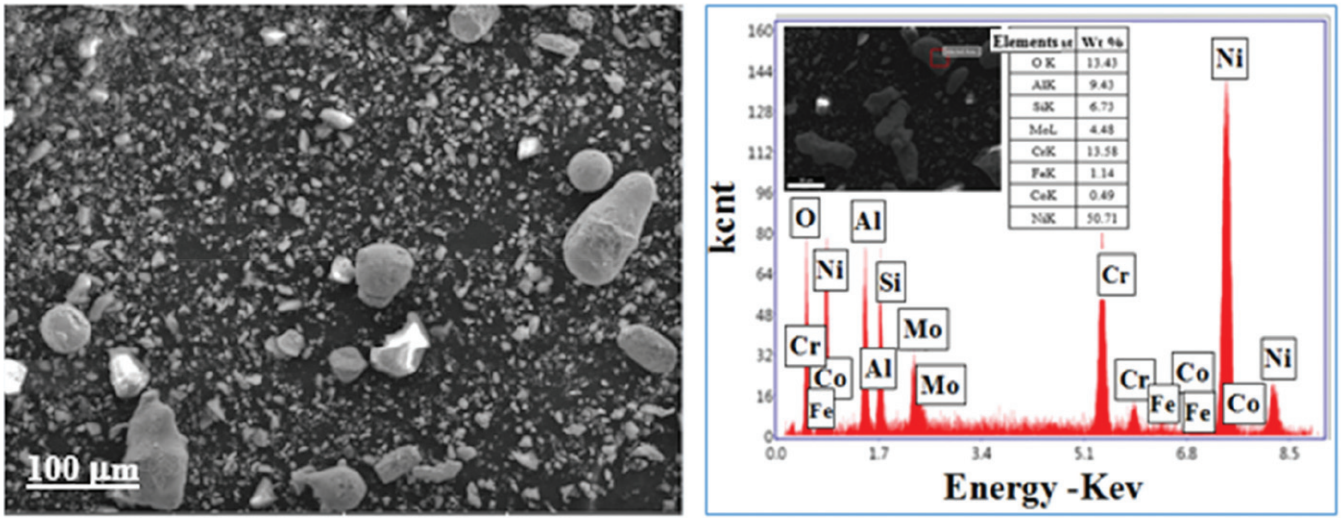

Figure 1: SEM image and EDS spectra of NiCrMoFeCoAl-30%SiO_2composite powder

with the assistance of the diamond paste (0.3 µm). The coated and bare surfaces underwent XRD investigation using the X-Ray diffractometer. It maneuvers at 40 kV and 30 mA employing CuK radiation. Within the 2θ range of 10° to 80°, the specimens were scanned. The surface, cross-sectional composition, and morphologies of coated and bare samples are characterised using the SEM/EDAX techniques.

3 Results and discussions

3.1 Characterization for As-deposited Coating

The optical microscope has estimated the coating thickness to be 200 µm. Figure 2 depicts the microhardness of an HVOF composite coating. With a load of 300g and a dwell time of 10 s, microhardness tests were carried out on a coated specimen along the cross-section employing the model VH1102. The T22 bare steel has a microhardness of around 270.$HV_{0.3}$. It has been established that the NiCrMoFeCoAl-30%SiO_2 composite coating has typical microhardness value of around 801.9$HV_{0.3}$. These coating have a porosity of less than 1.6%. Table 3 summarizes the coating characterizations.

3.2 XRD analysis of the As-sprayed Coating

Figure 3 shows the XRD diffractograms of blended powder and as-sprayed coating. The principal reflections of the blended powder and coated specimens are substantially identical. Major phases in NiCrMoFeCoAl-30%SiO_2 blended powder and as-sprayed coating are assigned to Al_2SiO_5, MoNi, and minor phases are attributed to Fe_2O_3. It has been stated on the coating's brief oxidation phase after being pre-oxidized with an Al_2O_3 phase protective oxide scale.

3.3 Surface Morphology of the As-sprayed HVOF Coating

Figure 4 shows a SEM image of the as-sprayed composite NiCrMoFeCoAl-30%SiO_2 coating. The elemental distribution of the specified domain and point surface is presented. The microstructure of the HVOF coating was found to be mostly homogeneous and packed tightly. The existence of substantial elements Si, Al, and Ni is confirmed by the EDS

