RESEARCH PAPER

Characterization of Ni-base Matrix Composite Coating produced by Thermal Spray Technique

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ARTICLE INFO

Article History:
Received 05 January 2023
Accepted 23 March 2023
Published 01 April 2023

Keywords:
Al_2O_3 nanoparticle
Ceramic Particles
Nickel-based composite coating
Thermal Flame-Spray

ABSTRACT

In this study, the thermally flame-sprayed of nickel coatings and incorporating ceramic particles (SiC and Al_2O_3) with different concentration and studied the comparing the effects of their particles on microstructure, morphology, and Vickers of incorporating ceramic particles (SiC and Al_2O_3) and their concentration were deposited on low carbon steel substrate. The microstructure investigation of the deposited alloy was studied using the optical microscopic and scanning electron microscope (SEM). And other characterizations of the coatings are examined through x-ray diffraction and roughness test. Vickers microhardness test is run for the coatings' hardness measurement. The results showed the homogenous distribution of particles by fully dispersing in the nickel matrix. The surface was dense and high adhesive and continuous with the best heterogonous codeposition mixture of ceramic particles (Ni-SiC with Al_2O_3). The surface roughness increased with the addition of composite powders (SiC and Al_2O_3). The surface hardness of the coatings has been enhanced as a result of the thermal flame-sprayed alloy coating.

How to cite this article
Al-Kaisy H A., Abdulkader N J., Khdheer M F., Ali H B. Characterization of Ni-base Matrix Composite Coating produced by Thermal Spray Technique. J Nanostruct, 2023; 13(2):453-461. DOI: 10.22052/JNS.2023.02.015

INTRODUCTION

Thermal spraying provides several skills, materials can be protected from a range of harmful mechanical, thermal, as well as tribological conditions. A large variety of coatings with radically different compositions and qualities are also made available. For the application of corrosion- and wear-resistant coatings on a variety of materials, thermal spraying technology offers efficient processes at low cost in numerous industries [1-4]. Because they have low cost and good corrosion, oxidation, and wear resistance, at elevated heat, nickel-based alloys have been frequently utilized through spraying materials [5-7].

Plasma transferred arc-welding, laser cladding, high-velocity-oxygen/air-fuel-spraying (HVOF, HVAF), plasma spraying, and flame low-velocity spraying (LVOF), are the methods most frequently used to deposit Ni-based self-fluxing alloy coatings (PTA or PTAW). Porosity and substrate adhesion issues have a negative effect on the performance and quality of thermally sprayed coatings. Remelting coatings employing a variety of technologies, such as furnace, oxy-acetylene flame, laser, and electric resistance, can enhance it [6–8]. The flame spraying with the remelting procedure is popular, adaptable, and cost-effective when compared to other methods [8-12].

Nickel is among the many metallic compounds that are preferred in industrial applications for high-temperature coatings or treatment of pipeline problems for transporting petroleum products because it shows superior mechanical and physical properties in addition to resistance to oxidation

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and corrosion, especially when mixed with ceramic powders such as alumina or silicon carbide [13-15]. According to the findings of S.Sharafat, et al., in (2002),[16], used a gas tunnel-type of plasma spraying, a novel ZrO2-(20-80%) Al_2O_3 thermal barrier composite coating was created. The best composite microstructure was discovered for 50% Al_2O_3 powder from the mixture, which enhanced mechanical characteristics. The hardness of the coating improved as alumina content rose. The transverse thermal resistivity of YSZ increased as total composite coating heat resistance by more thermally conducting Al_2O_3, which was independent of the powder composition of the thermal barrier composite in terms of HV fluctuation with spraying distance. Yunzhou Zhu et al., in (2008) [17], created the SiC composites by using a polymer infiltration and pyrolysis approach, and the effect of adding sub-micron SiC particles in the initial infiltration step, to the preceramic solution was assessed. Systematically investigated was the influence of pyrolysis temperature as well as silicon carbide filler content on the microstructures and characteristics of the composite materials. The findings indicate that when pyrolysis temperature increased, so did the failure stress as well as fracture toughness. The mechanical characteristics of the composites were improved by the sub-micron scale SiC filler. N. Beigi Khosroshahi, et al., in (2015) [18], produced from SiC particles with a uniform nickel phosphorous (Ni - P) electroless (EL) covering. Metal-coated ceramic particles can be used cast metal matrix composites. The wettability of these ceramic particles in molten metal is better. So, it was examined how coating parameters, the average particle size of the SiC particles with the best mechanical bonding and homogeneity was 80 µm. Salih Y Darweesh et al., in (2019) [19], Studied the cermet composites made of SiC and Ni combine an appealing range of mechanical and physical attributes, such as high hardness, high melting point, and superior corrosion resistance. In the past 30 years, research on self-bonding metals like Ni, Co, or Al has focused on more than just bulk materials. Thermal spraying by flame is the most crucial technique for depositing coating layers for a variety of applications, including high temperature corrosion, wear properties, electrical, and biomedical uses. In order to increase the adhesion strength of the deposition of the coating, nickel is utilized coated with ceramic carbides, such as Ni - SiC, as a bond coating with ceramic or cermet coating.

