

MICROSTRUCTURAL AND MECHANICAL CHARACTERIZATION OF Ni–Ti NANOCOATED B₄C-REINFORCED SS304 METAL MATRIX NANOCOMPOSITES

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Abstract: In this study investigation was carried out on the Nickel and Titanium metal nano coated SS304 metal matrix nano composites (MMNCs) reinforced with different percentages of Boron Carbide (B₄C) using magnetron sputtering process. Two substrates namely coated neat SS304 (CSS0B) and coated 95% SS304 + 5% B₄C (CSS5B) were fabricated via Powder metallurgy route and their mechanical and microstructural characters were studied. Microstructural characterization using Field Emission Scanning Electron Microscope (FESEM) confirmed homogeneous distribution of Ni, Ti, B₄C and constituent elements of SS304. The nanocomposite CSS5B illustrated excellent mechanical behaviour depicting a micro hardness value of 392 HV, indicating 45.7% higher than CSS0B.

Index Terms: Substrates, Field Emission Scanning Electron microscope, magnetron sputtering process, micro hardness, nano composite.

INTRODUCTION

The efficiency and service durability of mechanical elements were considerable reduced due to friction and wear. This results in substantial material loss and energy dissipation in machineries used in industries thereby increasing economic losses. Applying protective surface layers is an effective approach to enhance functional performance and extend the lifespan of engineering components (Ref 1). In recent years, nanoscale hard coatings have attracted significant interest because of their capability to increase surface hardness (Ref 2). Nanocomposite coatings produced through the incorporation of different nano sized reinforcements into a substrate exhibit enhanced hardness and improved wear resistance over conventional metals and alloys (Ref 3). SS304 stainless steel is extensively employed in aerospace, defence, and automobile sectors where components operate under elevated temperatures. Nevertheless, inadequate tribological behaviour restricts its wider application, making surface treatment essential.

Depositing nano-scale coatings on SS304 substrates markedly enhances their hardness and wear performance (Ref 4). Although numerous investigations have been reported on SS304 coating technologies, studies involving Nickel and Titanium nano coatings on SS304 metal matrix nanocomposites are still limited. Moreover, the synergistic use of Ni/Ti coatings together with B₄C reinforcements in SS304 systems has not been sufficiently investigated. As a novel attempt Ni and Ti metals were coated on SS304 MMNC in nano scale using magnetron sputtering process and the coated substrates were characterised using FESEM. Vickers hardness test was performed on the coated samples and their hardness values evaluated.

MATERIALS AND METHODS

The two substrates on which Ni/Ti nano coating was done were the SS304 MMNCs fabricated using powder metallurgy technique with different percentages of B₄C reinforced with the SS304 matrix (Ref 5). Nickel and Titanium metal targets with 4N purity were used for nano coating the SS304 MMNCs. The reinforcement percentage of the coated samples with their symbolic representations is depicted in Table 1.

Table 1. Reinforcement proportions of coated samples

Sl. No.	Reinforcement percentage
1.	Neat SS304- (CSS0B)
2.	95% SS 304 + 5% B ₄ C- (CSS5B)

Coating of samples



Fig.1 RF/DC magnetron sputtering unit

The magnetron sputtering unit model: PLASSYS as depicted in Fig.1 was employed for the deposition of Ni/Ti in nano scale on the SS304 substrates. The substrates are firmly mounted on the holder, and bombardment of the target by argon ions ejects target atoms, which subsequently accumulate on the substrate surfaces as a thin coating layer. Prior to placement inside the coating chamber, the substrates underwent ethanol cleaning, nitrogen drying, and pre-sputtering for about 5 min to eliminate surface contaminants. The chamber vacuum was maintained at 8×10^{-6} mbar using rotary and turbo-molecular pumping systems. Argon gas introduced into the deposition chamber at 10 sccm and the bombardment of the target initiated. With the targets being rotated at 25 rpm Ni/Ti deposition rate reached was 20 nm/min (Ref 6).

Testing

Microstructure characterisation using FESEM

The microstructure study of the coated nano composites was done using the FESEM apparatus-model: Zeiss Sigma. Test specimens measuring 10 mm in diameter and 10 mm in height were used for this study. The FESEM analysis was conducted as per ASTM E-766 standard.

Hardness Test

Vickers micro hardness tester- model FMV- AC-AT with a maximum loading capacity of 10 kg was employed for evaluating the hardness of the coated SS304 MMNCs. The tests were conducted confirming to ASTM E92 standards. For each specimen, hardness evaluation was carried out at five different surface locations under applied loads of 0.5 kg and 1 kg, and the average hardness value was subsequently calculated.