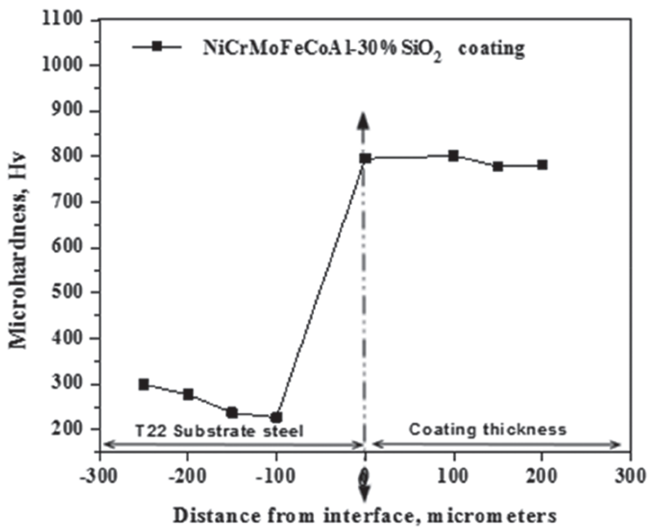

Figure 2: Microhardness profile for HVOF coating throughout the cross-section

Table 3: Variation of porosity, microhardness, and coating thickness of coated sample

HVOF coating	Porosity (%)	Vickers Microhardness, VHN ($HV_{0.3}$)	Coatingthickness (mm)
NiCrMoFeCoAl-30%SiO_2	1.69	801.9	197

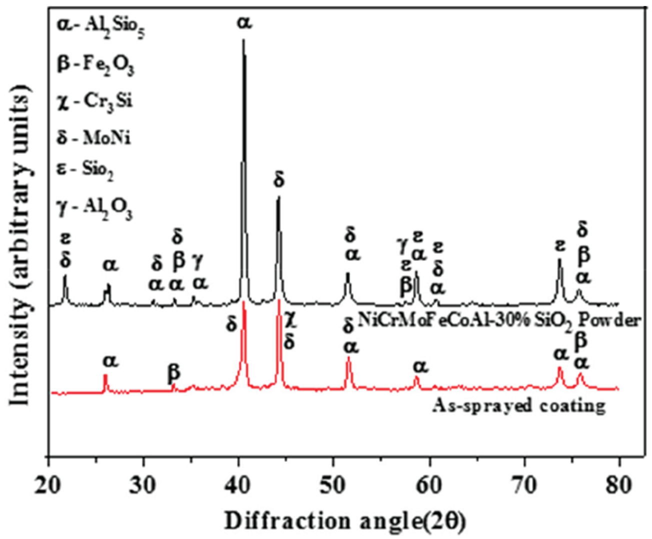

Figure 3: XRD diffractogramsof feedstock powder and as-sprayed NiCrMoFeCoAl-30%SiO_2 composite coating

analysis of the as-sprayed NiCrMoFeCoAl-30%SiO_2 coating at chosen region 1. Along with oxygen, the EDS spot 1 also shows the existence of Al, Si, and Mo.

3.4 Cross-sectional Analysis of the As-sprayed Coating

Figure 5 shows the BSEI of cross-sectional morphology and associated EDS analysis of the HVOF as-sprayed composite coating. For long-term stability, the HVOF's adherence to the bare steel is additional crucial factor. In the cross-section image, the HVOF coating has homogenous and compact splat-like characteristics, and the bare/HVOF coating interface seems hard and undamaged. The Ni, Mo, and Fe components are present in just trace amounts at point 1 of the cross-sectional HVOF as-sprayed NiCrMoFeCoAl-30%SiO_2 coating, which is mostly composed of Cr, Al, and O. Point 2 has a high concentration of Si, Cr, and Ni scales. The interface between the coating and the T22 bare steel is described in Point 3, which implies that the primary amounts of Ni, Cr, and O scales are noted.