This work's objective is to assess the surface coating's characterization on both pure nickel and a composite coated with Al_2O_3 and SiC at varied concentrations using a flame spraying deposition technique. The coating procedure is more versatile in the manufacture of coated attributed to several advantages.

The novelty of this study is to manufacture Ni-SiC, Al_2O_3 matrix composite coatings by thermal spraying. In order to improve coating's characterization, it is necessary to increase homogeneity dependent on choosing the best process parameters of materials coatings then analyzing the surface coatings to observed the improving microstructure and mechanical properties which suitable for various applications.

MATERIALS AND METHODS

For the spraying technique, a variety of commercial powders were employed. Many kinds of coatings have been produced using the thermal flame spraying method on a low carbon steel substrate. Each type of powder was sieved in a range of 45 to 200 µm utilizing a sieve analyzer with micro sieves. Various mixing ratios (wt./wt.) of ceramic powders have been prepared in the laboratory ball mill. The chosen ratio of the ceramic powders was mixed for 1 hr. to get a

Table 1. Samples coating composition on low carbon steel substrate

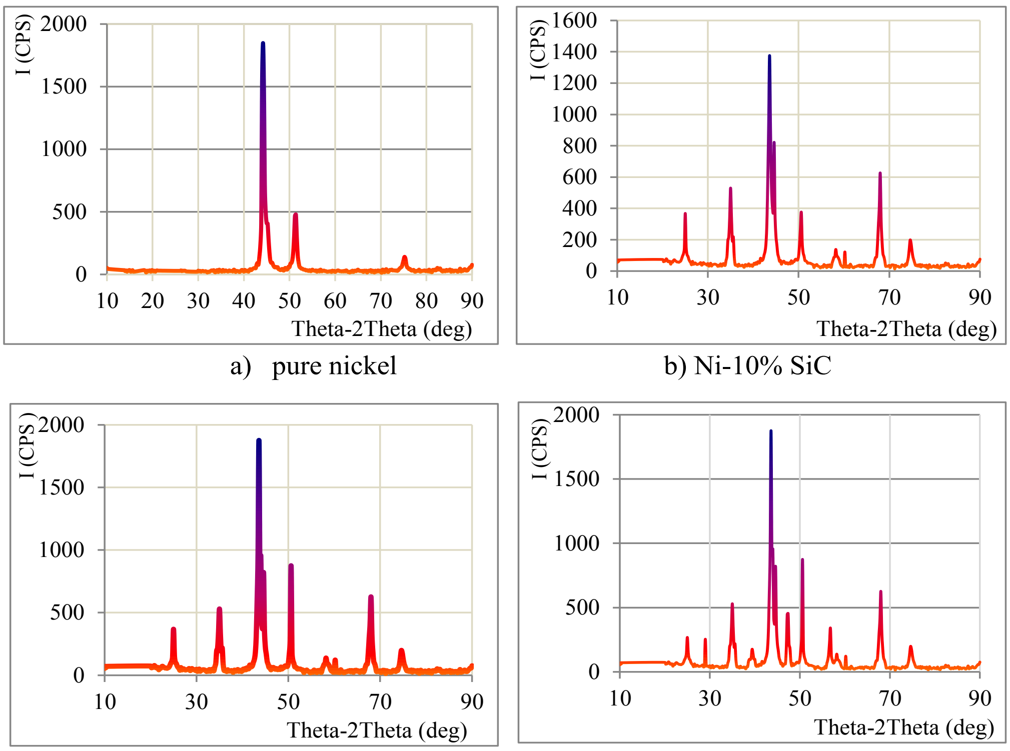
M1	Pure Ni coating
M2	Ni+10% SiC coating
M3	Ni+10% Al_2O_3 coating
M4	Ni+5% SiC +5% Al_2O_3coating

Table 2. Coating deposition operating parameters.