RESULTS AND DISCUSSION

FESEM analysis

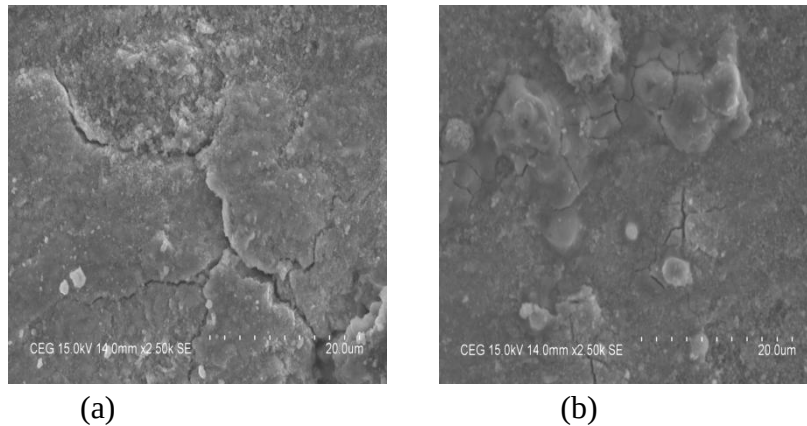


Fig. 2 SEM images of (a) CSS0B and (b) CSS5B

Fig. 2(a) illustrates the surface morphology of CSS0B, where a homogeneous Ni/Ti layer is continuously distributed over the substrate, producing a stable and firmly attached interfacial region that minimizes coating separation during sliding conditions. The deposited Ni/Ti layer establishes strong metallurgical and mechanical interfacial bonding with the substrate, thereby improving the surface load carrying ability under applied load. Fig. 2(b) presents the microstructural features of CSS5B. The SEM observations indicate the formation of a compact, homogeneous, and a perfect Ni/Ti coating layer without visible cracks, porosity, or peeling, confirming effective coating deposition. The presence of strongly bonded coatings together with the uniform dispersion of B₄C reinforcing particles improves the matrix-coating interfacial integrity, thereby contributing to enhanced hardness characteristics.

Hardness analysis

From the graph depicted in Fig.3 it is clearly evident that CSS5B exhibit higher hardness than the (CSS0B. At least five indentations were performed for each specimen to obtain the mean micro hardness value. The nano composite CSS5B exhibited a 45.7% higher micro hardness than CSS0B under an applied load of 1.0 kgf. This improvement is mainly attributed to dispersion strengthening, particle reinforcement effects, and refinement of grains induced by the surface coating process. The deposition of Ni and Ti in nanoscale on the SS304 nano composites impedes growth of grains by reducing the size resulting in improved hardness of the coated composites (Ref 8). CSS5B nano composite attained a hardness value of 392 HV, which is 45.7% higher than CSS0B, exceeding values documented in earlier studies (Ref 7,8). The homogeneous distribution of hard B₄C reinforcement throughout the SS304 matrix restricts dislocation movement, thereby improving the material strength. In addition, the Ni/Ti coating develops a compact and strongly bonded surface layer that enhances hardness by increasing the load- supporting capability of the material (Ref 9).

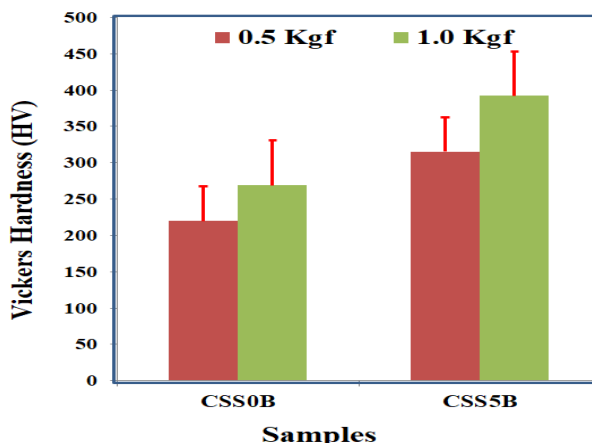


Fig. 3 Vickers Micro hardness (HV) of coated nano composites.

CONCLUSIONS

The following are the conclusions of this study.

- Ni/Ti coatings were deposited on both the neat SS304 (CSS0B) and the nano composite (CSS5B) using the DC magnetron sputtering process. Microstructure revealed uniform coating of Ni/Ti over the substrate surface.
- CSS5B achieved the highest hardness (392 HV) which was 45.7 % higher compared to CSS0B, confirming its effectiveness in enhancing surface properties.

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