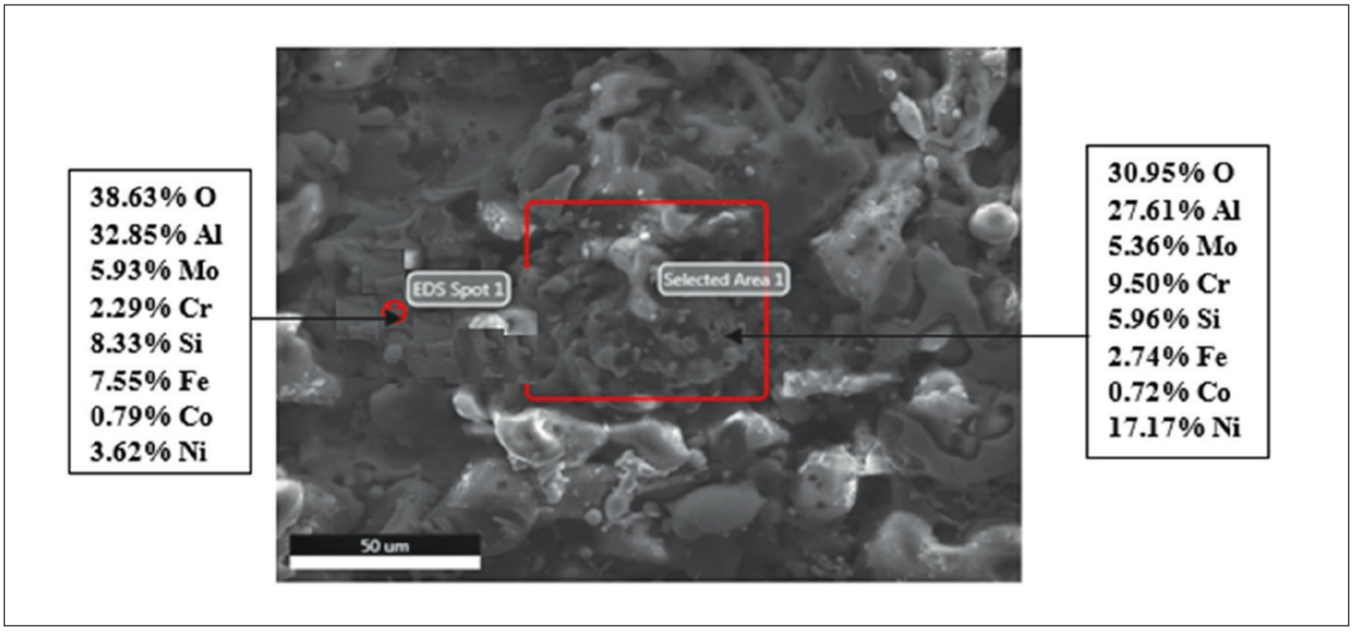

Figure 4: 4SEM/EDS analysis of NiCrMoFeCoAl-30%SiO_2 composite coating

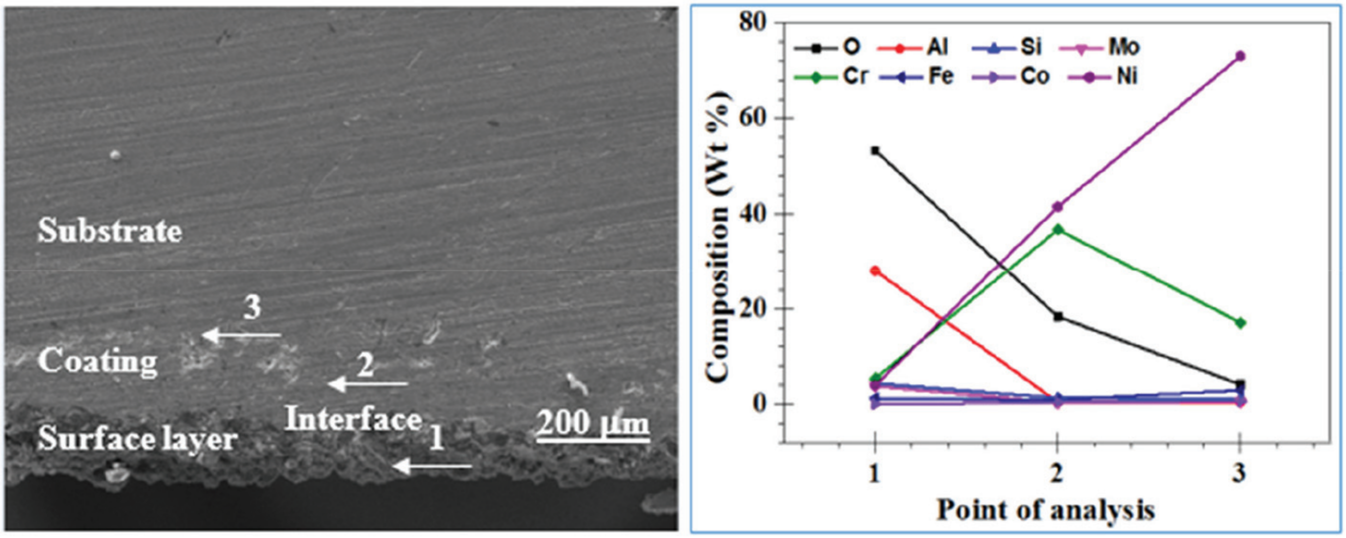

Figure 5: SEM/EDS analysis (wt.%) across the cross-section of the HVOF as-sprayedNiCrMoFeCoAl-30%SiO_2composite coating

4.0 Conclusions

1. It has been possible to obtain a NiCrMoFeCoAl-30%SiO_2 coating with a thickness size of 197 m and an average microhardness of coating in the range of 801.9 $HV_{0.3}$.
2. The NiCrMoFeCoAl-30%SiO_2 coating region did not produce the voids. The typical deviation value was small, explaining the homogenous structure with 1.69% low porosity.

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