Operating Parameter	Value
Oxygen-pressure	4 bar
Acetylene-pressure	0.7 bar
Displacement	20 cm
Powder feed rate	7 cm^3/min
Temperature	600 C°

uniform mixture. Table 1 lists the composition of premixed ceramic coating specimens. Different compositions were formed when these specimens were combined.

The spray gun produces a hot flame with the highest temperature of 3000°C by 2 gases (oxygen and acetylene), and the molten powder has been decided to carry in mixed gas and adheres to the surface that needs to be coated. Table 2 details the operating conditions for coating deposition. This device includes a chamber with a flange to retain the specimen as well as an oxy-acetylene flame. Particles of powder are carried by the flame and deposited on the substrate surface to the thickness of the coating. The ceramic coating layers were heated to 600°C for a sufficient amount of time to allow adhesion and finish the heat treatment procedure.



a) pure nickel b) Ni-10% SiC

c) Ni-10%Al_2O_3 d) Ni-5% SiC+5%Al_2O_3

Fig. 1. XRD analysis for pure nickel and coated layer.

RESULTS AND DISCUSSION

X-Ray Diffraction (XRD) analysis

Examination of the composite coatings has been conducted utilizing Phillips Norelco X-Ray Diffractometer working with CuKα (λ=1.54Å) radiation at 40.0 KV and 30.0 mA with Check style that could be resistance check hub 2θ extend begun and conclusion degree is (10-90°). Testing step has been (1°) as well as the speed at (8°/min).

The XRD design of coating handle in (Fig. 1a) appears the immaculate Ni - top at (111), (200) and (220) crystallographic plane with low-intensity top was watched. Unadulterated Ni crests have moved towards the higher point values on the expansion of ceramic particles. Interests, the XRD range of the coating did not unver any crests credited to warm decay items of SiC.

X-ray diffraction analysis confirmed that the peaks corresponding to the -SiC phase in the coating were identical to those discovered in the powder, suggesting that the modified SiC feedstock can resist the high thermal inputs of the flame spraying method, or the value of carbide made by spraying wasn't big enough for XRD to notice. Whenever the oxide binder melts during spraying, it releases a liquid medium that acts as a matrix phase, holding the SiC particles together with nickel to make a coating with elevated cohesive strength.

According to XRD analysis, a cubic silicon carbide structure indicates sharp Bragg diffraction peaks, representing a very well crystallized SiC, the most intense peaks were detected at 2θ= 36,41 ,72 and 60 representing SiC. Usually, the patterns of the X-ray diffraction in amorphous systems display widened peaks, as shown for nickel matrix, which is entirely amorphous. Without a doubt, the crests comparing to the αSiC stage within the coating stayed similar to the ones identified in the powder, demonstrating that the modified SiC feedstock is capable to resist the tall warm inputs of the fire splashing handle or that the amount of carbide delivered amid splashing was not within the discovery extend of XRD.

Changes in x-ray diffraction design of splash composite coating surface happening within the mineralogical components amid warm splash on metal substrate of the Ni base composite coating with SiC and alumina are too taken note in Fig. 1b, Fig. 1c, and Fig. 1d. From the figures, able to say that the crystallinity of the nickel has been impressively diminished upon the expansion of SiC and Al_2O_3 particles and the concentrated of the crystalline crests diminishes and broadens. this decrease in crystallinity upon the expansion of

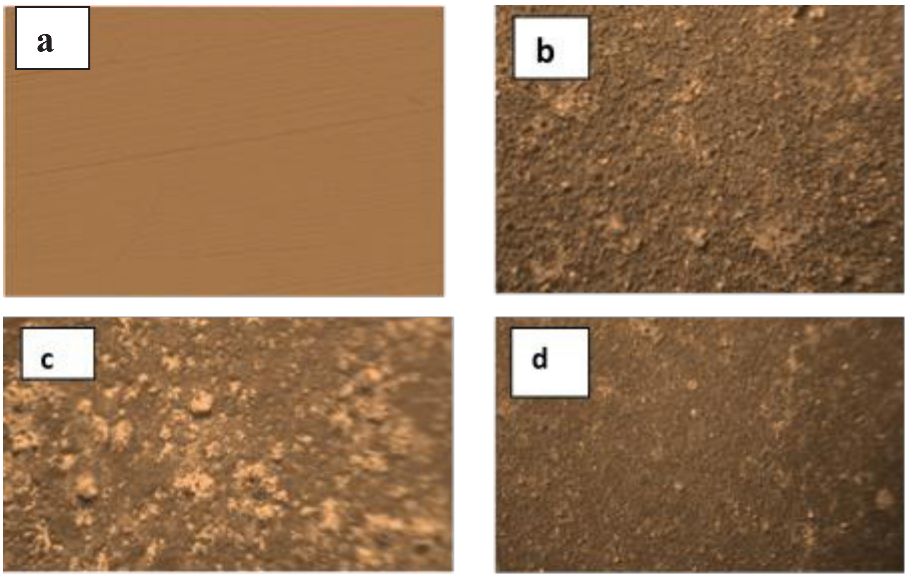


Fig. 2. computerized optical microscope composites coating (a) low carbon steel (b) Ni-10% Al_2O_3 (c) Ni-10%SiC(d) Ni-5% Al_2O_3+5% SiC by thermal spray deposition.

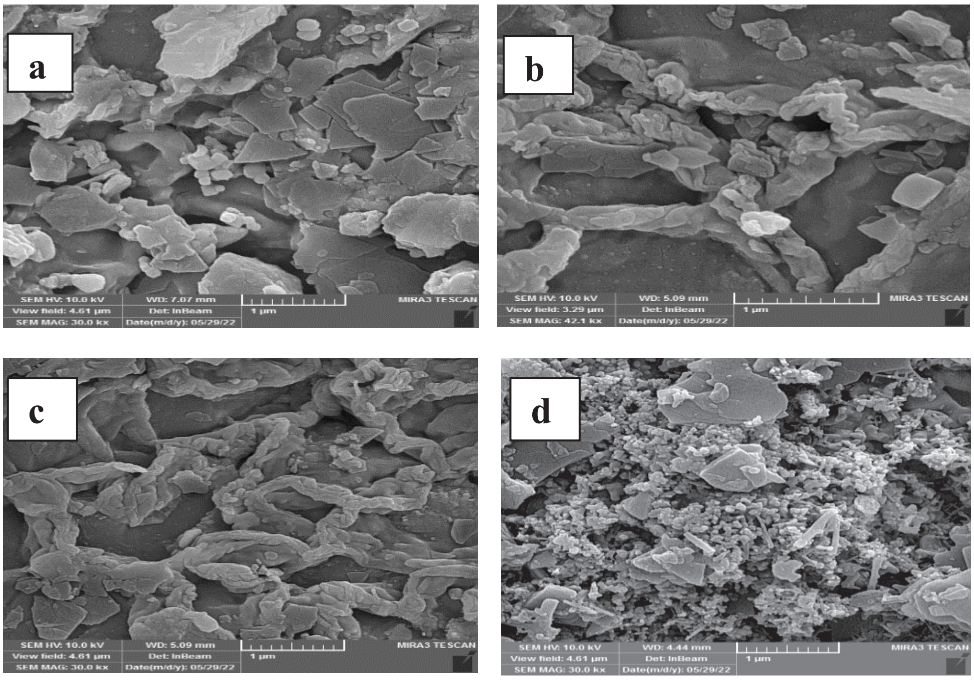


Fig. 3. SEM images the coating by thermal spray deposition. a) pure nickel (b) Ni-10% SiC (c) Ni-10%Al_2O_3 (d) Ni-5% SiC+5%Al_2O_3

ceramic are credited little ceramic particles inside coating changes the chain re-organisation and encourages for higher ionic conduction.

Micro Structural Analysis

Fig. 2 shows the optical images, that are given the clear shape of the coating with nickel matrix on the metal substrate (40X). It indicates the low carbon steel substrate surface with the pure nickel coating deposition, while the other image indicates the deposited nickel-base composite coatings on the substrate via the thermal flame spray deposition coating method. These pictures showed that the particles were evenly dispersed in the nickel matrix, with a dense and highly adherent surface, and that the distribution was continuous with the best possible heterogonous codeposition mixture of ceramic particles (Ni-SiC with Al_2O_3) with high surface roughness compared with smooth surface coating for pure nickel. with forming the SiC was incorporated with lots of agglomerations without any porosity in the of nickel MMC composite coating Fig. 3 appears the stored nickel base composite coatings on the substrate by fire warm shower testimony coating strategy which demonstrated the uniform dispersion of particles with a full scattering in nickel framework to be thick and profoundly cement surface and nonstop with a best the heterogonous codeposition blend of ceramic particles (Ni-SiC with Al_2O_3) with tall surface unpleasantness compared with smooth surface coating for unadulterated nickel. with shaping the SiC was joined with parcels of agglomerations without any porosity within the of nickel MMC composite coating.

Fig. 4 shows the cross sectional for coated specimen by optical photographs. Consequently, an optical microscope with a 40X objective was used to measure the average coating thickness. The optical pictures in fig.5 demonstrate a coating thickness of 169 µm, as measured on the coated specimens.

Surface Roughness

Roughness of the surface pure nickel coating are smoothly and soft. While, the composite coating high surface roughness, it seems to be that composite coating was homogenously distribution in the metal matrix. The substrate surface became rough with adding the composite powders (SiC and

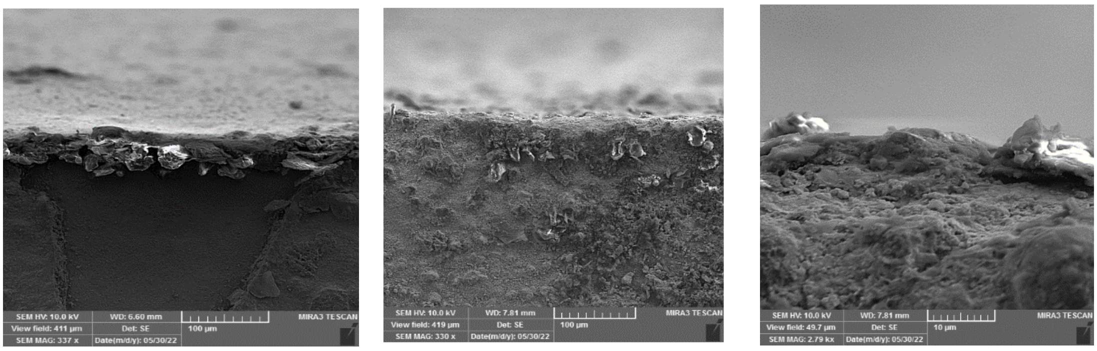


Fig. 4. The cross sectional for coated specimen by optical microscopy

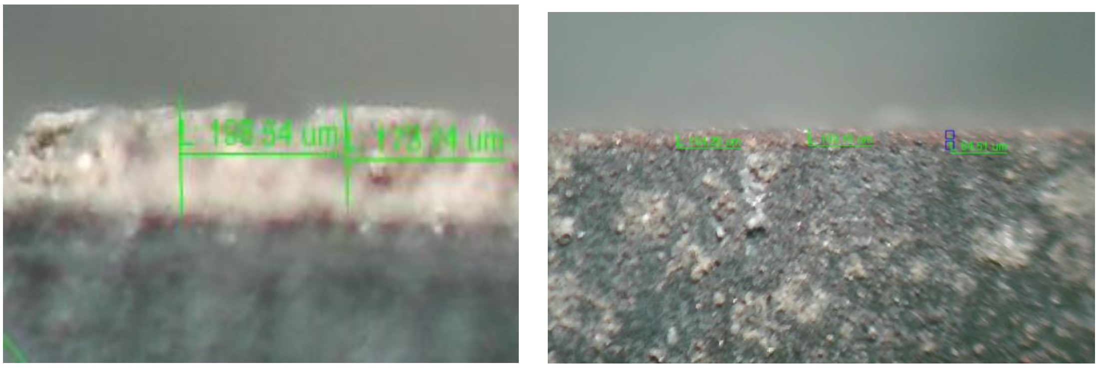


Fig. 5. computerized optical microscope thickness measurement the Ni- based composites coating.

Al_2O_3), that mean the increase in ceramic particles content is important to enhance the coating roughness in all samples this shown in fig.6.

Unpleasantness of the surface unadulterated nickel coating is easily and delicate. Whereas, the composite coating tall surface unpleasantness, it can be seen that composite coating was homogenously scattered within the metal network. The surface of the movies got to be roughened with the expansion of composite powders (SiC and Al_2O_3) and, which suggests that the increment in ceramic particles substance are dependable for the improvement of the coatings harshness in all tests.

Micro-hardness

The Vickers micro hardness test for the samples with pure Ni and composite coatings on metal substrate is measured at three different positions, the average of the measurements is noted. Composite coating shows a high average hardness values of HV as mentioned in Fig.7. The pure nickel coating is discovered to provide a uniformly soft finishing with high adhesion due to its high compatibility of metal coating on substrate. However, it seems that the range of microhardness values for the composite coatings is greater than that of the pure Ni coating. Moreover, the microhardness values of the composite coatings increase in the composition of coating with the addition of Al_2O_3 and SiC by thermal flame spraying technique composite coatings. The Vickers miniaturized scale hardness test of unadulterated Ni and composite coatings tests on a metal substrate is performed at three distinctive positions and the normal of the estimations were detailed.

The composite coating appears a generally tall normal hardness esteem of HV as said in Fig. 7, the immaculate nickel coating is found to be uniform wrapping up delicate with tall attachment due to

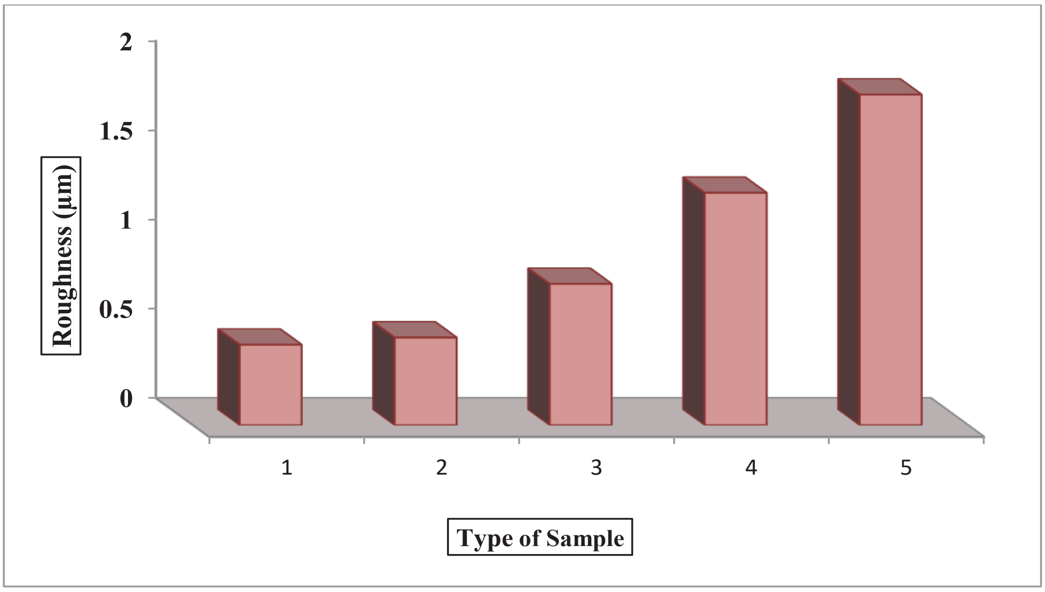


Fig. 6. Variation of surface roughness of the Ni- based composites coating by thermal spray deposition

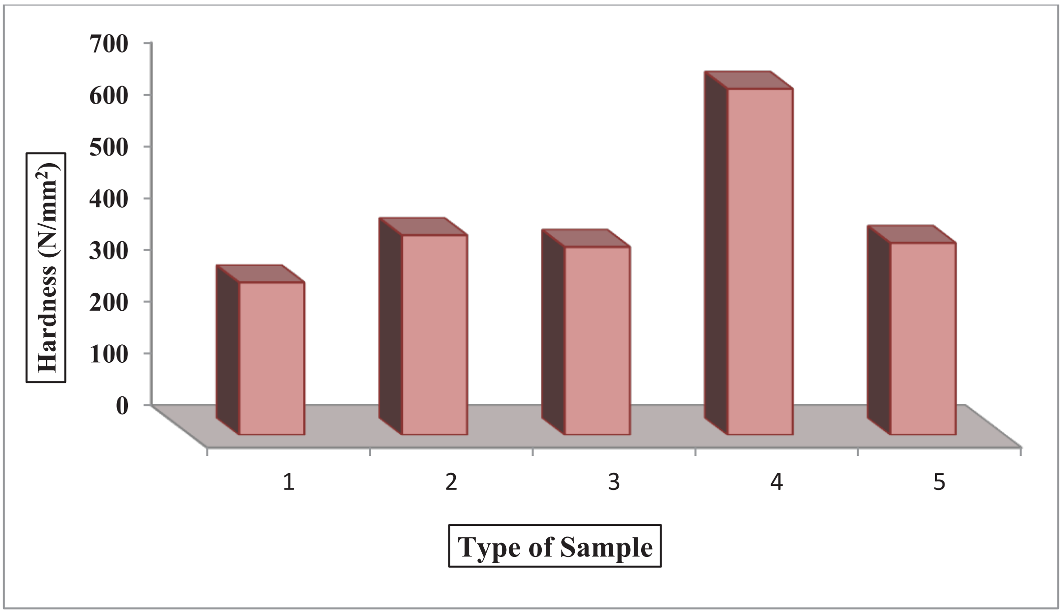


Fig. 7. Variation of Vickers Micro hardness of Pure Ni and the Ni- based composites coating by thermal spray deposition.

its tall compatibility of metal coating on substrate. Clearly, the composite coatings have the more extensive run of microhardness values in comparison with the unadulterated Ni coating (Fig. 7). Also, the composite coatings microhardness values increment within the composition of coating with the expansion of Al2O3 and SiC by flam warm shower procedure composite coatings and he micro-hardness composite coatings have a wider range of values [20]. At that point, the microhardness upgraded as it were once the surface is consolidated homogenously with

Ni-SiC. Consequently, it can be clear that the heterogeneous nature of the delivered surface could certainly diminish the tribological characteristics of the coated substrate. Because the molecule exchange has been continuously extremely slow than among metal particles that also lead to a diminishing concentration of the adsorbed particles at the cathodic sites, the adsorption is gotten to be insignificant. Then, only when the surfaces are uniformly integrated with Ni-SiC are the microhardness improved. Since the manufactured surface is heterogeneous, it stands to reason that the coated substrate's tribological capabilities would also be diminished. Adsorption is negligible because particle transport is usually slower than metal ions, resulting in a drop in the concentration of the adsorbed particles at the cathode surface.

CONCLUSION

Flame spray coating technology can be used in the manufacture of metal-based composite coatings to improve the corrosion resistance and surface hardness of low carbon iron alloys with thickness of coating about 169 µm. It was found that the presence of SiC within the nickel network as a coating layer improves the surface properties. In Addition, The amorphous nature of the composite coating is evident in the XRD patterns, indicating that the ceramic particles within the nickel base matrix have an effect on the structural features of the coating. This is due to the fact that the ceramic particles used within thermal spraying on the surface are physically fused, with fusion occurring between them, both in composites for mixed coatings. Computerized optical magnifying instrument of the Ni- based composites coating by warm shower statement, managed the uniform dispersion of particles with a full scattering in nickel lattice to be thick and profoundly cement surface and nonstop with a best the heterogonous.

The micro hardness values of composite coatings increase in the composition of coating with the addition of Al_2O_3 and SiC by flam thermal spray technique composite coatings. the decrease in the size of nickel grains compared with the grain size of carbide within the coating layer led to more interlocking with a homogeneous distribution within the coating structure, which caused an improvement in the fine-grained hardness of the composite coating due to the resultant dispersion strengthening condition.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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